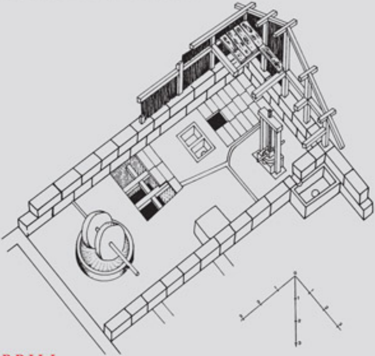
TECHNOLOGY AND CHANGE IN HISTORY

A Handbook of Food Processing in Classical Rome

For Her Bounty No Winter

David L. Thurmond



BRILL

A HANDBOOK OF FOOD PROCESSING IN CLASSICAL ROME

TECHNOLOGY AND CHANGE IN HISTORY

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A HANDBOOK OF FOOD PROCESSING IN CLASSICAL ROME

For Her Bounty No Winter

BY

DAVID L. THURMOND

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On the cover (front): Press room (*torcularium*) of a Roman villa rustica set up for processing olives, previously published as fig. 137 in A. Maffei and F. Nastasi, edd., *Caere e il suo territorio da Agylla a Centumcellae* (1990). Courtesy of the Istituto Poligrafico e Zecca dello Stato, Rome, drawing by E.A. Stanco.

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INTRODUCTION

This book has evolved from a simple question: How did the people of Rome at the height of her power (roughly the first century BCE and the first two centuries of the common era) manage to feed themselves? Eating, after all, is the most basic of human activities; we all do it more or less daily, often several times daily, and often in my own country almost unconsciously: we find the food, we prepare the food as needed—and increasingly there is no need, at least on our part—we ingest the food, and we go on our busy ways. In a sense, then, food is an issue for most of us only if it is lacking, and it is rarely lacking and often available in such quantity and variety that the overconsumption of it is far more compelling an issue for many of us than simple dietary requirements.

It therefore requires a conscious effort of the intellect and imagination to step outside our own frame of reference in order to conceive what a compelling story the issue of eating was for ancient Rome. For one thing, Rome in the first centuries of the common era was huge, almost inconceivably huge for her time . . . but only in a relative sense. We now suppose that Rome at the end of the first century had a population of something over a million souls, perhaps on the order of 1,100,000. Today, of course, that figure defines a substantial city, but hardly a megalopolis. But as Gideon Sjoberg, the author of the seminal work on the archetypal preindustrial city, discovered,[1] the one factor which most defines and delimits a preindustrial city is its available technologies, and these technologies typically create severe limitations on population size. Thus a preindustrial 'city' is one on the order of 20,000–50,000 persons; a large city is perhaps on the order of 50,000–100,000, and any figure beyond that is monstrous. So severely does technology limit preindustrial growth, in fact, that Sjoberg simply refused to believe that Rome could have been much more than a half-million in population at her greatest extent, despite compelling evidence to the contrary.[2]

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[1] Gideon Sjoberg, *The Preindustrial City: Past and Present* (Glencoe, IL: The Free Press, 1960).

[2] Sjoberg follows J. C. Russell ["Late Ancient and Medieval Population," *TAPA*

Thus in order to appreciate the relative size of this ancient behemoth we should perhaps think in terms of a modern post-industrial city on the order of 10 to 15 million souls. Obviously, the simple problem of food distribution in a city of that size is enormous; 'finding' the food becomes an issue of the food first 'finding' us. The Roman system of transport, of course, was the wonder of its age, and rightly so, but that is in comparison to what had come before it and would come thereafter for many, many centuries—arguably, right up until the beginning of the twentieth century. For example, all roads did indeed lead to Rome, and those roads were extensive, ultimately consisting of perhaps some 50,000 miles of major thoroughfares and some 250,000 miles of improved roads. But those figures are easily dwarfed by those of almost any modern Western country. Furthermore, if contemporary accounts and comparative evidence are indicative, goods moved along those roads at a modern snail's pace; achieving much more than three or four miles per hour over any sustained distance on heavy transport—essentially wagons pulled by yokes of oxen—was impossible. And land transport was enormously expensive in relative terms. Today, for comparison, the cost of cartage represents pennies on the dollar in the overall cost of a consumer good, and much of that fractional cost represents cartage in trucks over roads. In preindustrial cities such as Rome, in contrast, the cost of cartage for goods shipped over any distance represents a major portion of overall cost; furthermore, overland transport is especially expensive, perhaps on the order of seven or eight times the cost of riverine transport, perhaps some 25–30 times as expensive as marine transport.[3]

Rome in the second half of the first century had a thriving seaport at the mouth of the Tiber River, thanks to the invention of hydraulic cement, but Rome herself was some 15 miles (24 km) up

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48 (1958): 37–101] though he suspects Russell's surmise of 200,000 is perhaps too conservative: Sjoberg (1960): 82–85.

[3] Kevin Greene, *The Archaeology of the Roman Economy* (London: B. T. Batsford, Ltd., 1986): 39–40. John Percival, in his discussion of the factors determining the economic viability of villa farms (*The Roman Villa: An Historical Introduction* [Berkeley, U. of Cal. Press, 1976] 158–9) cites Jones' famous calculations, based on the Price Edict of Diocletian, that a cartload weighing 1,200 lbs. would double in price in 300 miles, and that a quantity of grain could be shipped from one end of the Mediterranean to the other for the same price as carting it 75 miles overland (A. H. M. Jones, *The Later Roman Economy, 284–602* [Oxford: Blackwell, 1964]: 841 and 842, respectively).

the Tiber, and the river was too shallow to admit of deep-draft vessels; thus goods had to be transshipped at Portus into shallow-draft vessels and laboriously towed, hauled, or rowed up the Tiber to the port facilities in the southwestern part of the city. Furthermore, marine transport was seasonal in the ancient Mediterranean, lasting from about mid-April to late October, and eating is not seasonal. And ancient vessels were square-rigged, which made hauling into the prevailing summer winds slow and inefficient. Perhaps, then, we should place our imaginary city on an island in the South Pacific; Rome was in many ways just as isolated by her sheer size and the slowness and expense of transport.

But these issues are only secondarily our concern. Imagine that the food supply of our city must travel slowly over long distances without the benefits of sterile packaging, industrial refrigeration, or the range of chemical and biological preservatives we now command. To return to that simple question: How did Rome manage to feed herself, given a huge urban population, severe limitations on the efficiency of transport in both time and cost, and the difficulties of distributing food that was still minimally edible, given those same limitations? We begin to see that our simple question has far-reaching if not profound implications for our understanding of how Rome worked and why she worked the way she did.

So how *did* Rome manage to feed herself? Sometimes, quite simply, she did not. Famine will have been a constant threat for the urban poor who represented some 90–95% of the total population of the city, and periodic food shortages were certainly an even more pressing concern.[4] Sjoberg discovered that population growth in preindustrial cities is invariably the result of immigration as opposed to expansions of indigenous population; preindustrial cities are not healthful places. Nevertheless, Rome did manage to expand, and she did manage to feed her people, at least most of them, most of the time. She did so first by adopting a subsistence diet for the masses which focused on staple products which required the least degree of biological stabilization while providing the rudiments of human nutrition in the form of carbohydrates, fats and proteins. And she relied on the genius of empirical trial and error to discover, assimilate and disseminate techniques for processing foodstuffs so that they 'found'

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[4] E.g., Peter Garnsey, *Famine and Food Supply in the Graeco-Roman World: Responses to Risk and Crisis* (Cambridge: Cambridge U. Press, 1988).

the urban masses in a reasonably safe and digestible state. That is the story this book attempts to tell.

The Romans were not inclined to reinvent the wheel, fortunately for them. They were heirs to several millennia of food processing techniques as well as patterns of urban distribution. Food processing, in fact, is the impetus for human civilization itself. One modern scholar, for instance,[5] sees advances in civilization as contingent on cycles of glut and dearth which provide the imperative for development of techniques for preserving part of the glut to subsist upon during periods of dearth, a process which leads directly to urbanization as well as trade and barter and the cultural exchange attendant on such contact. For example, Gallic hams sent to Rome and the exchange of wine technology to these regions and beyond, or early Britons' sending of surplus grain to feed Roman soldiers, and receiving in exchange Mediterranean wine and wine vessels along with the trappings of classical civilization.

The most fundamental purpose of food processing is simply to preserve food in an edible, i.e., unspoiled, non-pathogenic state. Reduced to common denominators, there are two basic ways to achieve this: add preservatives to the foodstuff and/or take away the 'rotting' agent such as air, moisture, heat, etc.[6] 'Rot' is caused by microorganisms which feed on the same foodstuffs, and microbes are classified generically as protozoans, algae, viruses, molds and yeasts (microscopic fungi), and bacteria. Perhaps more important for our purposes is classification according to their ability to aid or harm humans. In this scheme microbes are beneficial, inert, spoilage (those that do not cause disease but produce substances which spoil the color, flavor, texture, or odor of food), and pathogenic (causing sickness in humans). Obviously, a critical role of food processing is to prevent the invasion and/or growth of the latter organisms, often by promoting the growth of beneficial ones.[7]

All microbes require six basic environmental conditions for growth and reproduction: time, food, moisture, correct temperature, oxygen,

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[5] C. Anne Wilson, "Preserving Food to Preserve Life: The Response to Glut and Famine from Early Times to the End of the Middle Ages," in C. Anne Wilson, ed., *'Waste Not, Want Not': Food Preservation from Early Times to the Present Day* (Edinburgh: Edinburgh U. Press, 1991): 5.

[6] Lynette Hunter, "Nineteenth- and Twentieth-Century Trends in Food Processing: Frugality, Nutrition, or Luxury," in Wilson (1991): 138.

[7] P. M. Gaman and K. B. Sherrington, *The Science of Food: An Introduction to Food Science, Nutrition, and Microbiology* (Oxford: Pergamon Press, 1977): 217.

and proper pH. Manipulating these factors to promote or inhibit selective microbial growth is of paramount importance in food processing. To begin with time, for example: a single bacterium may multiply to a colony of over two million in about seven hours. Fortunately, the process is one of arithmetic doubling, such that the vast majority of growth occurs in the last two hours. Also, there is typically a lag time of about thirty minutes during which there is no growth at all. Thus, establishing biological parameters during the first hours of processing is critical unless the raw product (e.g., dry cereals) is relatively stable to begin with.[8]

Microbes, as do all other living things, require minimal moisture levels to thrive. Amount of available water (as opposed to actual humidity) is defined as water activity, symbolized A_W, pure water having a A_W of 1.0.[9] The water activity of most fresh foods is 0.99, but sugars and salts may lower this dramatically because of their high specific gravity and concomitant high osmotic (i.e., hypertonic) action. Thus sugars and salts act as preservatives in part because of their drying effect on food cells. Likewise, naturally dried foods have a A_W of 0.6 or less, too little moisture for most bacteria, though some yeasts and molds can survive in less and some yeasts are osmophilic, i.e., can thrive in dry or effectively dry conditions. Typical minimal water activity for various microbes are 0.91 for most spoilage and pathogenic bacteria; 0.88 for most spoilage yeasts; 0.80 for most spoilage molds; and 0.60 for osmophilic yeasts. The technical name for the lowering of water activity to the point of biological stability is anhydration. The corresponding food processes are drying and dehydration or desiccation. Technically 'drying' is used to mean withdrawal of moisture under natural conditions of sun and wind, whereas dehydration or desiccation is scientifically controlled removal of moisture via artificial steam, forced air, conditioned air, etc. In this study the terms will be used interchangeably, since the ancients had no effective artificial means available on a wide scale.

As mentioned, the use of salt or sugar as preservative is closely related and often complementary to dehydration in food processing. When salt and/or sugar concentrations increase, microorganisms have

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[8] Gaman and Sherrington (1977): 233–5.

[9] John A. Troller and J. H. B. Christian, *Water Activity and Food* (New York: Academic Press, 1978): esp. Ch. 1 and Ch. 5; Gaman and Sherrington (1977): 236–7; R. A. Lawrie, *Meat Science* (Oxford: Pergamon Press, 1995): 16.

increasing difficulty obtaining sufficient water for normal metabolic processes. Simultaneously, such environments select for the growth of so-called halophilic (i.e., salt-tolerant) organisms which often overgrow and 'elbow out' pathogens and often simultaneously metabolize carbohydrates in the food (the substrate) to lactic acid, thereby reducing pH to safer levels.[10] At solutions of 25% or more, salts arrest all microbial growth but makes the food unpalatable; at lower concentrations they inhibit organisms except the salt-tolerant ones previously mentioned. The reduced form of one salt, saltpeter (i.e., sodium or potassium nitrate) is particularly effective against one of the most stubborn of food-borne pathogens, *Clostridium botulinum*, which is almost immune to sodium chloride at normal curing levels.[11] Saltpeter as a preservative, in this case as potassium nitrate, was for centuries an 'impurity' in the manufacture of some forms of common salt, and traditional cultures clearly recognized that 'salt' from these locales conferred additional benefits in the curing process, though ignorant of the mechanism. The preservative power of saltpeter alone was discovered only in the seventeenth century with the manufacture of gunpowder, of which saltpeter is the main constituent. As we shall see, it is the reduced form of nitrates, namely nitrites, which have preservative and antipathogenic effect, but certain bacteria common in the fermentation of meat and cheese have the additional ability to reduce nitrates, including those of saltpeter, to nitrites.

As late as 1961, some 90% of the world's population was still dependent for basic nutrition upon naturally dried foods, especially cereals, and upon fermented foods. When we hear of fermentation in this country we automatically think of alcoholic fermentation of beverages; actually, fermentations of one kind or another are vital elements in the processing of grains, legumes, vegetables, milk products, meats, fish and fish products. Food fermentation refers to the catabolism by microorganisms of labile carbohydrates, fats and proteins to more stable substances which are often coincidentally more digestible, substances such as ethanol, acetic acid, lactic acid, etc. Additionally, fermentation products such as acetic acid can themselves be used to stabilize other foods.[12] But the mechanisms for the

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[10] Lawrie (1995): 16.

[11] Jennifer Stead. "Necessities and Luxuries: Food Preservation from the Elizabethan to the Georgian Era" in Wilson (1991): 68.

[12] Carl S. Pederson, "Processing by Fermentation," in J. L. Heid and Maynard A. Joslyn, edd., *Fundamentals of Food Processing Operations: Ingredients, Methods and Packaging* (Westport, CT: AVI Pub. Co., 1967): 480–97.

preservative powers of food ferments are, we are now beginning to realize, considerably more complex than that, and some of the most exciting research developments in microbiology are emerging from our exploration of those complexities. I happily predict that most of what I will have to say in this area will be rendered obsolete in the next ten years. It is almost as if the microbiologists in the area of food science and those in the realms of medicine are finally discovering each other. For example, food scientists are discovering that any number of organisms, most notably yeasts and lactic acid bacteria, are capable of producing toxins—called biocins—capable in turn of killing competing microflora, their own forms of penicillin, as it were. And these quite apart from the presumed preservative agents such as ethanol or lactic acid. On the other hand, medical researchers confronted with the dire evolutionary consequences of massive and sustained use of antibiotics and the frighteningly rapid evolution of resistant strains of germs, are finally discovering the efficacy of probiotic therapy, i.e., using live beneficial germs to compete with and overgrow pathogenic ones, just as food sciences have been doing for millennia. The human body has its own colonies of microflora, particularly on the skin and in the gut, and they are absolutely necessary for the maintenance of health. Thus, use of broad-spectrum antibiotics to kill a single pathogen in a single part of the body is roughly as clumsy as dropping a neutron bomb on a city in order to destroy the crack houses infesting a single street. Not surprisingly, perhaps, some of the real heroes on this new medical frontier are the same humble little lactic bacteria which have been stabilizing and predigesting our foods, efficiently and largely anonymously, in the gut and in the food vat, from the dawn of human evolution and human civilization, respectively.

The primary metabolyte of lactic bacteria is lactic acid, one of the world's most essential food preservatives. Most microbes grow best at pH ranges of 6.6–7.5, i.e., neutral. The human digestive tract is naturally acidic, and acidification of foodstuffs is therefore an excellent way to render foods safe from most microbes and yet palatable to humans. Bacteria, especially pathogenic ones, are more sensitive to acidity than molds and yeasts, and no bacteria can grow at pH below 3.5. Thus spoilage of naturally acidic foods such as fruits is typically caused by yeasts and molds, whereas foods with neutral pH such as meat, milk and seafood are highly susceptible to bacterial infection. Since practically no foods are alkaline, maximum pH of foods is irrelevant for our discussion. Acidity of foods can be lowered by adding an acid such as vinegar (dilute acetic acid) or by way of metabolic changes such as the fermentation of milk sugars to create the lactic acid of yogurt and other fermented milk products.[13] But here again the dynamic is more complex than we had thought. For example, it is now thought that in free fatty acids including acetic acid the 'undissociated' part of the molecule may be more effective as a bacteriostatic agent than the reduction of pH itself, perhaps by disrupting cellular growth of microbes through destruction of cell membranes or by inhibition of essential cellular enzymatic activity.[14]

The availability of oxygen affects the growth of microbes in various ways. For example, molds are strictly aerobic, that is, require oxygen for metabolism, whereas yeasts are facultative anaerobes; that is, they are either aerobic or anaerobic depending on availability of oxygen, their growth phase, and other factors. Bacteria are classed as aerobes or anaerobes. Inorganic salts, quite apart from their hypertonic action, act as oxidizing or reducing agents and thus greatly affect the amount of oxygen available. Potassium nitrate, for example, acts in part as a reducing agent in the preservation of meat. But the most important food process in the pursuit of anoxia (absence of oxygen) is simply exclusion of atmospheric oxygen from foods.[15] For example, a number of foods were carefully sealed by the Romans in air-tight containers, often in environments where fermentations or respiration of the foods created carbon dioxide, whose density provided a protective blanket at the surface or surrounding the food. Alternately, some semi-solid foods such as cheeses and meats were treated to develop a semi-impermeable rind or enclosed in semi-impermeable casings so that the interior of the food article was anoxic. Of course, organisms could continue to grow at the surface, especially molds. Where ambient molds and bacteria were beneficial (and they often do contribute to food flavor and stability, incidentally) they were encouraged. Where ambient microflora were noxious, the food article was frequently smoked. Smoking creates a layer of creosote on the surface of the food which is effective against spoilage molds and bacteria. Today smoking is so much a part of

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[13] Gaman and Sherrington (1977): 239.

[14] H. E. Swisher and L. H. Swisher, "Use of Acids in Food Processing," in Heid and Joslyn (1967): 139–47; John T. R. Nickerson, "Preservatives and Antioxidants," in Heid and Joslyn (1967): 219–24.

[15] Gaman and Sherrington (1977): 238–9.

the desired flavor profile of many traditional foods that we forget its original purpose.

Additionally, each microbe has a maximum, minimum and optimum temperature for growth, the optimum being typically closer to the maximum than the minimum. Microbes are classified according to heat tolerance as psychrophilic ('cold-loving'), which grow well at temperatures below 68°F (20°C) and whose optimal range is 50–68°F (10–20°C); mesophilic ('moderation-loving') whose optimal growth range is 68–113°F (20–45°C); and thermophilic ('heat-loving'), which thrive in temperatures above 113°F (45°C) and whose optimal range is 122–140°F (50–60°C). Psychrophiles such as *Achromobacter* and *Pseudomonas* may cause spoilage of refrigerated foods, and thermophilic pathogens frequently infect dairy products, but the vast majority of spoilage and pathogenic organisms are mesophiles, with an optimal growth range around 98°F (37°C), the temperature of the human body, as might be expected.[16]

Thus, in a very real sense, the most important 'food process' from the standpoint of antipathogenesis, not to speak of taste and digestibility, is thorough cooking. But of course the beneficial effects are temporary, since there are ambient microbes waiting to feast upon the food (and infect humans) when it cools to a more 'palatable' temperature. Thus heat stabilization today combines heat treatment (pasteurization) with isolation of the foodstuff in sealed, sterile containers, i.e., canning. The Romans never really achieved anything like sterile canning. In fact the earliest true canning recipe seems to have appeared only in 1680, and it was another two hundred years before Nicolas Appert placed canning on a commercially viable basis.[17]

Likewise the Romans knew that cold temperatures inhibited spoilage and infection. Thus they took advantage of natural refrigeration in cellars and underground chambers, and processed highly susceptible foods during winter months when ambient temperatures were naturally low, and used bodies of water that were naturally chilled for storage of foodstuffs. Furthermore, we know that the ancients were capable of creating artificial refrigeration; in ancient Egypt and India, for example, people placed flat, porous dishes filled with water upon insulation made of dry grass, and relied on evaporation and air currents to chill the liquid. After a cool, windy night ice would form

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[16] Gaman and Sherrington (1977): 237–8.

[17] Stead in Wilson (1991): 91–93.

on the surface of the water. This was the same concept, incidentally, used in the first patent for refrigeration in 1819[18] But artificial refrigeration on a commercial scale for food processes is strictly a product of the nineteenth century.

Finally, the reader may be surprised to learn that the ancients processed foods with some fairly effective chemical antioxidants and antibiotics and that they are some of the very ones he will find lurking, probably long neglected, in the spice rack in his kitchen, plus many others he perhaps does not have there. Ancient Romans had access to a veritable arsenal of spices and he was well aware that they were effective against infections in and on foods, just as in and on the human body.

We see, then, that the primary goal of food processing, namely biological stability, was and is achieved by creating a fairly limited number of microenvironments in the food: anhydration, either from lack of actual moisture (dehydration) or from lack of available moisture (hypertonic osmosis); acidification, anoxia (absence of oxygen), probiosis (selective colonization of microflora), antibiosis, both microbial and chemical, and selective temperature. The corresponding food processes are also limited, though the variations are endless: desiccation, curing, pickling, selective fermentation, smoking, spicing, heating, and refrigeration. It will be evident that few of these food processes are mutually exclusive, and so the actual processing of some of the more biologically unstable foodstuffs such as milk and animal flesh may involve elements of all of these, at least in succession; to the student of ancient food science, a ripened cheese is a glorious thing.

But the very qualities of certain foodstuffs that make them naturally biologically stable also render them highly indigestible. The seed coat of dry cereal kernels, for example, is practically impermeable and so these kernels are essentially indigestible by human digestive juices in the amount of time the seeds remain in the digestive tract. Humans are hardly alone in this; avian species which subsist on seeds have developed a special stomach, the craw, to predigest seeds, and a number of species actually ingest tiny pebbles so that the peristaltic action of the craw on the pebbles creates a sort of prototype 'mill'. And we are reminded that animal molars, as the etymology

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[18] H. G. Muller, "Industrial Food Preservation in the Nineteenth and Twentieth Centuries," in Wilson (1991): 14–33.

of their name implies (L. *mola* = 'mill'), are also prototype mills. Our ancient food processor is therefore faced with a two-fold challenge: foods which are innately stable tend to require extensive processing (e.g., the milling, bolting, and fermentation of cereals) to make them digestible, whereas foods that are most digestible such as milk and animal flesh are, *ipso facto*, most unstable and often harbor the most dreaded of food-borne pathogens.

To these challenges the Romans brought their genius for empirical research. It is a well founded truism that the Romans were the ancient people least inclined toward theoretical speculation and most talented at practical engineering. Nowhere is that any more evident than in the realm of food science. By their willingness to learn from the experience of other cultures and by their own persistence in the laboratory of practical agronomy the Romans learned and promulgated effective food processes to feed Rome's masses. The Roman legions are rightly credited for providing the stability that made the Roman Empire possible, but there are other soldiers and other tactics which are just as important in explaining that phenomenon. These soldiers have names like acetic acid and sodium chloride and *Lactococcus cremoris* and *Saccharomyces cerevisiae*, and the tactics we adumbrate are the food tactics with which ancient agronomists and food processors marshaled these soldiers. They are a small but vital part of what made Rome the largest and most powerful city in the ancient Western world. Without some such processes no city is possible, much less the Leviathan that Rome evidently was.

CHAPTER ONE

CEREALS

Introduction

We begin by looking at those elements of the Roman diet which for antiquity as for modern Italy constituted the staple diet, the aptly named Mediterranean Triad of cereals—especially wheaten bread—olive oil, and grapes, this last particularly in the form of wine and wine byproducts.[1] It can hardly be coincidental that the first of these combines a high degree of food value with the greatest degree of natural stability.

The processing of cereals—of grass seeds, in essence—is the origin, in fact, of all other food processes with the exception of cooking. One cereal or another has formed the staple of every major culture in the world since the so-called Neolithic Revolution saw the first systematic efforts at agriculture. Indeed, a strong case can be made that the process of drying and storing of grass seeds, as lacking as it may be in the glamor of whistle-and-bell technology, is the single greatest technological advance in mankind's long history. Stated simply, the coevolution of *homo sapiens* and various cereal grasses is the basis for civilization.[2] Plants, those passive geniuses in the realms of chemistry and microbiology, nevertheless largely lack one important reproductive skill, namely motility, and therefore have for several hundred million years devised clever strategies to induce insects and animals to spread their genes more widely and more effectively. A number of plant species discovered that one mammal in particular, because he was gifted with consciousness and abstract thinking,

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[1] Peter Garnsey has made an insightful and carefully nuanced assessment of the role of the Mediterranean Triad as well as other foodstuffs in the classical diet. See *Food and Society in Classical Antiquity* (Cambridge: Cambridge U. Press, 1999): 12–21. For some tentative estimates of consumption of cereals in Greece and Rome, L. Foxhall and H. A. Forbes, "*Sitometreía*: The Role of Grain as a Staple Food in Classical Antiquity," *Chiron* 12 (1982): 41–90.

[2] Cf. Michael Pollan, *The Botany of Desire: A Plant's-Eye View of the World* (New York: Random House, 2001): introduction.

was especially susceptible, not only to the food value of plant products, but to beauty, pleasure, even intoxication. We can all cite examples of ways in which plant species have modified their evolutionary course to adapt to those predilections; what we tend to overlook is how much *homo sapiens* has been modified in the process. One of the most spectacular examples of that phenomenon is the bargain between man and cereals of the *Triticum* and *Hordeum* genera, the wheats and barleys.

There is ample evidence from the Paleolithic that man had by then learned to horde certain foodstuffs in caves to ward off famine during the winter months when foraging and hunting were desperate endeavors. At some point in the process man (or more likely woman, since we now suspect that females were the gatherers in those cultures which should perhaps more correctly be called gatherer-hunter rather than the reverse) observed empirically that grass seed stored when fully matured and dried or parched was less susceptible to molds and fermentation and that storage environments which were cool and dry had the effect of reinforcing their natural biological stability. Thence it was a short but vastly momentous step to seeking out those grains which were most stable when dried and saving some of their seed to be sown.

It is now reasonably clear that this process began around 10,000 years ago in the upland regions of Mesopotamia and of western Anatolia with the wild ancestors of wheats and barleys. It is also clear that wild *Triticum boeoticum* is the likely progenitor of cultivated einkorn, *T. monococcum*; that wild emmer, *T. dicoccoides*, is the ancestor of cultivated emmer, *T. dicoccum*; and that wild barley, *Hordeum spontaneum*, is the progenitor of cultivated barley, *H. vulgare*.[3] The main distinguishing trait between the wild and cultivated varieties of each grain is the mechanism of seed dispersal. The wild progenitors have a brittle ear whose spikelets spontaneously disarticulate at first maturity—sometimes a whole stand of the wild grasses will disseminate in as little as two days—in order to disperse the seeds. In the cultivated varieties, this adaptation no longer exists; seeds remain on the spikelets well after maturity and are in fact now dependent on

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[3] Daniel Zohary, "The Progenitors of Wheat and Barley in Relation to Domestication and Agricultural Dispersal in the Old World," in P. J. Ucko and G. W. Dimbleby, edd., *The Domestication and Exploitation of Plants and Animals* (London: Duckworth, 1969): 47–66.

human agency for their proper dispersal. But the evolutionary bargain has also required nomadic *Homo sapiens* to give up the yurt and adopt a sedentary lifestyle. It is normal to speak of man's domestication of the cereals, when at best such talk is a failure of the imagination, at worst pure arrogance; it was in fact the cereals which induced man to forego his nomadic ways and take up a proper *domus*. It was the cereals that literally 'domesticated' us.

Though Roman farmers at all levels practiced polyculture, that is, cultivation of a variety of crops, among cereals as elsewhere, the staple grain for Rome throughout her history was wheat, and why this should be so is perhaps not so obvious as it might seem to a Westerner. All the other grains have wheat's nutritional advantage, namely, a high starch content which can be metabolized by the human digestive system to produce carbohydrates, the high-energy food of the human engine, and can even be artificially metabolized by various enzymatic processes as a sort of 'predigestion'. Cereal grains, particularly wheats, are thus efficient sources of calories. One kilogram of wheat, for example provides 3,300 kcals of energy and thus an adult human's daily caloric needs can be satisfied by 500–660 grams (about a pound) of wheat. Cereals also have some proteins and a substantial proportion of other essential nutrients such as thiamine and niacin, vitamin E, calcium and iron.[4] All the grains also share the same stability when dried since desiccation is nature's way of preserving the seed germ and its food supply until conditions for germination are opportune. Seeds of all the grains contain a germ, the embryo of the future seedling, and a far larger endosperm, a layer of almost pure starch which will nourish the seedling until it roots and begins to feed itself. The grainseed also contains lesser amounts of bran (seed coat) and water. It is this endosperm, however, which is the single greatest source of carbohydrates in the diets of every human culture.

However, man's ability to digest raw starch is poor. One strategy for making starch more nutritionally available is thus to 'predigests' it by cooking it. Above 140°F, a mixture of water and cereal starch gelatinizes to form porridge or gruel, which is both palatable and reasonably digestible but very unstable microbiologically and always more or less fluid. Both disadvantages can be eliminated if much of

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[4] Garnsey (1999): 19–20.

the moisture is baked out, but here not all grains are equal. High consumption of unleavened, whole-wheat breads high in bran content is associated with such deficiency diseases as iron-deficient anemia, dwarfism and rickets. The reason is the presence of phytate acid in the bran and germ of cereals which impedes the absorption of essential minerals. Unleavened and undersieved bread flours, especially associated with the diets of the poor, will have led to mineral-deficiency conditions among the poor of antiquity.[5] Furthermore, unless baked in very thin sheets the resulting 'bread' is unpalatable and difficult to chew. By subjecting the paste to a fermentation the resulting bread becomes bacteriostatically stable, lighter, more digestible, and wonderfully palatable.

Thus leavened bread is the most desirable cereal food, and common wheat is unsurpassed for making bread.[6] This is so for two reasons, both of which relate to highly elastic proteins in the endosperm of cereal seeds, glutenin and gliadin, which combine to form a proteinaceous matrix called gluten. This gluten traps the carbon dioxide byproduct of yeast (i.e., alcoholic) and lactic fermentation and this results in the trapped bubbles which give leavened bread its wonderful texture. Simultaneously, yeasts and lactic bacteria predigests some of the complex sugars in wheat starch and make them somewhat more digestible for humans. Now wheat contains a higher concentration of gluten proteins than do other cereals, and certain kinds of wheat do not require parching to rid them of their tough seed coverings, a process which tends to destroy the elasticity of gluten. Thus wheat and more specifically the so-called 'naked' varieties became the Roman grain *par excellence.*

But that was a historic development. The Romans of our period were well aware that they had only relatively recently become bread eaters, nor did they ever abandon completely their taste—or need—for porridges, especially, we may suspect, among the poorer urban class and the peasantry.

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[5] Garnsey (1999): 20–21.

[6] L. A. Moritz, *Grain Mills and Flour in Classical Antiquity* (Oxford: Clarendon Press, 1958): xviii–xx. Cf. J. André, *L'Alimentation et la Cuisine à Rome* (Paris, 1961): 52–67.

Roman Cereal Grains

Pliny, our best source of information on cereal varieties in Rome, divides all grains into the two categories of cereal such as barley and wheat and legumes such as broad beans (fava beans) and chickpeas.[7] Alternatively, he adds, they may be divided into spring grains—millet, panic grass, lentils, chickpeas, emmer wheat—and autumn grains such as soft wheat, barley, broad beans, and turnip (raised by the Romans for its seed as well as its tuberous root). All this is perfectly accurate, though we are a bit surprised to find legumes listed as grains. But seen from an ancient perspective even this has much to recommend it; legumes, like cereals, are stabilized by way of drying, and additionally, the Romans sometimes made bread from and with legumes.[8]

The cereal grains known to the Romans were numerous.[9] Maize was, of course, unknown to them, and rice and sorghum were exotic; oats were known but considered suitable only for animal feed and thus harvested before fruiting and otherwise regarded as a weed in wheat fields. Rye was known but grown only north of the Alps. The millets—true millet and panic—might be consumed by humans in times of famine, but probably not otherwise to any great extent. Wheat and barley were thus the two main cereal species in classical antiquity.

Barley had always been, and remained, an important cereal for the Romans, though never as important as for the Greeks. Barley has much to recommend it; it is an excellent reserve crop; it grows in marginal land and is far more drought- and cold-resistant than wheat. Additionally, it has the shortest growing season of all cereal crops—60 to 70 days in spring and about 180 days in winter—and can therefore be sown after other crops fail. Thus barley as a staple had a long history in Rome, though it was regarded as inferior

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[7] *NH* 18.48–51.

[8] For the sake of consistency we will treat them as a subcategory of vegetables in Ch. 4.

[9] N. Jasny, "The Wheats of Classical Antiquity," *Johns Hopkins University Studies* 62 (1944): 141ff.; idem, "The Daily Bread of the Ancient Greeks and Romans," *Osiris* 9 (1950): 227–53; Moritz (1958): xxii–xxiii; idem, "Husked and 'Naked' Grain," *Classical Quarterly* 49 (1955): 129–34; M. S. Spurr, *Arable Cultivation in Roman Italy c. 200 BC–c. AD 100* (London: Society for the Promotion of Roman Studies, 1986 [= *Society for the Promotion of Roman Studies Journal of Roman Studies Monographs No. 3*]): 10–17.

food, at least from the third c. BCE, after which time it was punishment rations for derelict Roman soldiers.[10] Most barley grown in antiquity was so-called six-row and was therefore 'husked'. To clarify, the seeds of all grasses grow on spikelets and are partially enclosed by two modified floret leaves, the *lemma* and *palea* [Fig 1]. On so-called 'husked' grains these are fused with the epicarp or outermost covering of the kernel and therefore cannot be removed by traditional threshing. So-called 'naked' grains are not really naked at all but simply have *lemma* and *palea* more loosely attached and thus removable by threshing. Confusion in the ancient sources on this point is compounded when scholars refer to the husks as glumes, which are in fact two additional modified leaves which enclose the entire spikelet during flowering.[11] The fact that six-row barley is a 'husked' grain means that its *lemma* and *palea* cannot be removed by ordinary threshing; it is thus one of the cereals which must be roasted and pounded to achieve this end; but roasting largely destroys the elastic properties of gluten, as previously mentioned. In short, barley bread can be and was made by the Romans, but it is and was inherently inferior to wheaten bread; thus barley remained primarily a porridge grain.

Of the types of wheat, *Triticum*, available to the Romans, the original one in evolutionary terms was undoubtedly *T. dicoccum*, that is, emmer wheat, Latin *far*.[12] Pliny, citing Hemina, attributes to the early Roman king Numa the custom of roasting emmer, "since after roasting it was more healthful as food," though he adds that Numa forbade roasted emmer in religious rituals—against the *mos majorum*![13] All the hoariest Roman religious oddities were conventionally attributed to good King Numa, successor to Romulus, and thus the historicity of Pliny's attribution is worthless, but the fact that the archaic marriage ceremony of *confarreatio* takes its name from the emmer cake exchanged by bride and groom suggests that his dating of emmer's use as a foodstuff to earliest times is perfectly sound. That

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[10] Polybius 6.38.6.

[11] Muller and Tobin (1980): 122.

[12] Note that the Latin *far* is often rendered by translators and food historians alike as 'spelt' which it manifestly is not. Spelt (*Triticum spelta*) was known in Rome only from the first century CE and was never significant as a food cereal. Both Brehaut and Ash in their translations of Cato and Ash in his translation of Varro translate *far* as 'spelt'

[13] Pliny, *NH* 18.7–8.

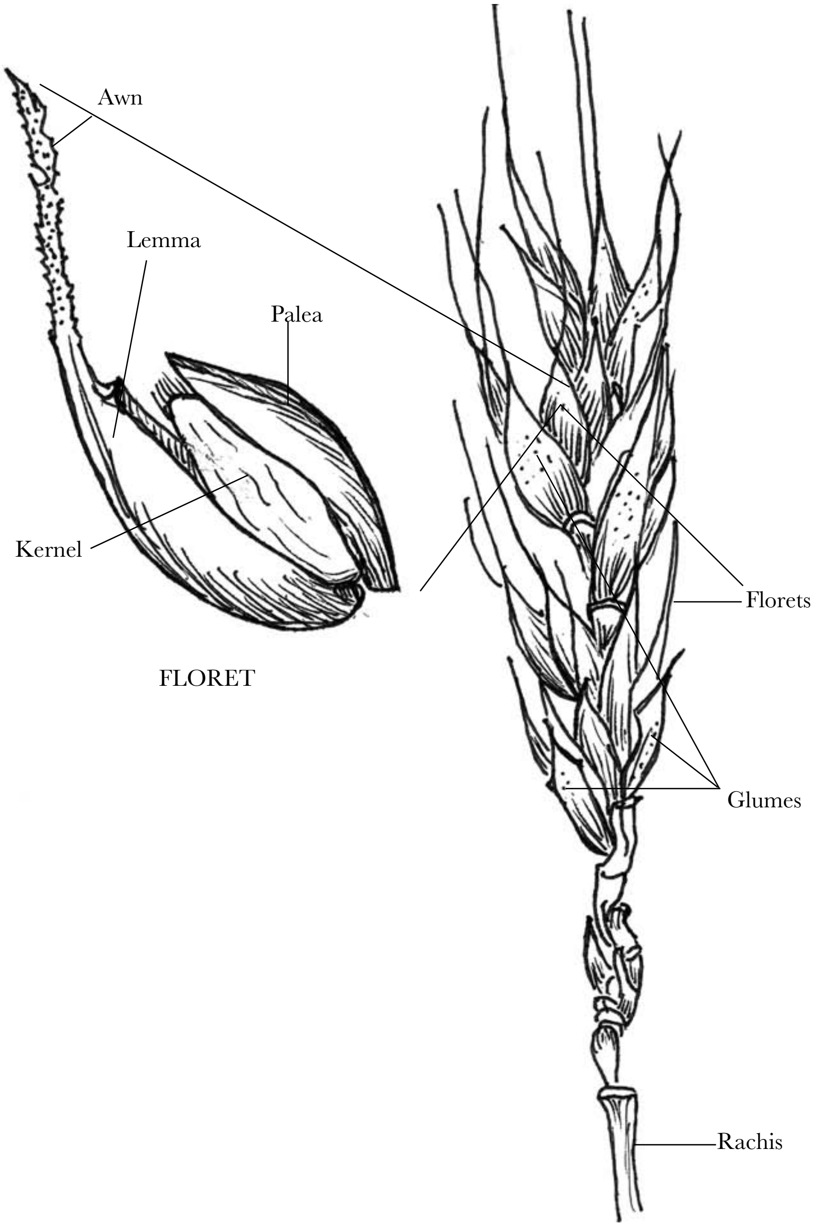

Fig. 1. The Anatomy of a wheat spikelet. Note that glumes are separate from the seed pod itself. So-called ‘husked’ wheats have lemma and palea fused with the epicarp of the kernel, whereas ‘naked’ wheats have loosely attached palea and lemma and can therefore be threshed without parching.

fact is now confirmed by finds of carbonized seeds of emmer in a number of pre-Roman and early Roman contexts.[14] But emmer suffers from the same disability as barley, namely, its status as a 'husked' grain; thus emmer bread must have been a flat, dense article, and emmer was yet another grain which was used during the classical period primarily for porridge.[15] Moritz, in fact, thought that by Pliny's own time (mid-first century AD) *far* had largely disappeared from the Roman diet, but Spurr adduces good reasons for rejecting his argument.[16]

Of the so-called 'naked' wheats, the Romans knew *Triticum durum* and *T. vulgare*. The former, called rather confusingly by the Romans simply *triticum*, is the tough durum or semolina wheat still used to make pasta. *T. vulgare*, called by the Romans *siligo*, is common bread wheat. This latter was unquestionably the most desirable breadmaking wheat in Rome, especially when its seed coat, the bran, had been removed. The reason is quite simple: it alone, given the milling technology available to the Romans, could yield a fine, white, glutenous flour capable of making excellent Roman bread.[17]

Parching

It will already have become obvious to the reader that the various steps in the processing of these grains was largely dictated by their individual physiological structure. Let us turn our attention to these processes. Unfortunately for the researcher, the three most important forms of food processing on Roman villa farms, the prototype Roman agribusiness, were evidently contracted out to itinerant entrepreneurs. Thus our most important literary sources, agricultural writers such as Cato, Varro and Columella, are not as explicit about the processing of grains, olives and grapes as we could have wished. Then, too, once the grain left the villa's granaries and was sold to

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[14] Spurr (1986): 12–13.

[15] Thomas Braun questions whether emmer required toasting to make husks brittle before removal by pounding. Cf. Braun, "Barley Cakes and Emmer Bread" in John Wilkins, David Harvey and Mike Dobson, edd., *Food in Antiquity* (Exeter: U. of Exeter Press, 1995): 25–37. Contra: K. D. White, "Cereals, Bread and Milling in the Roman World," op. cit. 38–43, esp. p. 39.

[16] Moritz, (1958): xxii; Spurr (1986): 11–13.

[17] Moritiz (1958): xx–xxvii.

the state or the *pistores*, men who served as both millers and bakers, it underwent what was essentially a commercial processing about which our Roman authors speak only incidentally. Fortunately at this point archaeology is able to fill many of the gaps.

The first step which can rightly be deemed a food process as opposed to an agricultural one has already been adumbrated, namely threshing, that is, the process of ridding the grain kernels of unwanted, indigestible peripheral elements such as the glumes, the husks, the awns (the long spike attached to the lemma) and the rachilla (the central stem of the spikelet to which the individual seeds are attached). These elements are referred to collectively as chaff. As we have already seen, this process begins in the case of 'husked' grains with roasting or parching. Parching of the 'naked' grains occurs if at all after the threshing and has as its end to prevent the germination of the seed and reduce moisture content and thus make the grain more biologically stable. Secondarily the process imparts some sweetness to the grain by converting some starches of the endosperm to dextrin. Ovid[18] says that in early days farmers were accustomed to roast grain directly in the hearthfire, an unsatisfactory strategy because of the danger of housefires and the intermingling of parched grain and ashes. Thus at some point a special oven called a *fornax* was invented, and a religious festival, the Fornacalia, instituted in honor of such ovens. What this oven may have looked like we do not know; the etymology of the word *fornax* as well as its connection to the name of the *furnus*, the later baker's oven, suggests that it was a similarly domed, brick structure. Curtis notes that construction of a *fornax* will have been an expensive investment for a subsistence farmer and surmises that perhaps several farmers shared a common oven.[19] Frayn[20] suggests that rural millers may have operated these parching ovens but began to use the similar *furnus* when they moved to urban centers and assumed the role of bakers as well as millers.

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[18] Ovid *Fasti* 2.519–30. Cf. *Fasti* 6.313–14; Festus, 82L.

[19] Curtis (2001): 369 and n. 89.

[20] Joan M. Frayn, *Subsistence Farming in Roman Italy* (London: Centaur Press, 1979): 109–10.

Threshing

The threshing took place on an open-air threshing floor (*area*) especially constructed for the purpose. Columella[21] recommends it be paved with hard stones so that the beating hooves of the draft animals or the threshing sledges can operate more efficiently. Doubtless such threshing floors ran the gamut from simple cleared hilltops to elaborate constructions. Several of the latter are now excavated.[22] The threshing floor of the villa of San Giovanni di Ruoti, for example, is ideally situated to catch the breezes used in winnowing. That at the Villa Pompeiana della Pisanella near Pompeii was large, elevated and nicely paved. It seems to have been slightly sloped to allow for quick drainage to cisterns and was again well sited to receive the winds. It was located next to the villa and thus easily seen by the owner or overseer, and had a large room leading directly onto it, interpreted as a *nubilarium*, that is, a room large enough to receive crops waiting to be threshed.[23]

Pliny tells us[24] that on such a floor were threshed durum wheat, common wheat and barley. Reserved portions of these cereals are sown dehusked, he adds, since they are not roasted, which would of course kill the germ. (Pliny is manifestly mistaken here about barley, as he is on other matters with frustrating regularity.) Emmer, millet and panic are threshed only after parching; thus their reserved portions are not threshed but sown in the husk. Pliny also discusses the same motive forces for the process as does Columella, namely, threshing sledges (*tribula*) dragged by oxen across the threshing floor (*area*) and treading by draught animals. Curiously, in the latter case he specifies mares. Could this be some sort of fertility magic? Pliny adds a third method, beating the grain with flails (*perticae*),[25] simple sticks or rods with which the spikelets of grain are beaten by hand, but has nothing more to say about them. The reason is evident: the

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[21] *DRR* 1.6.23.

[22] Spurr (1986): 73–75.

[23] Spurr (1986): 75, citing A. Pasqui, "La Villa Pompeiana della Pisanella presso Boscoreale," *Monumenti Antichi* 7 (1897): 397ff. Cf. Columella *DRR* 1.6.24; Varro, *RR* 1.13.5.

[24] *NH* 18.61.

[25] Pliny, *NH* 18.298–99. Complete testimonia for the instuments is found in K. D. White, *Agricultural Implements of the Roman World* (Cambridge: Cambridge U. Press, 1967): 152–56 and Figs. 114–17.

Roman flail, unlike its later permutation which survives in some areas to this day, was not hinged to allow the thresher to strike the grain from a nearly upright position such that the lower portion strikes the grain along its whole length. The Roman flail was a simple rod, probably curved, which will have been extremely awkward and inefficient.[26]

On the other hand, the use of draft animals in threshing is as old as agriculture itself and is still used in isolated parts of the Mediterranean. Basically the animals are simply turned out onto the threshing floor and led about until the friction of their hooves has removed sufficiently the chaff. The threshing sledge to which both authors refer [Fig. 2] consists of a board or sledge studded on the bottom with iron nails and carrying a driver who provides additional weight for friction and directs the draft animals which pull it around the *area*.[27]

Winnowing

After the kernels have been separated from the chaff in one way or another, the grain is winnowed, that is, subjected to wind to allow the chaff to separate from the kernels. This step is performed on the same floor,[28] either with simple shovels, *ventilabra* [Fig. 3A] with which winnowers toss the grain into the air and allow wind to blow away the lighter chaff, or in special baskets, *vanni* [Fig. 3B] which operate in the same way to remove chaff while the heavier kernels gradually fall to a catchment at the bottom of the basket.[29]

Ensilage[30]

It is one of the frequent ironies of our subject that the most critical processes are the least technologically glamorous, and such is the

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[26] K. D. White, *Farm Equipment of the Roman World* (Cambridge: Cambridge U. Press, 1975): 207–9.

[27] Varro, *RR* 42.1; Columella, *DRR* 2.21. Cf. White (1967): 152–6. Spurr ([1986]: 77) cites a modern example of the use of the threshing sledge, as well as examples of use of draught animals for the purpose.

[28] Columella, *DRR* 1.6.23.

[29] Cf. White (1967): 32–5; White (1975): 75–77.

[30] Spurr (1986): 79–82; Curtis (2001): 325–35.

Fig. 2. The ancient threshing sledge (*tribulum*) as seen from the bottom. Flints or metal studs are embedded in the bottom, friction from which threshes wheat as the sledge is dragged over the ears. The insert is a detail of the flints. (From Storck and Teague (1952): Fig. 17. Courtesy of University of Minnesota Press).

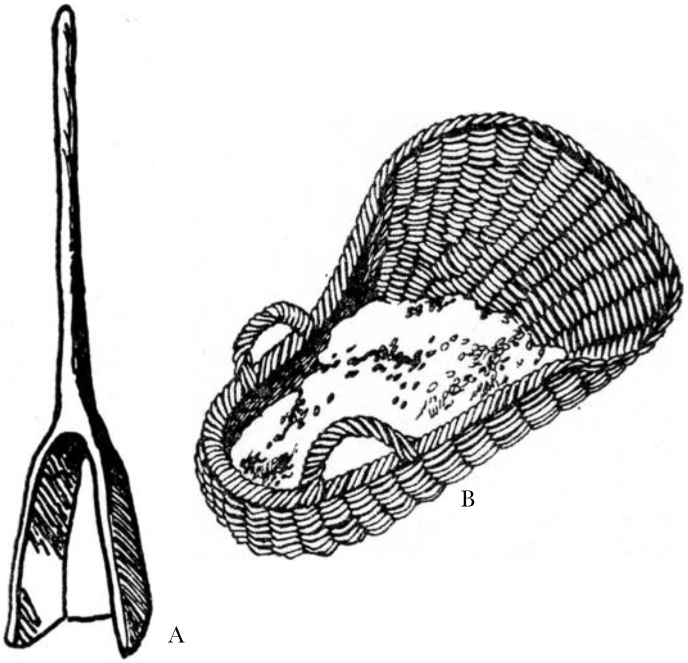

Fig. 3A. Winnowing shovel (*ventilabrum*) with which threshed wheat is thrown into the air so that chaff is blown away by breezes. Fig. 3B. A winnowing basket (*vannus*). The user tosses the grain and chaff in an elliptical motion so that chaff blows away and the denser kernels settle into the catchment beneath the handles. (From White (1967): Fig. 12, and White (1975): Fig. 25. Courtesy of Cambridge University Press).

case with the next step in processing grains. I refer to the storage of grain in areas which are cool, dry, and free of vermin and therefore capable of maintaining the stability of the grain. Grains and legumes which dry on the vine or stalk are living entities naturally able to resist catalyzing agents. Additionally, a low water activity, on the order of 14–15 percent naturally, greatly inhibits such agents.[31] Such grains properly stored can remain viable and sound for up to four years and will retain their food value indefinitely.

Pliny[32] discusses in some detail the biological stability of various grains:

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[31] Lipolytic molds in cereal grains, for example, will not grow below 12% moisture content. Cf. John Troller and J. H. B. Christian, *Water Activity and Food* (New York: Academic Press, 1978): 55.

[32] *NH* 18.73. All translations of the agronomists in this work are those of the Harvard Loeb series, unless otherwise noted.

> The causes of the keeping power of grains are several: either in the husk of the grain itself when it is multiple, as in millet, or in the oil content (*pinguitudo*) of the juice which suffices in itself instead of moisture ("qui pro umore sufficiat tantum") as in sesame, or in the bitterness of the juice as in lupine and chickling vetch. In wheat in particular pests are bred because it naturally generates heat [in piles] because of its density and is covered with a thick scurf (furfur = bran?). The palea of barley is thinner as is that of legumes and therefore they don't breed pests. The broad bean is covered by a thicker coat and therefore ferments. Some people sprinkle wheat itself with *amurca* [vegetal water from olive oil pressing; cf Ch. 2] as a preservative, eight gallons to the quadrantal, while others use for this purpose Chalcis or Carian chalk or even absinthe. There is also an earth of Olynthus and Cerinthus in Euboea which prevents rot. And grain stored in the husk scarcely ever degenerates. The most practical method, however, is storage in silage pits called *siri* as is done in Cappadocia and in Thrace and Spain and Africa, where particular care is taken to excavate in a dry soil and quickly to strew chaff [the standard Roman desiccant] underneath, and then to store the grain unhusked. If no air penetrates, then nothing insalubrious will be generated here. Varro is our authority that wheat thus stored will last for 50 years, and millet even for 100.

The key, obviously, is to provide a proper storage facility, and secondarily to treat with chemical agents. About such facilities Pliny says that some authorities recommend building silos with brick (brick-faced concrete?) walls a yard thick, windowless to shut out drafts, facing the northeast or north (i.e., in the lee of the winter wind), built without lime (an inexplicable comment), and smeared with *amurca*, the intensely bitter vegetal water derived from the pressing of olives, which the Romans used as an all-purpose pesticide. Such granaries, he adds, are to be filled from above and so presumably are partially at or below ground level. In other places, he says, granaries are built of wood, elevated on pillars to provide as much circulation of air as possible.[33] [Fig. 4] There is no contradiction here between efforts to exclude drafts but promote circulation of air. It is not the air in the drafts *per se* which is deleterious but its potential moisture and the spoilage organisms such as molds and yeasts which are present to some extent in every breath we take. Circulation of air *within* the granary, on the other hand, helps to maintain a lower water activity in the grain and thus inhibit spoilage. Elsewhere[34]

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[33] *NH* 18.301–06.

[34] *NH* 18.322.

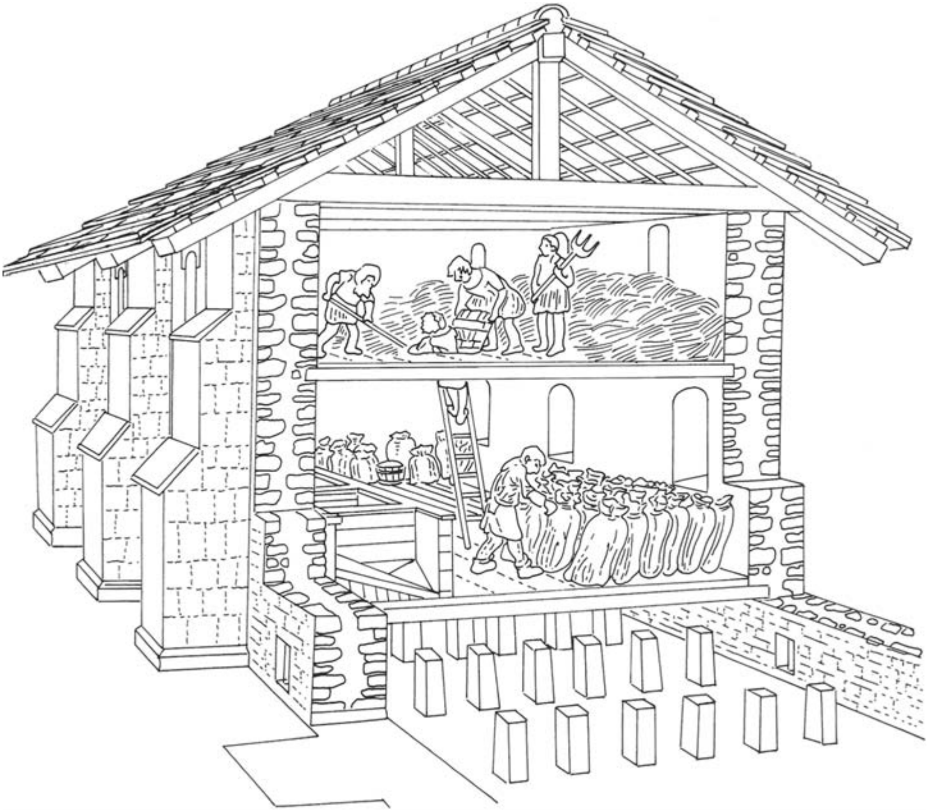

Fig. 4. Reconstruction of a military granary at Housesteads, England, showing the *suspensurae* and the loft. (from James Crow, English Heritage Book of Housesteads. Chrysalis, 1995. Courtesy of Robert I. Curtis).

Pliny tells us the authorities recommend aerating cereals and legumes and storing them toward the end of the moon's cycle (Pliny believes in farming 'by the signs'). The aeration he refers to is simply tossing the grain in the air with spades periodically to loosen the compaction which facilitates fermentation and other forms of spoilage. But, he adds, many forbid the aeration on the grounds that the weevil will penetrate compacted grain only four inches and so the uppermost layer is sacrificed to maintain the purity of the rest. Obviously the food agent has to decide whether weevils or microbial spoilage represents a greater threat. Pliny recognizes that thickly husked grains such as millet have more keeping power (as indeed they do) as do those with high oil content such as sesame, and those of bitter flavor such a lupines. Right on two of three counts; fatty seeds are actually far more unstable than low-fat seeds, but it is perfectly true that weevils have an aversion to bitter taste quite as much as humans. Thus some ancient farmers and grain agents sprinkled wheat kernels with *amurca* or with wormwood—the bitter principle at work—or with chalk from Chalcis or Caria. Elsewhere Columella[35] recommends that grain, hay and fodder be stored in lofts and that if they must be stored at ground level, the earth should be dug up, soaked with amurca, packed down with rammers, overlaid with *pavimenta testacea*, i.e., a brick pavement, whose mortar is mixed with amurca instead of pure water. Curtis[36] gives an excellent description of two such granaries which roughly fit the agronomists' recommendations, from excavations in Latium at Vicovaro and near Ravenna at Russi.

Pliny and Columella obviously refer to granaries of a fairly sophisticated sort but also mention simple grain pits. Elsewhere, too, we hear of simpler granaries, essentially nothing more than pits or silos dug into the earth.[37] In the past it was thought that something so unsophisticated could suffice only in the eastern and southern parts of the Empire where rainfall was relatively scarce. We now suspect that such pits will have sufficed quite well elsewhere owing to a

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[35] *DRR* 1.6.9.

[36] Curtis (2001): 328–35. Cf. Walter M. Widrig, "Two Sites on the Ancient Via Gabina," in Kenneth Painter, ed., *Roman Villas in Italy: Recent Excavations and Research* (London: British Museum, 1980 [= *British Museum Occasional Papers No. 24*]): 131; A. Carandini et al., *Settefinestre: una villa schiavistica nell'Etruria romana I* (Modena: Edizioni Panini, 1985): 163–8.

[37] Varro, *RR* 1.63.

simple but remarkably effective phenomenon. We are told that such silos were constructed in such a way as to minimize surface area, where grain will be in contact with air and moisture, and were further sealed with plaster to exclude air. The effect of such an arrangement has now been experimentally documented;[38] such silos are topped up with grain to the surface, capped with a rounded clay cap which extends beyond the lip of the silo, over which a mound of earth is heaped to keep the clay cap moist and thereby prevent migration of air and water. Grain on the outside and top of the carefully compacted mass is exposed to moisture from the surfaces of the silo and germinates, simultaneously using up residual oxygen and respiring carbon dioxide. As it does so it coalesces at the surface into a solid mass some 1–1 1/2" (2–3 cm) thick which provides a semi-impermeable barrier to further moisture migration. Since CO_2 is considerably denser than air and there are no air currents to otherwise disperse it, it sinks to the bottom of the silo, displacing residual oxygen. Thus the sacrificial grain of the 'skin' of the grain bulk provides a remarkably stable environment for the remainder. The sacrificed grain is on the order of 2%, a figure which compares favorably with most modern storage systems. That a similar mechanism is at work in our Roman silo is indicated by Varro's admonition[39] to those entering a *sirus* to wait for some time after removing the cap, since people have otherwise been suffocated. Obviously carbon dioxide is as effective in inhibiting human invaders as microbial ones.

Granaries are prescribed by our authors for the villa owner, but effective storage was even more critical for the huge volume of grain imported to the city of Rome to feed the urban masses, and here, fortunately, we have significant archaeological evidence such as the extensive remains of the (probably spuriously named) Porticus Aemilia, a vast commercial granary or *horreum* near the Tiber River between the Aventine and Monte Testaccio [Fig. 5]. It is a marvelous example of the Romans' newfound confidence in their favorite architectural medium, concrete, and the arcuated forms it permitted. In this case we have a veritable *tour de force* of *opus incertum* barrel vaults, arranged in a series of tiers descending to the docks at the river, "a

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[38] Peter J. Reynolds, *Iron-age Farm: The Butser Experiment* (London: British Museums Publications Ltd., 1979): 71–77.

[39] *RR* 1.63.

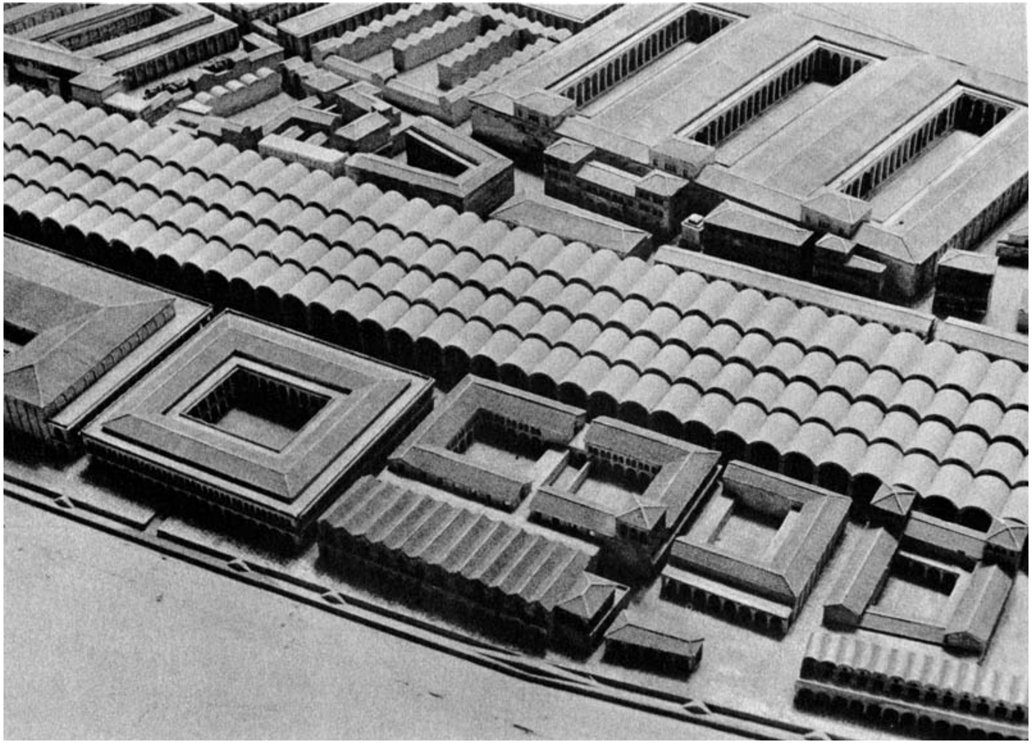

Fig. 5. The so-called Porticus Aemilia, a huge *horreum*, or warehouse, along the Tiber River in the southwest part of the city, showing the Romans' increasing confidence in barrel vaulting. (From William L. MacDonald, *The Architecture of the Roman Empire* (1982): Plate 1a. MacDonald's photo of the model city at the Museum of Roman Civilization at Rome. Courtesy of Yale University Press).

total of 200 large vaulted units, well lit and ventilated by clerestory windows as well as by an open and highly flexible layout."[40] In short, a cool, dry, well ventilated edifice where bulk commodities of all sorts, including grains, could be safely stored.

At least three great *horrea* have been located in Ostia, with permanent raised floors. Grain may have been stored either in bins, in sacks, or loose on the floor. Hermansen[41] thinks there is no doubt that grain was shipped in bulk, as evidenced by legal questions where grain belonging to different owners and/or shippers was dumped promiscuously in a ship's hold without partitions. Also, pictorial evidence of two ships being offloaded seems to show shipment as loose grain. But the grain was evidently offloaded to granaries in sacks. Was it then emptied from the sacks into the granaries? There is no evidence for bins, and they are probably precluded by room divisions which themselves suffice as bins for storage in manageable portions. For loose storage, the floor had to be completely dry and waterproof and the grain carefully dried and cooled. Sacks needed to be dry and easily accessible. This latter arrangement seems most likely, especially since several artistic representations show porters offloading commodities of some sort in sacks into horrea. Further, most grain was stored at Ostia only long enough to be transshipped on barges to the city, and sacks will have made this convenient.[42]

The *horrea* at Ostia were constructed with Pliny's raised floors, *suspensurae*. In this case these were formed by raised, longitudinal truncated walls 16" (40 cm) tall and by stacks of *bipedales*, Roman tiles 2' (60 cm) square, upon which a typical concrete *pavimentum* was built. These are similar to the systems of *horrea* found in military forts. Rickman[43] thinks that these *suspensurae* date from the second century CE and that other references (Columella 1.6.16; Varro 1.57; Pliny 18.302) are to wooden floors raised upon joists. There is some evidence at Ostia that older wooden floors were replaced by the brickwork *suspensurae* described. However this may be, the import is clear; granaries were designed to provide a dry, waterproof, airy

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[40] L. Richardson, Jr., "The Evolution of the Porticus Octaviae," *American Journal of Archaeology* 80 (1976): 57 and Pl. 12.

[41] Gustav Hermansen, *Ostia. Aspects of Roman City Life* (Edmonton: University of Alberta Press, 1981): 227–35.

[42] Geoffrey Rickman, *Roman Granaries and Store Buildings* (Cambridge: Cambridge U.P., 1971) 85–86.

[43] Rickman (1971): 293–7.

environment for the huge quantities of grain necessary to feed Rome's population. Hermansen[44] estimates a grand total of 33,300 square meters of storage potential at Ostia, a figure that would represent 32,190 tons of grain. The grain import from Egypt and Africa is recorded as 60 million modii per year[45] which equals 390,000 tons, a figure Hermansen finds suspect. But if it is accurate, then Ostia's storage capacity at a given time would represent about 8.25% of Rome's annual import from Egypt and Africa in the first century CE. Hermansen estimates the facilities at Portus would accommodate an additional 14,500–19,400 tons (depending on assumptions concerning depth of storage) and thinks that Romans continued to use some storage space at Puteoli as well. Ostia's storage potential represents the old-style grain dole allotment for 84,000 recipients per year (at five modii per month per person). Assuming a moderate turnover of three times capacity per year, Ostia alone may have shipped some 95,000 tons annually from her *horrea*, enough to sustain nearly half a million souls.

Braying of Porridge Grains

At this point the processing of grains bifurcates, as our study of the nature of the grains has already suggested. Specifically, threshed grains may be made into various forms of porridge or mixed with lesser quantities of water and fashioned into leavened and unleavened breads. Obviously there is no absolute division in the types of grains which may be used for each—a delicious porridge can be made from the groats of 'naked' wheat, and we know perfectly well that breads (presumably flat breads) were sometimes made from 'husked' grains such as barley, emmer, and even millet—but in general the husked grains were used in Rome for porridges, and the naked wheats, both durum and common, were used for breads. We will look at the processing of porridge grains first.

After husked grains are parched and threshed they must be milled. The ancient 'milling' device *par excellence* was not a mill at all but rather the mortar and pestle—ages old, simple and cheap, requiring

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[44] Hermansen (1981): 231–35.

[45] Aurel. Victor, *De Caes. Epit.* 1.6; Josephus, *Bell. Iud.* 2.383 & 386.

only the simplest motive force, and ever serviceable.[46] The generic name of the dehusked grain resulting from a first crushing in a mortar, *ptisanê* in Greek, *(p)tisana* in Latin, is applied to the groats as well as the porridge made from them. During this process of dehusking, the grain may simultaneously be roughly crushed, but perhaps not even so finely as rough groats. But additional pounding, in conjunction with sifting, will produce a 'cracked' grain we call groats or grits and for which the Romans had specific names in the case of each species of grain.[47] That 'pounding' was in fact the original form of milling in Rome is assured by the etymological connection of these terms with the act of pounding which produced them and most prominently by that of the eventual name for the Roman miller-baker, *pistor*, with the act: *pistor* means nothing more nor less etymologically than 'pounder'. And just as today there is a persistent demand for semolina as well as softer flours, so in antiquity there was persistent demand for groats (G. *chondroô*, L. *alica*). Such groats were typically made into *puls*, emmer porridge, and *polenta*, barley porridge.[48]

For the instruments themselves we have both literary and archaeological evidence. Mortars are, of course, among humanity's oldest tools and their form is inherently conservative. The earliest mortars and pestles in fact were nothing more than concavities in rocks and stones used with them for pounding nuts and other foodstuffs. Indeed, subspecies of chimpanzees are known to select such stones, apparently with some deliberation, for cracking nuts, so we might almost say mortar and pestle are inventions of our common simian ancestry. Mortars and pestles vary in size from the tiny forms used for braying herbs and medicaments to huge immobile stone basins where four pounders can work co-operatively. In Rome there were both wooden and stone forms and combinations of the two [Fig. 6].[49] The mortar was the *pila*, the pestle the *pilum* (ironically, the Latin

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[46] White (1975): 9–10; John Storck and Walter Darwin Teague, *Flour for Man's Bread: A History of Milling* (Minneapolis: U. of MN Press, 1952): 17–24.

[47] Moritz (1958): 146–47.

[48] Moritz (1958): 147–50; André (1961): 62–64; Max Wahren and Cristoph Schneider, *Die Puls. Römishcer Getreidebrei* (Augst: Römermuseum Augst, 1995 [= *Augster Museumshefte* 14]). Note the etymological connection with modern *polenta*, made now almost exclusively with maize groats. For a modern experiment in processing barley, L. Foxhall, "Appendix: Experiments in the Processing of Wheat and Barley" in Foxhall and Forbes (1982): 77.

[49] Cf. Moritz (1958): 12–28, 146–47; André (1961): 62–64; White (1975): 9–12.

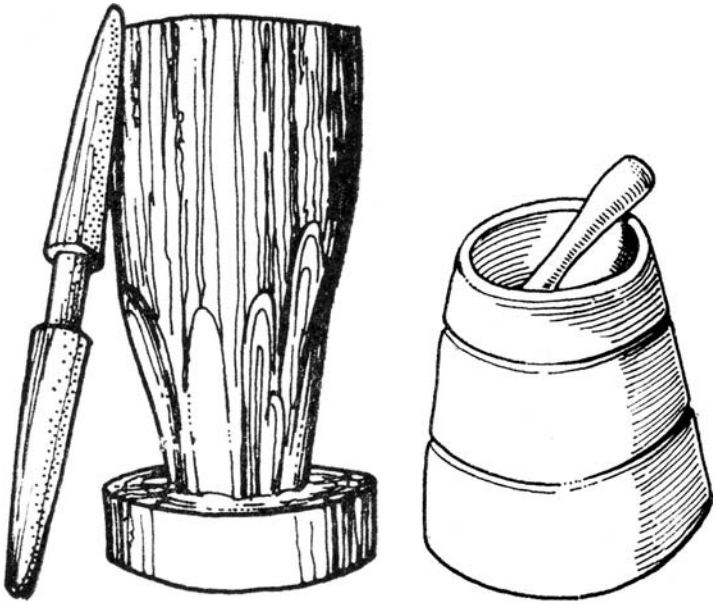

Fig. 6. Roman mortars and pestles. (From White (1975): Fig. 4 and 5. Courtesy of Cambridge University Press).

mortarium was not a mortar at all but a mixing bowl, though the term is used incidentally for the *pila*). Pliny[50] specifies a wooden mortar with a wooden pestle the end of which is capped with iron, the particular form having the advantage over stone that it does not completely pulverize the kernel. Cato in his list of utensils has a *far* pestle[51] as well as a wheat mortar,[52] suggesting that different forms of the implements were adapted to different tasks, at least on the well appointed villa farm that Cato envisions.

The process itself is easy enough to imagine, though even here there were specific adaptations for the specific grains and the desired quality of groats to be derived from them. Pliny[53] implies that the pounding of barley to make *alica* for *polenta*, barley porridge, was essentially a home operation in which the groats were soaked for an unspecified length of time, then allowed to dry overnight, then roasted and "milled" (he is using the term generically and means "pounded

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[50] *NH* 18.112.
[51] *Agr.* 10.5.
[52] *Agr.* 14.2.
[53] *NH* 18.73.

in a mortar"). The step of soaking grain in this way is called 'conditioning' or 'tempering' and is still very much a part of the milling process; the hydration tempers the bran of the kernel and 'mellows' the endosperm so that cracking will result in more pronounced fracture of the two elements and easier separation of the edible starch from the inedible bran. Particularly interesting in this regard is Pliny's remark that some temper a second time before 'milling', inasmuch as a second, shorter tempering is still the norm today. Pliny adds that some avoid the necessity of tempering by braying the grain while it is still green (to remove the husks); they then wash off the husks in baskets, sun-dry the grain, bray again (i.e., to remove the bran), clean again (by sifting?), then pound to desired fineness. All perfectly logical, though I question whether we should envision our ancient food processors storing large quantities of groats processed in this way; groats are much more biologically unstable than whole grain. On the other hand, Varro[54] attests that emmer groats are taken from storage and parched at the 'mill', so the practice was not uncommon.

For the Romans the porridge grain of choice was not barley but *far*, emmer; its porridge is *puls*, and the Romans of the classical period looked back nostalgically upon their agrarian ancestors as '*puls*-eaters.' The processing was much the same. Presumably some such tempering process as we have just discussed was used, though our sources do not say. In any case, Pliny tells us[55] the grain is pounded in a wooden mortar with an iron-capped pestle. After the husks have been pounded off (and sifted, though Pliny does not specifically say as much) the naked kernel is brayed a second time using the same implements. The resulting cracked grain can be pounded and sifted to standard consistencies, and Pliny specifies three grades of emmer groats: *minimum*, 'smallest'; *secundarium*, 'seconds'; and *grandissimum*, 'biggest', the last-named called in Greek *aphaerêma*, 'select grade'. This suggests that the larger groats were preferred, perhaps because there was less bran and grit intermingled with them. Pliny adds that sometimes a Campanian chalk is added to the groats to improve color and fineness.

Pliny also speaks of 'spurious' emmer groats made from a poor African strain. In this case the kernels are mixed with sand before

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[54] *Agr.* 1,69.1.

[55] *NH* 18.113–14.

braying, yet even with such an abrasive the husks are inadequately removed and only half the amount of dehusked grain results. Next white lime is sprinkled on in the proportion 1 to 4 parts, and when this has "adhered" (?) the cracked grain is bolted through the *cribrum farinarium*, the coarsest sieve. The 'overtails', i.e., the material which remains on the sieve, are called *excepticia*, 'residual', and of course are largest in size. The 'throughs', the portion which passes through the sieve, are again bolted in a finer sieve, the resulting overtails being called 'seconds' again; the throughs are again bolted and the throughs rated as *cribaria*, 'sieve-groats'. Only the sand, Pliny assures us, is left from this third sifting, but the product here described must still have been an unpleasantly gritty commodity.

It might appear odd that Pliny specifies no second or third braying between siftings, but a law of diminishing returns applies here; the more the overtails of a sifting are ground, the more the bran is pulverized and therefore the 'brannier' the resulting product.

A third form of groats was apparently made from durum wheat and the resulting porridge called *tragum*.[56] Pliny tells us it was processed in the same way as barley groats, a valuable tidbit of information since it implies that the wheats were all tempered in the same way as barley.

Our literary sources all seem to suggest that these processes were domestic ones. To what extent they were commercial as well is impossible to say. Certainly mortars and pestles are frequently found in archaeological contexts which clearly identify commercial mill-bakeries, but mortars can be used for braying any number of substances useful to the baker, most notably salt. For what it is worth, Cato[57] says that the *vilica* (overseer's wife), the housekeeper of the Roman villa farm, should know how to make flour and fine emmer groats, implying a domestic chore. But her role here may have been supervisory, since elsewhere[58] he tells us that slaves should be set to work pounding emmer groats on feast days, and Pliny[59] says the motion of the pestle, as is well known, is (sometimes?) the work of *convicti*, slaves chained together and undergoing punishment. Whether

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[56] Pliny, *NH* 18.76.

[57] *Agr.* 143.3.

[58] *Agr.* 2.4. Ash in his Loeb translates *far* as 'spelt' and compounds the mistake by rendering *expinsi* as 'grinding'. Wrong on both counts: not 'ground spelt' but 'pounded emmer'.

[59] *NH* 18.113.

such groats were offered for sale or were strictly for home consumption by the slaves themselves is impossible to answer. I have found no mention in the literature of the purchase of groats at a commercial mill-bakery in Rome, but given the paucity of such references that means very little.

Milling of Bread Grains

Conversely, there is little doubt that true milling of breads remained a domestic as well as commercial process throughout classical antiquity, at least on a modest and *ad hoc* basis. But milling and baking are among the most important commercial processes the classical world has bequeathed to Western culture. Bread at one time or another was made from all the grains, not only barley, emmer, durum wheat, and common wheat, but also millet and panic, not to speak of legumes such as beans and peas and nuts such as acorns and chestnuts.[60] But the introduction of naked wheat corresponded with the emergence in the Roman world of professional miller-bakers, and within a short time, at least in the city, it was common practice to procure one's 'daily bread' from the bakeshop.[61] According to a doubtful tradition,[62] there had been public ovens for baking from the time of Tarquin the Proud, but a more reliable tradition has professional miller-bakers appearing in Rome in 170 BC. Moritz[63] points to a reference in Plautus' *Asinaria* to a *pistor* who sells breads and therefore also presumably mills and bakes it. If we assume a Roman context for this 'Greek' play, we can push back the date of arrival of the miller-bakers some fifteen to twenty years. In any case miller-bakers were eventually well organized into *collegia* and received grain from the public granaries at a subsidized price fixed by the magistrates. Additionally, wealthy households owned specialist slaves who might bring exorbitant prices at sale if their skills as miller-bakers were highly reputed.[64]

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[60] Columella, *DRR* 2.4.19; Pliny *NH* 18.54 and 100.

[61] Moritz (1958): 69; Alexis Soyer, *The Pantropheon: Or, a History of Food and its Preparation in Ancient Times* (New York: Paddington Press, 1977): 35–37; André (1961): 61–65.

[62] Pliny, *NH* 18.11; cf. 18.107.

[63] Moritz (1958): 69. For a general history, Storck and Teague (1952): Ch. 1–10.

[64] Aulus Gellius, *NA* 15.9.

Historically the earliest true mill, that is, an instrument for grinding rather than pounding grain, was the saddle quern, of almost universal provenience and still very much a part of traditional cultures.[65] It is a simple device, typically consisting of a table, often stone and sloped to allow gravity to sift the heavier endosperm starch from the lighter bran and having a catchment at one end for the meal; and an upper, traveling millstone, convex on the top and flat on the bottom and light enough to be worked back and forth on the table stone to grind the grain between them by means of simple friction. The operation is simple, if toilsome: the operator places grain on the surface of the table, grasps the upper millstone on either side (sometimes this stone is even equipped with projecting knobs for this purpose), places it on top of the grain, and alternately pushes the stone away from himself and pulls it toward himself until the grain is cracked and bran and endosperm are separated.

Its successor in classical antiquity was the hopper-rubber or Olynthian mill, so-called because a number of such millstones were recovered from a shipwreck off the Greek site of Olynthus [Fig. 7].[66] The mill seems to have evolved as a refinement of the saddle quern. Such mills display great variation in the size and shape of their stones, in the patterns of striations on their rubbing surfaces, in their method of attachment to the lever which operates them, and in several other particulars, but in the most common type the bottom millstone is flat and the upper stone rectangular or square with a pyramidal concavity cut into its upper surface to funnel grain to a rectangular slot in the bottom of the stone, the first true grain hopper, as it were, for regulating the flow of grain to the grinding surfaces and, perhaps more importantly, eliminating the necessity of stopping the operation and lifting the upper stone to feed in grain by hand. Moritz[67] argues convincingly that the *mola trusatilis*, 'push-mill' of Cato[68] and Varro as reported by Aulus Gellius[69] was just such an Olynthian

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[65] Moritz (1958): 34–41; Storck and Teague (1952): 48–55.

[66] Cf. Moritz (1958): 42–52; Storck and Teague (1952): Fig. 37; Forbes (1965): 46–48; Curtis (2001): 335–6. The corpus of such stones has now been painstakingly collected and analyzed by Rafael Frankel, "The Olynthus Mill, Its Origin and Diffusion: Typology and Distribution," *American Journal of Archaeology* 107 (2003): 1–21.

[67] Moritz (1958): 62–66.

[68] *Agr.* 10.4 and 11.4.

[69] Aulus Gellius, *NA* 3.3.14.

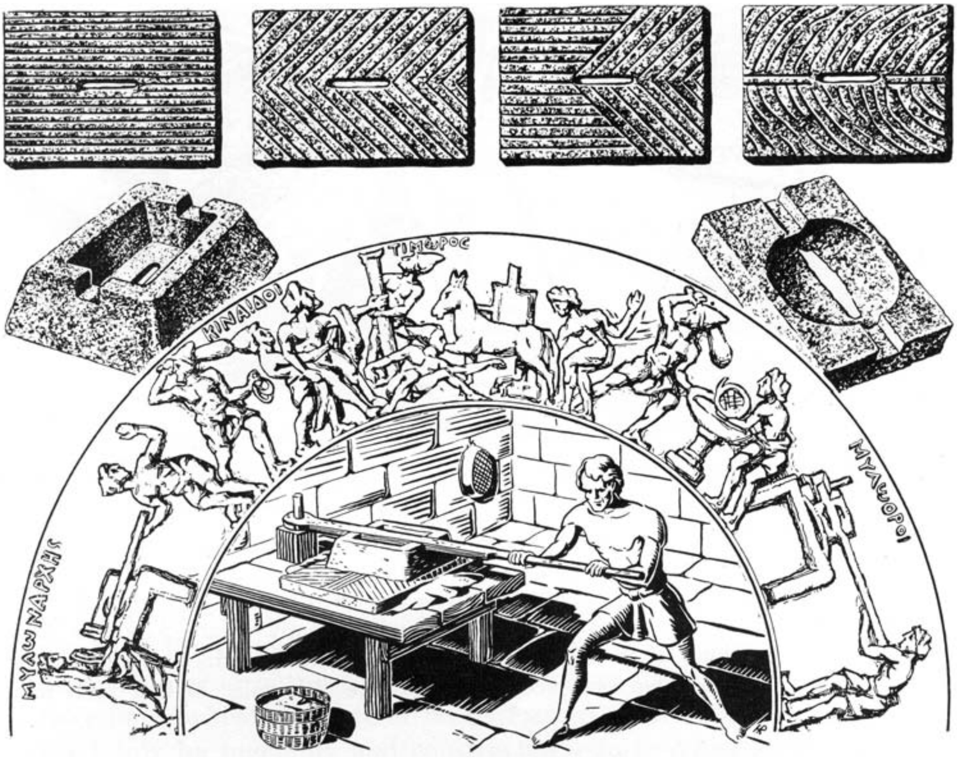

Fig. 7. The *mola trusatilis*, the so-called hopper-rubber, as reconstructed from a Greek vase. Above are the stones which give these mills their name, showing the hoppers on the upper sides and various patterns of grooving to facilitate grain fracture and movement of grist to the perimeter of the stone. (From Storck and Teague (1952): Fig. 37: Courtesy of University of Minnesota Press).

mill,[70] though Frankel[71] thinks it more likely that Cato's 'push mill' is in fact the saddle quern, given the absence of any Olynthian mills in Latium or Campania in the archaeological record, these being the areas where Cato farmed. But the total sample of such mills is still relatively small, and examples have been found in both northern and southern Italy.

The operation of the Olynthian mill can be deduced from its design and from pictorial evidence. The two millstones lie on a table one upon the other. Across the top of the upper millstone at front and back are notches to receive a stick operating as a lever. The stick is attached to the upper stone so that this stone will move from side to side upon the lower stone. The stick is also attached to a stationary spindle at the back of the upper stone which acts as a fulcrum. Alternately, the lever is enclosed in a niche in the wall behind the table in the manner of a press, but in this case the lever is moved horizontally rather than vertically.[72] The miller takes a quantity of grain to be milled and empties it into the hopper. He stands at the end of the push stick opposite the fulcrum and rotates his end back and forth, thereby grinding the grain which feeds through the slot in the hopper onto the grinding surface. Additionally, many of the surfaces of the millstones of these implements are grooved to create greater fracture force and to facilitate movement of the meal to the lateral peripheries of the stone where, now as a mixture of flour, groats and bran, it falls to the surface of the table and is collected. Presumably at this point the mixture is sifted to separate the constituent parts; overtails may have been reground and further sifted, though we have no evidence of this.

Traditionally the rotary hand quern, *mola manuaria* [Fig. 8] has been considered the next step in the evolution of mills, but Moritz argues convincingly that it is in fact a retrograde development from the larger and more sophisticated Pompeian rotary mills.[73] Since in either case the rotary quern was used for simpler hand-milling operations, it is logical for our purposes to consider it here.[74] Our first

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[70] Moritz goes to considerable lengths to prove that the mill to which Plautus was famously forced to indenture himself because of financial reverses was not a Pompeian rotary mill, as commonly supposed, but this sort of push-mill.

[71] Frankel (2003): 2.

[72] Frankel (2003): 6–7 and Fig. 6.

[73] Mortitz (1958): 97–121.

[74] E. Cecil Curwen, "Querns," *Antiquity* 11 (1937): 133–51; idem, "More about

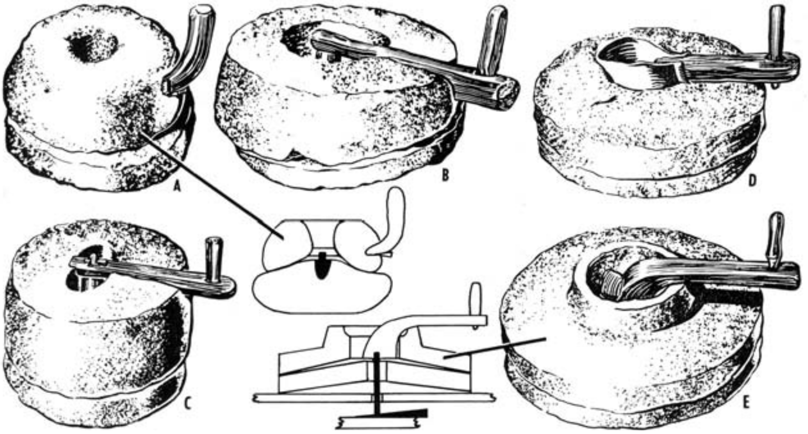

Fig. 8. Models of hand querns (*molae manuariae*) from Britain, both pre-Roman (A) and Roman (B–E). (From Storck and Teague (1952): Fig. 48. Courtesy of University of Minnesota Press).

literary evidence for the rotary quern comes from the pseudo-Vergilian poem, *Moretum*, "The Salad", ll. 24–29: "The humble farmer then calls his hands to the work [of milling], dividing it between them; the left hand is intent on serving, the right on the working of the mill. The right spins the disk around, describing circles, and sometimes the left will spell its tired sister by swapping jobs with her." These little mills are numerous in the archaeological record as well, and are still used today.[75] The rotary quern is essentially two cylindrical millstones of the same diameter, one atop the other. On the top surface of the upper stone, the *catillus*, or along its circumference, is a socket to receive a hand crank. The adjoining surfaces of the millstones are radially grooved and may be sloped, perhaps to move the flour to one side, but they tend to become horizontal as time goes by. Both stones are mortised in the center of this surface, the lower, the *meta*, to receive a spindle, the upper to fit over the spindle and rotate on it freely to force the *catillus* to move concentrically. The upper surfaces of some *catilli* are concave to serve as a hopper but seem grossly inadequate for this purpose since there is no provision to adjust rate of flow of the unmilled grain. For the

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Querns," *Antiquity* 15 (1941): 15–32; V. Gordon Childe, "Rotary Querns on the Continent and in the Mediterranean Basin," *Antiquity* 17 (1943): 19–26; White (1975): 12–14; Curtis Runnels, "Rotary Querns in Greece," *Journal of Roman Archaeology* 3 (1990): 147–54; Curtis (2001): 337–41.

[75] Moritz (1958): 97–121; Forbes (1965): 148–51; White (1975): 12–15.

typical rotary quern Curtis[76] describes the rynd, a device for holding the spindle of the mill in such a way that it partially supports the weight of the upper stone and permits a slight separation of the upper and lower stones. This allows grain to be fed from the hopper between the stones. A variation found as early as 70 CE at Glastonbury in England is the bridgetree, a sort of lever beneath the spindle which can be finely adjusted (the technical term is tentering) to vary the space between the stones in order to create variations in the fineness of the resulting meal. In this case the spindle penetrated not only through the rynd and bedstone but also through the table on which the quern rested as well, reaching nearly to the floor of the mill house, where it sat on an adjustable wooden lever, the 'bridgetree' proper.

Again the operation of such mills is apparent from the design and from pseudo-Vergil's rather meager description. The miller feeds the grain into the hopper (using pseudo-Vergil's left-hand servant) and with his right hand grasps a crank handle, either projecting vertically or horizontally directly from the running stone or perhaps as a true offset crank with a horizontal member between two vertical spindles to increase torque and therefore mechanical advantage. With the crank the miller rotates the *catillus* in one direction (as the poem seems to imply) or in semicircles of alternating direction. The flour mix is gradually moved to the circumference of the stones by centrifugal force and by the radial grooving of the stones.

These little devices became and remained extremely common throughout the Roman Empire and a case can be made that they followed Roman armies in their conquests of these regions; we know that handmills were a common feature of Roman army camps, and Roman strategists prescribe one handmill for each tent-unit (*contubernium*) of 5–10 men. We are reminded that our word 'companion' originally referred to a fellow soldier with whom one shared his daily bread, *panis*. The rotary quern must also have been a common item in many rural households as well.

But the crowning achievement of Roman, if not ancient, milling, is undoubtedly the so-called Pompeian donkey mill, the *mola asinaria*. [Fig. 9] These mills were introduced to Rome around the time of Plautus and the advent of professional miller-bakers, and the fact is

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[76] Curtis (2001): 339.

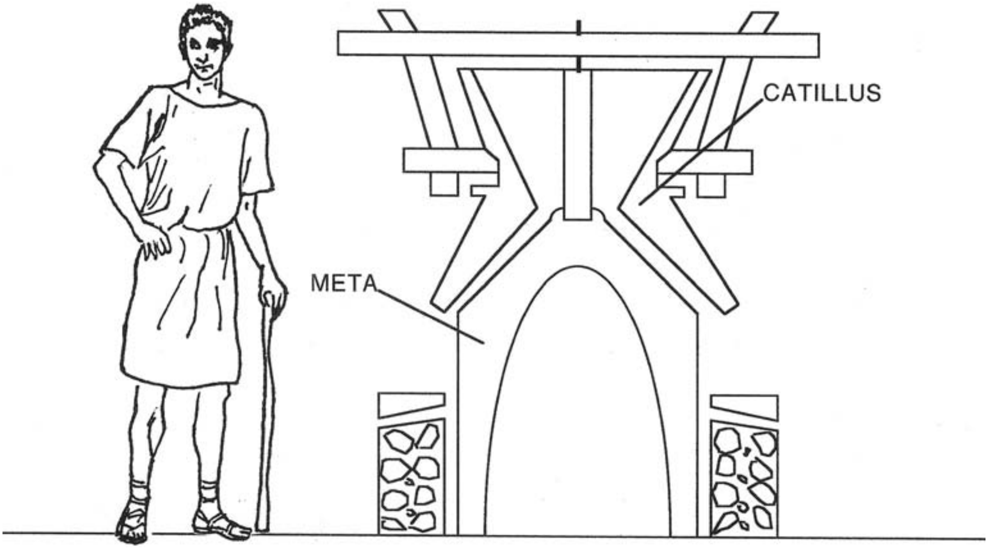

Fig. 9. Schematic cross-section of the Pompeian donkey mill (*mola asinaria*) showing the bedstone (*meta*) and running stone (*catillus*). In reality the *meta* is slightly convex so that rotational friction is restricted to a small area.

probably not mere coincidence.[77] The provenience of the mills is still an open question. At one time the first *pistores* were thought to be of Greek extraction, and it was therefore assumed that the mills themselves came from the East as well, though Moritz was dubious.[78] Curtis cogently describes the possible evolution of the Pompeian mill from the so-called Morgantina mill found in Sicily and perhaps introduced there from Spain or Punic areas[79] For his part Pliny[80] quotes Varro as saying they were invented at Volsinii (modern Bolsena,

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[77] On the standard mill-bakery, see H. Blûmmer, *Technologie und Terminologie der Gewerbe und Künst bei Griechen und Römern* (Leipzig, Teubner, 1912): 58–67; T. Warsher, "Breadmaking in Old Pompeii," *Art and Archaeology* 30 (1930): 103–12; N. Jasny, "Wheat Prices and Milling Costs in Classical Rome," *Wheat Studies of the Food Research Institute* 20 (1944): 137–70; Betty Jo Mayeske, *Bakeries, Bakers, and Bread at Pompeii: A Study in Social and Economic History* (diss., U. of Maryland, 1972 and Ann Arbor, 1979); idem, "Bakers, Bakeshops and Bread: A Social and Economic Study," in *Pompeii and the Vesuvian Landscape* (Washington, D.C.: The Archaeological Institute of America, 1979): 39–58; P. C. Rossetto, *Il Sepolcro del fornaio Marco Virgilio Eurisace a Porta Maggiore* (Rome: Istituto di Studi Romani, 1973); D. P. S. Peacock, "The Mills of Pompeii," *Antiquity* 63 (1989): 205–14; Curtis (2001): 341–48.

[78] Moritz (1958): 53–61.

[79] Curtis (2001): 341–43.

[80] *NH* 36.135.

in northern Italy), a statement Moritz partially credits. Whatever its provenience, the design of this mill has been extensively studied, since so many examples—some 37 from Pompeii alone, as well as others from Ostia and various towns of Italy—have been preserved to us. There are also numerous artistic representations, and even a graffito. The materials and design are highly uniform, with a few notable exceptions. Using petrographic studies as well as careful measurement of the entire corpus of millstones, D. P. S. Peacock[81] has created a typology. Though recent petrographic studies do not confirm Peacock's hypothesis that existing millstones derive from Orvietto,[82] there can be little doubt that such stones were being produced near Orvieto in Umbria from the mid first century BCE. The locale is in fact *Vulsinii novi*, Bolsena, the Volsinii mentioned by Pliny as the site of invention. Such millstones were made of a characteristic volcanic leucitite and represent the majority of 'classical-style' mills at Pompeii. The other general type was of leucitite-augite-tephrite material but was relatively scarce and generally associated with private dwellings rather than commercial mill-bakeries. The most prevalent 'classic-Pompeian' form (Peacock's type 3c, his Fig. 2) has an hourglass shaped upper stone (*catillus*) which gives it its characteristic shape. Such mills are usually situated on and partially encased in a cylindrical pedestal about 4 1/2' (1.38 m) in diameter and 1 1/2' (.46 m) tall; this serves as a staging platform and a catchment table for the flour mix as it emerges from the mill. Upon this pedestal is a lower millstone or *meta*, a cone with a cylindrical base, about 2' 4" (.7 m) in diameter and about 2'7"–3'4" (.8–1 m) in overall height. The profile of its upper part is never exactly conical, however, but rather slightly bell-shaped so that the grinding surface is limited to one area of the millstones. The top of the cone has a hole 3 1/4" (8 cm) square, presumably to receive a 'dosage cone', a device similar to a rynd for controlling the flow of grain onto the grinding sur-

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[81] Peacock (1989): 205–14. Millstones were articles of international trade. For example, volcanic millstones of the 'Pompeiian' type were widely exported from Mulargia in Sardinia as early as the 4th c. BCE and are found as far west as Mallorca in the Balearic Islands. See Olwen Williams-Thorpe and R. S. Thorpe, "The Import of Millstones to Roman Mallorca," *Journal of Roman Archaeology* 4 (1991): 152–59. Cf. O. Williams-Thorpe and R. S. Thorpe, "The Provenance of Donkey Mills from Roman Britain," *Archaeometry* 30.2 (1988): 275–89.

[82] F. Antonelli, G. Nappi and L. Lazzarini, "Roman Millstones from Orvietto: Petrographic and Geochemical Data for a New Archaeometric Contribution," *Archaeometry* 43.2 (2001): 167–89.

faces. We now apparently have archaeological evidence for these.[83] A number of bronze weapons was found in one of the bakeries in Ostia, but some of the bronze articles identified as lance heads are now thought to be dosage cones, fitted into the square holes in the bedstone and cemented with lead, remains of which have also been found. Precisely how they controlled the flow of grain is unknown, but it may well be that their points were inserted into the bottom of a hopper suspended over the running stone. This upper or running millstone, *catillus*, is a hollow double cone of hourglass shape, each cone about 2 1/2' (.76 m) in height and the same in diameter, the bottom cone of which fits down over the bedstone to provide the friction of rotation, while the upper cone serves as a funnel to the hopper. This 'biconical' design is ingenious, since the *catillus* can be inverted as the grinding surface wears away, such that the life of the millstone is doubled. The dark gray, hard, porous lava rock of which all the millstones are made has ideal fractural qualities.

On opposite sides of the narrow part of the *catillus* on the exterior are two square projections or bosses with a smaller square socket or mortise in their centers to receive a square timber. At right angles to these sockets on the sides of the bosses are small holes for doweling the timber securely in place. From artistic representations we see that these timbers are part of a yoke-like frame which bisects the catillus across its top and is fitted around its sides such that it somewhat resembles a lyre. This is obviously the frame to which the donkey was attached to rotate the *catillus* upon the *meta*, though the exact details of this are difficult to ascertain from our representations.[84]

These same reliefs show us the mills in operation. A donkey (occasionally a horse is shown. Either this is artistic license or such horses were about ready for the knacker's yard; horses were the expensive sports cars of the ancient world) is yoked to the mill and travels around it counterclockwise while a slave stands nearby with a whip to goad him. A second slave gathers the meal from the platform where the *meta* meets the pedestal, the latter sometimes showing a channel cut into it to better catch the meal. The hopper is sometimes depicted, attached above the catillus to receive the grain. Some

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[83] Jan Theo Bakker, "Caseggiato dei Molini—Interpretation," in Jan Theo Bakker, ed., *The Mill-Bakeries of Ostia: Description and Interpretation* (Amsterdam: J. C. Gieben, 1999): 56–57.

[84] Moritz (1958): 74–90; White (1975): 15.

reliefs show grooving on the exposed part of the *meta*, though none of the extant models display this feature, nor need the millstones have been grooved as they were for handmills, given the fractural qualities of the stone. The grain was fed into the mill at a controlled pace, was ground by the rotational friction of the porous lava millstones, and worked its way by gravity and centrifugal force if not the action of grooving to the bottom of the *catillus* where it fell to the shoulder of the pedestal and was collected for further processing. On one relief can be seen a small bell attached to the mill, apparently to let the mill owner know when the mill stopped operating for whatever reason. In the vicinity of the mills in one relief are grain measures, easily identified as the *modius* and *semodius* (1 peck = 8.81 L and 1/2 peck = 4.4 L respectively). We also see ruler-like wooden sticks for leveling the top of the grain or flour in these measures.[85]

An indication of the efficacy of this invention is the fact that for 2,000 years the only fundamental technological refinement of this basic apparatus—rotary motion of one millstone upon a second, stationary millstone—was the harnessing of other motive forces to drive it. The ancients made only experimental use of wind power for rotary motion, but we now have evidence that they had mastered the use of water power in milling.[86] The Augustan writer Vitruvius provides an excellent description of the basic machinery of such mills.[87] [Fig. 10] A vertical waterwheel (undershot or overshot) is used to drive a crown and pinion gear, which simultaneously translates the horizontal motion of the wheel's axle to the vertical rotation of the mill spindle and acts as a reducing gear to increase the power of this spindle. In this case the cylindrical *meta* is perforated to permit the spindle to

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[85] Moritz (1958): 78–90; Forbes III (1965): 151–52.

[86] The definitive work is now Örjan Wikander, "The Water-Mill," in Örjan Wikander, ed. *Handbook of Ancient Water Technology* (Leiden: E. J. Brill, 2000): 371–400, which contains an exhaustive bibliogrpahy. Cf. idem, "Water-Mills in Ancient Rome," *Opuscula Romana* 12 (1979): 13–36; idem, "The Use of Water Power in Classical Antiquity," *Opuscula Romana* 13 (1981): 91–104; idem, *Exploitation of Water Power or Technological Stagnation* (Lund, 1984): 11–23; idem, "Evidence for Early Water-Mills—An Interpretation," *History of Technology* 10 (1985): 151–79; Storck and Teague (1952): 93–114; Moritz (1958): 122; Forbes III (1965): 152–53; White (1975): 15–18; Daniel Castella, *Le moulin hydraulique gallo-romain d'Avenches "en Chaplix"* (Lausanne: Cahiers d'archéologie romande, 1994 [= *Aventicum* 6]); Bakker (1999): 9–11; Curtis (2000): 348–58.

[87] *De Arch.* 10.5.2.

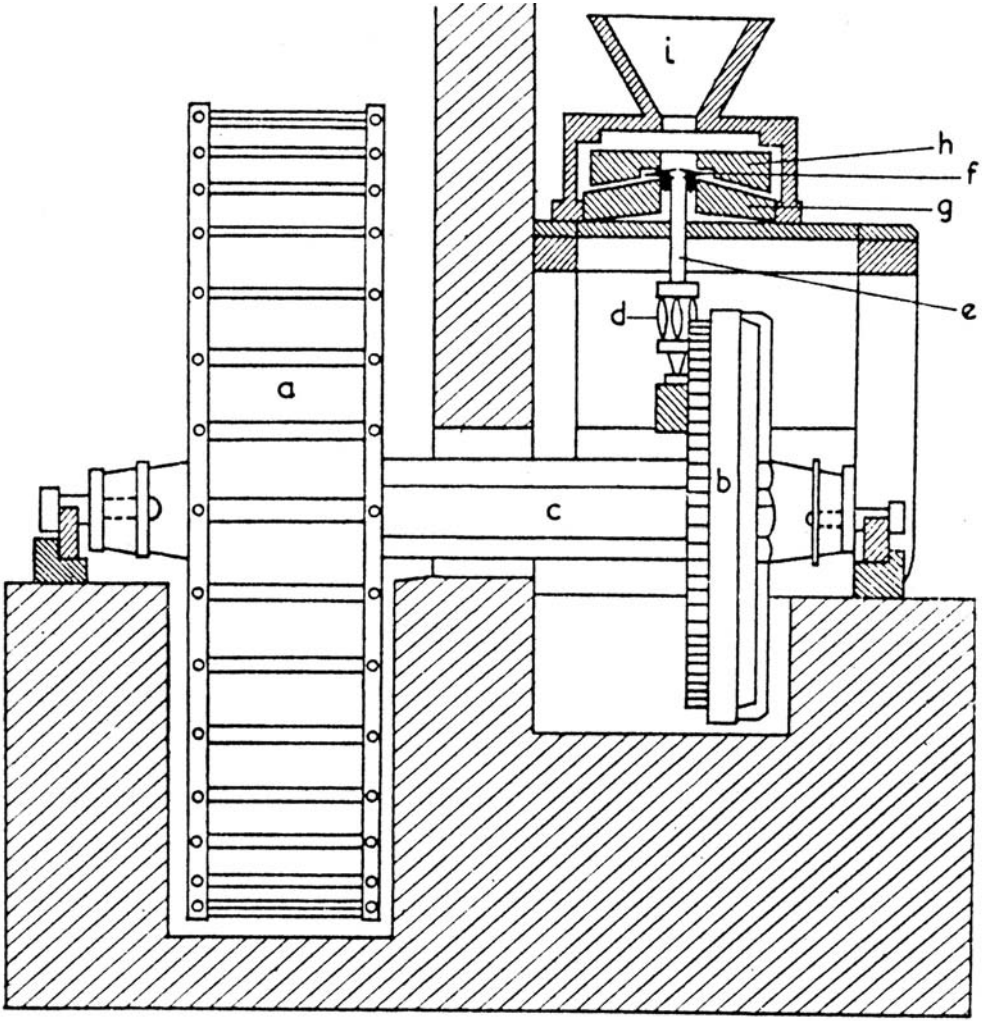

Fig. 10. A Roman watermill, as described by Vitruvius. The waterwheel (a) sends horizontal rotation by way of a drive shaft (c) to a crown-and-pinion gear (b and d) which redirects the rotation vertically and also 'gears up'. Vertical rotation is transferred through the bedstone (g) to the running stone (h) being fed from a hopper (i). (From *Saalburg Jahrbuch* 3 (1950): Fig. 45. Courtesy of the Saalburg Museum).

travel freely and the spindle is dovetailed into the cylindircal *catillus* so that it rotates on the *meta*. Above the millstones is a hopper for grain feed. Wikander[88] now lists 56 archaeological sites for such mills which are reasonably securely identified, dating from antiquity up to 700 CE. At one time it was thought that such water mills were an oddity until late antiquity, but it is now evident that they were becoming widely diffused as early as the first century CE when Vitruvius described them, and by the time of Diocletian's Price Edict (301 CE) the water mill was a standard technology along with the handmill and the donkey mill. Such mills fall into a number of types which are not evolutionary but used simultaneously. Two main types are the vertical-wheel type and the horizontal-wheel type. Of Wikander's list, 32 have a vertical wheel and 19 a horizontal wheel. Of the vertical-wheel types, 16 are undershot, that is, the force of the water is directed at the bottom of the wheel, and 9 are overshot. There are also three possible examples of breastshot wheels, in which water hits the back of the wheel at or slightly above the level of the axle. Horizontal wheels occur primarily in mountain terrain where streams have greater gradient and velocity. Here water is thrown through a chute upon oblique paddles mounted on the wheel, thus a true turbine. But the only certain examples date only from the seventh century CE, a fact which may not be significant, given the paucity of evidence.

Water was provided to the wheels by a variety of natural sources, and the notion that a lack of suitable streams in the Roman Empire hampered diffusion of this technology is mistaken. Otherwise water was occasionally brought from a distance in flumes or aqueducts. Mills on the Janiculan Hill in Rome were supplied by water diverted from the Aqua Traiana.[89] In only one case do we have evidence that an aqueduct was constructed exclusively for the purpose of operating water mills, and this is at Barbegal, to be discussed below. In the Baths of Caracalla, waste water from the baths themselves was channeled to the basement mill.[90] Tide mills, for which daily tides are used to fill reservoirs with sea water, are attested at two sites,

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[88] Wikander (2000): 371–78.

[89] Cf. Wikander (1979): 15–24; M. Bell, "An Imperial Flour Mill on the Janiculan," in *Le ravitaillement en blé de Rome et des centres urbaines des débuts de la République jusqu'au Haut Empire* (Naples: Centre Jean Bérard, 1994): 73–89.

[90] Thorkild Schiøler and Örjan Wikander, "A Roman Water-Mill in the Baths of Caracalla," *Opuscula Romana* 14, 4 (1983): 47–64.

both late. Thus the main problem with water as motive force was not supply but control to achieve efficiency. For example, if a water wheel is immersed directly in a river or stream, water level will inevitably rise too high or fall too low, at least seasonally. The standard solution is the construction of a mill race whose volume is controlled by a gated sluice, often supplied by a mill pond. Alternately, the level of the wheel may be changed to match water levels. Floating or boat mills are a sort of variation of the latter, and they were widely diffused and attested early. The most famous examples are those constructed in Rome in 537 CE when the Goths sabotaged the aqueducts and Belisarius placed two mills on boats on the Tiber River, then two more below them and so forth.

The wheels themselves exhibit considerable variation. From pictorial evidence as well as archaeology, we see that wheels were spoked and had 'wings' (*pinnae*) around their periphery to catch the force of the water. Sometimes the spokes themselves widen to form the wings, for example at Venafro in Molise, central Italy, and at Hagendorn in Switzerland.[91] The spokes and wings are stabilized by two side walls. Dimensions vary considerably. The shafts of the more typical vertical wheels were placed on wooden blocks fitted with iron bearings and probably greased with animal fat. One end of the shaft is attached to the so-called 'pit-wheel' or gear wheel. How the shafts of horizontal wheels were housed remains vague. Vitruvius clearly states that the gear or pit wheel should be larger than the drive wheel, which implies that the mill is geared down, that is, the shaft of the gear wheel and thus its extension the spindle rotate more slowly than that of the drive wheel, thus producing more power but less velocity. This has been doubted. But such an arrangement, if it existed, was doubtless soon replaced by a lantern pinion, one of which has actually been preserved, and whose use is clearly implied at the millworks at the Baths of Caracalla. This lantern pinion geared up the attached spindle, the lower end of which rested on a bearing stone, the upper end running through the lower bedstone and being attached to the upper running stone just as Vitruvius indicates. Actual stones vary in size considerably, but most are about 20–33" (55–85 cm) in diameter. The bedstones are conical in early times, the running stone having a corresponding hollow on its lower

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[91] Wikander (2000): 384–89.

surface to match, but gradually take on a flat profile. The millhouses in which these stone operated were extremely small, the earliest attested being only 16' × 23' (5 m × 7 m).

Such water mills were extant at the time of Augustus and may have occurred on the Tiber itself in the environs of Rome. By the time of Honorius' and Arcadius' edict of AD 398 regulating their operation,[92] they were obviously well established here if not common. The most exuberant use of the technology, however, occurs in southern Gaul near Barbegal [Fig. 11] where the Romans placed a large installation in the late third or early fourth century AD.[93] Used for over 100 years, it had eight pairs of wheels arranged along a descending millrace, each driving a separate set of millstones. At one time it was estimated that the output from this site alone when in full operation would have sufficed not only for the 10,000 inhabitants of nearby Arles but also for the population for some distance around.[94] Part of that estimate was based on a typographical error in the archaeologist's original report (the slope of the hill on which it was built was listed as both 30%, i.e., c. 17°, the correct figure, and 30°), part on some very dubious presuppositions. Re-excavation has now firmly established that early operation of the mill belongs to the early second century CE, perhaps the latter part of Trajan's reign, and supports Sellin's contention[95] that the mill capacity was overestimated. Curtis suggests,[96] very wisely in my opinion, that there are so many unknown variables involved with the mill and its operation that estimates of capacity are reckless. But when the mill operated at full capacity, it must have been quite impressive.

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[92] *Codex Theodosius* 14.15.4.

[93] F. Benoit, "L'usine de meunerie hydraulique de Barbegal (Arles)," *Revue Archéologique* 15 (1940): 18–80; Forbes II (1965): 93–95; R. H. J. Sellin, "The Large Roman Water Mill at Barbegal (France)," *History of Technology* 8 (1983): 91–109; Paavo Roos, "For the Fiftieth Anniversary of the Excavation of the Water-mill at Barbegal: A Correction of the Long-lived Mistake," *Revue Archéologique* (1986): 327–33; Trevor Hodge, "A Roman Factory," *Scientific American* (Nov. 1990): 58–64; Philippe Leveau, "The Water Mill in its Environment: Archaeology and Social History of Antiquity," *Journal of Roman Archaeology* 9 (1996): 137–53; Curtis (2001): 353–57.

[94] Bernoit (1940): 78.

[95] Sellin (1981): 413–26. Cf. Leveau (1996): 137–57.

[96] Curtis (2001): 355, n. 60.

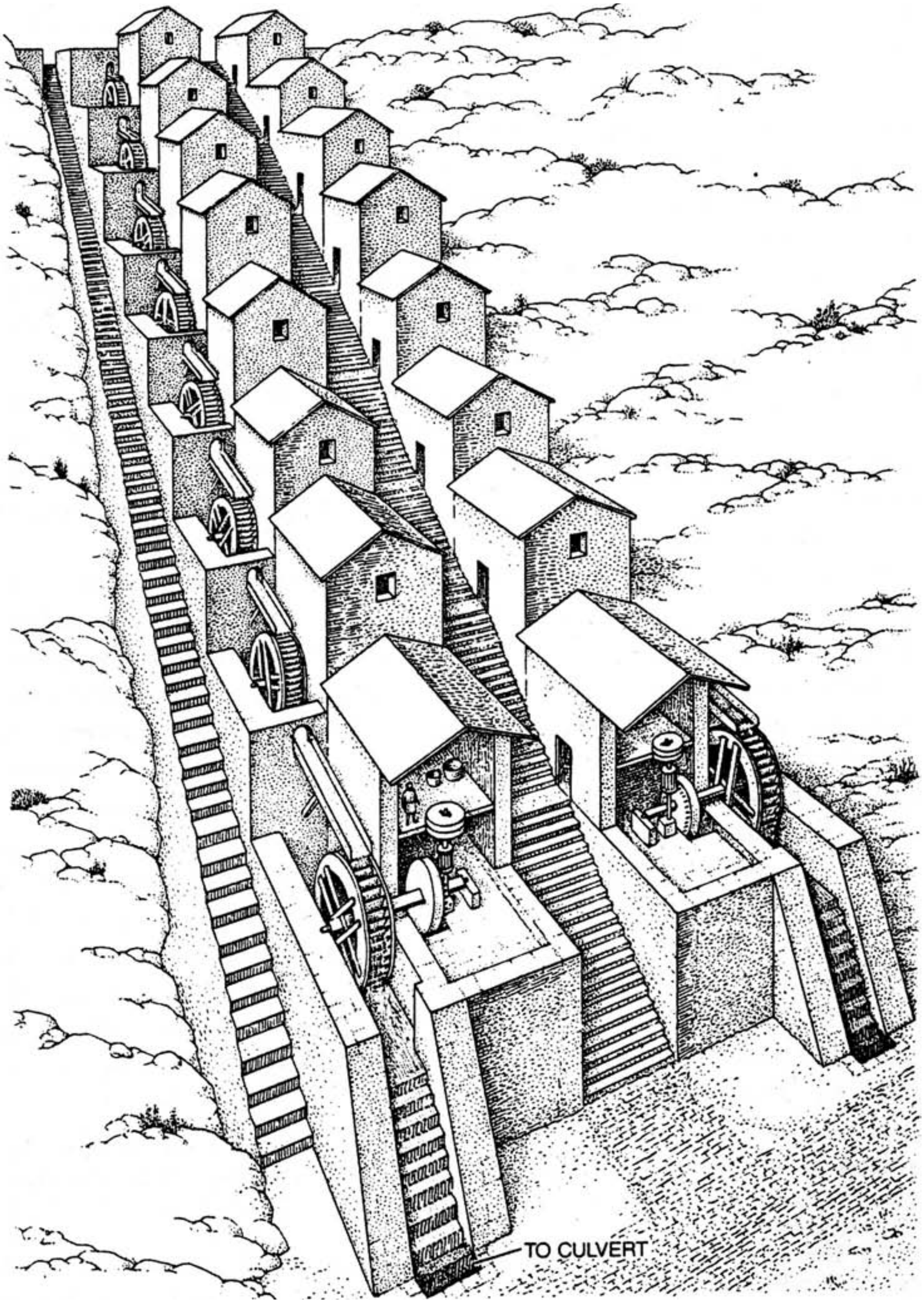

Fig. 11. Reconstruction of the Roman watermills at Barbegal, southern France. (From Hodge (1990): 6. Courtesy of *Scientific American*).

Bolting

Thus far the milling process. The grist which initially emerges from such mills is far from a finished product, however. Early on humans found it desirable to 'refine' meal by separating variable components of the kernel such as gradients of the starchy endosperm, bran, the scutellum, that is, the shield-shaped membrane which separates the endosperm from the seed embryo, and the embryo itself, the germ. This for various practical and nutritional reasons, as well as mere preferences, not least the snob appeal of certain grades of flour. Thus various techniques were contrived for effecting this separation.

The first of these occurs before the grain is milled; it is the conditioning or tempering of the grain discussed earlier, to facilitate bran fracture.[97] To reiterate: tempering involves adding a suitable amount of moisture to wheat and allowing it to stand a suitable time such that the bran is toughened and the endosperm simultaneously 'mellowed' to facilitate separation of the two. Quantity of water and tempering time vary with species of grain and strain of wheat as well as its initial moisture content. Tempering must have been an empirical process in Rome. For comparison, today hard wheat is normally tempered to 15–16% moisture content, heat being used in many cases to expedite the process. The grain is today typically cleaned and tempered a second time for twenty minutes to an hour with a smaller quantity of water in order to raise moisture content another half percent. It is therefore quite astonishing when Pliny in his discussion of the process casually remarks that some people soak barley a second time before braying. About Roman tempering of wheat *per se* we have no evidence, but the step is critical in processing wheats and we may therefore assume the same basic technique for this grain as well.

It is obvious that the quality of flour obtained in milling was in part a function of the degree to which bran was separated from flour. But this is hardly the only difference. The generic name for fine meal and flour (intended for baking instead of porridge) was *farina*, but terminology further defines a number of grades of flour, judged by fineness of grind (in general, the finer the better) and whiteness, i.e., the degree to which the darker bran, scutellum, and

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[97] Yeshajahn Pomeranz and J. A. Shellenberger, *Bread Science and Technology* (Westport, CT: AVI Pub. Co., 1971): 20.

germ have been eliminated. Moritz believes that early man's preference for white bread—a preference by no means confined to the Romans—may have been based on the empirical knowledge that bran (L. *furfur*) is indigestible and therefore that high-bran breads deliver less nutrition per unit of weight than their more refined relatives.[98] If so, we can speculate that perhaps he noted some of the deficiency diseases previously mentioned that are also associated with coarse, high-bran bread diets. To be sure, "to know the color of one's bread"[99] was Roman shorthand for knowing one's place in society, and we hear of several examples where bread of different colors is offered at the same meal to guests of different social rank.[100] Bran removal relies on the fact that bran is more resistant to grinding than starch, particularly if tempered. Thus if the miller does not grind too finely, particles of bran will be much larger than those of starch and can be sifted out. Ergo the use of the sieve, or bolter, or cribble. It is unlikely that Roman mills, particularly the Pompeian style mills from which the majority of Romans apparently derived their flour, could be finely tentered for a coarse or fine grade of flour, though a case has been made that some adjustment was possible, as we have seen. We should most likely imagine successive grindings and boltings. Bolting separates flour already ground to desired fineness from the bran before the latter is pulverized too finely to be separated and also prevents clogging of the grinding surface with fine grist.

The evidence from Roman bolting practice is largely inferential but reasonably secure. We can infer a great deal from descriptions of the sieves themselves. [Fig. 12] One version of the sieve was Cato's *cribrum farinarium*[101] The fact that Cato recommends its use for straining whey from cottage cheese suggests that the weave of the sieve was not particularly fine. We hear elsewhere[102] of a *cribrum pollinarium* to produce *pollen*, the finest available grade of wheat flour. Pliny[103] contrasts this *cribrum pollinarium* with a *cribrum excussorium*, both

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[98] Moritz (1958): 151–58; 164–68.

[99] Juvenal, *Satire* 5.74–75.

[100] The ancients knew perfectly well, on the other hand, that whole-wheat bread improved bowel function, evidently a concern for the idle rich: Petronius, *Satyricon* 66.2.

[101] *Agr.* 76.3. Cf. White (1975): 102–4.

[102] Plautus, *Poenulus* 513.

[103] *NH* 18.115.

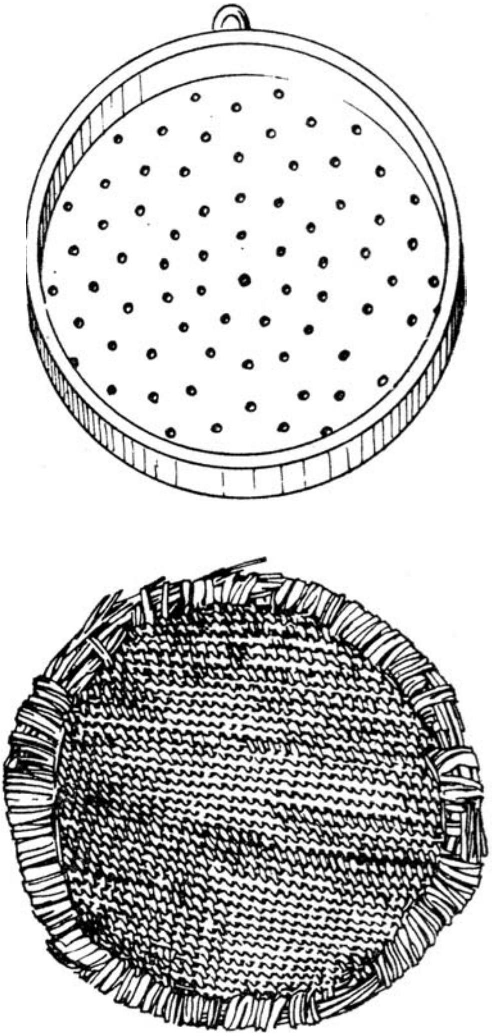

Fig. 12. Roman cribbles or bolters, *cribra*, for sifting grist and flour. The bolter above is for crude sifting, the one below for fine sifting. (From White (1975): Fig. 32 and Fig. 33. Courtesy of Cambridge University Press).

being made with linen, as well as two 'narrower' (finer?) sieves. Moritz[104] thinks the *cribrum farinarium* is equivalent to the *cribrum excussorium* and therefore distinguishes two grades of sieves, one primarily to separate bran from meal, another to separate finer flour from the overtails of the first sieve.

Positing this scenario, we can at least begin to make sense of the Roman grades of flour mentioned (rather inconsistently) by Pliny.[105] Flour of *siligo*, that is, *Triticum vulgare*, soft bread of common wheat, was graded into *siligo* (the flour, not the grain; this double meaning is secure), *flos, cibarium*, and *furfur*; whereas *triticum*, i.e., *T. durum*, durum or semolina wheat, was graded into *similago, pollen, secundarium*, and *furfur*. The *furfur* is, as we have mentioned, the bran, so we are left with three grades of flour in the case of both wheat strains, graded by fineness and residual bran content. The *cibarium* and its durum-wheat analog *secundarium* were probably the standard products sold to the public in bulk or as bread, and in most cases were probably the only grade produced. To what extent the 'throughs' from these products were sold as a finer product or was reground is impossible to judge, but the names themselves indicate this was done to some extent. Based on modern experimentation recreating Roman equipment and techniques, the so-called Lewes experiment conducted by Moritz and others,[106] a second grinding is probable. In this case the process must have proceeded thus: the tempered grain was milled and bolted in the coarse sieve to separate the 'overtails', including the bran, from the third-grade flour; then the overtails were reground and the grist thus produced bolted through a finer sieve (e.g., the *cribrum pollinarium*) to separate the 'throughs', the top-grade flour, from the branny second-grade flour, what today is called by the millers the 'red dog'. We then have standard flours, *siligo* and *similago* (from soft wheat and semolina, respectively) from the coarse sieve, the *cribrum farinarium* or *excussorium*; next the top-grade flours *pollen* and *flos* from the *cribrum pollinarium*, leaving a meal mixed with finely ground bran. Another bolting through the coarse sieve produces *cibarium* or *secundarium* as well as *furfur*, bran.

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[104] Moritz (1958): 64–67. Cf. K. D. White (1975): 102–04.

[105] Moritz (1958): 168–83.

[106] Moritz cites an article in *Milling* (24 June 1950), unavailable to me.

Some mention should also be made of the extent to which these flours may have been adulterated with various substances. In preindustrial societies adulteration of bulk products including foodstuffs is the norm, so much so that it is assumed by buyers and figured into the price offered in the invariable haggling. Thus Pliny tells us that fava beans can be used to make bread, that its flour is called *lomentum* and is used in commercial bread "to increase its weight, as is meal from other legumes, even fodder crops."[107] Pliny's phrase, "to increase weight," is telling, suggesting that bean and pea flour was a cheaper adulterant designed to boost profits. But, ironically, despite such imputed motives the resulting product was a better product from the standpoint of nutritional value; the principle of combining cereal and leguminous flours to produce more complete 'composite' flours has been understood empirically for millennia. Today in the Middle East, for example, sesame and chickpea flours are mixed with wheat flour. Leguminous flours are deficient in sulphur-containing amino acids in which cereals are rich, but are rich in the lysine cereals lack. Thus composite flours which combine the two provide an adequate balance of protein precursors in the human diet, whereas cereals alone or legumes alone are deficient.

Breadmaking

It could be argued that breadmaking is more a culinary process than a food process, but two factors argue the contrary. First is the fact that baking in classical Rome as today was primarily a commercial process combined with the milling process. Second is the fact that breadmaking involves a number of procedures, both chemical and physical, whose primary or secondary functions are to make flour (as opposed to the relatively stable but indigestible seed grain) eminently digestible. The fact that such procedures also render a product highly palatable with broad appeal is in no way contradictory.[108]

The roots of breadmaking are ageless. Excavations have revealed bread ovens from Babylonia dating from 4,000 BCE. The date of

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[107] *NH* 18.30.

[108] For the basic processes, cf. Stanley P. Cuvain, "Breadmaking Processes," in Stanley P. Cuvain and Linda S. Young, edd., *Technology of Breadmaking* (London: Blackie Academic and Professional, 1998): 8–43.

introduction of the technique in Egypt is obscure, but it played a prominent role in the diet and ritual of that culture from the earliest dynasties. The use of alcoholic and/or bacterial fermentation to leaven bread dates from the end of the Neolithic (c. 1800 BCE); yeast fermentation seems to have been discovered coincidentally in several places around this same time. From Egypt and the East breadmaking and leavening spread to the eastern Mediterranean. Leavening was introduced into Greece, where a flat barley bread had long been a staple, in the eighth century BCE, and commercial bakeries are known there from the fifth century BCE.

It was probably from Greece that the idea of commercial milling and baking was introduced to Rome in the early second century BCE, as previously discussed. Within a short time these mill-bakeries were supplying the staple of the diet to Rome's rapidly expanding urban population.

As usual in the case of such commercial processes, considered *déclassé* by the Roman aristocracy from which her authors derived, the details must be gleaned from the agronomists and the encyclopaedists as well as from archaeological studies. Special mention should be made in the latter case of the frieze relief of the tomb of a Roman miller-baker named Eurysaces [Fig. 13]; the tomb, near the Porta Maggiore, illustrates with startling clarity and panache the various steps in the breadmaking process.[109] Particularly helpful also are comparative studies, inasmuch as there has been a seemingly continuous tradition in craft baking from antiquity right up to the present.

A case in point: we have no shred of evidence from the ancient *testimonia* that flour was aged before baking, though this has been standard practice for centuries if not longer in places where white bread or some facsimile is the prestige product. Unbleached, freshly milled wheat flour has a pale yellow or cream color. During storage (on the order of six months) a degree of natural bleaching occurs as the pigment xanthophyl is oxidized. Aged flour thereby produces a whiter and thus more marketable loaf. More important, perhaps,

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[109] Paolo Ciancio Rossetto, *Il Sepolcro del fornaio Marco Virgilio Eurisace a Porta Maggiore. I Monumenti Romani V* (Rome: Istituto de Studi Romani, 1973); Mario Petrassi, "Il monumento del fornaio a Porta Maggiore," *Capitolium* 49, 2–3 (1974): 48–56; Olle Brandt, "Recent Research on the Tomb or Eurysaces," *Opuscula Romana* 19,2 (1993): 13–17; Curtis (2001): 358–60 and Fig. 28.

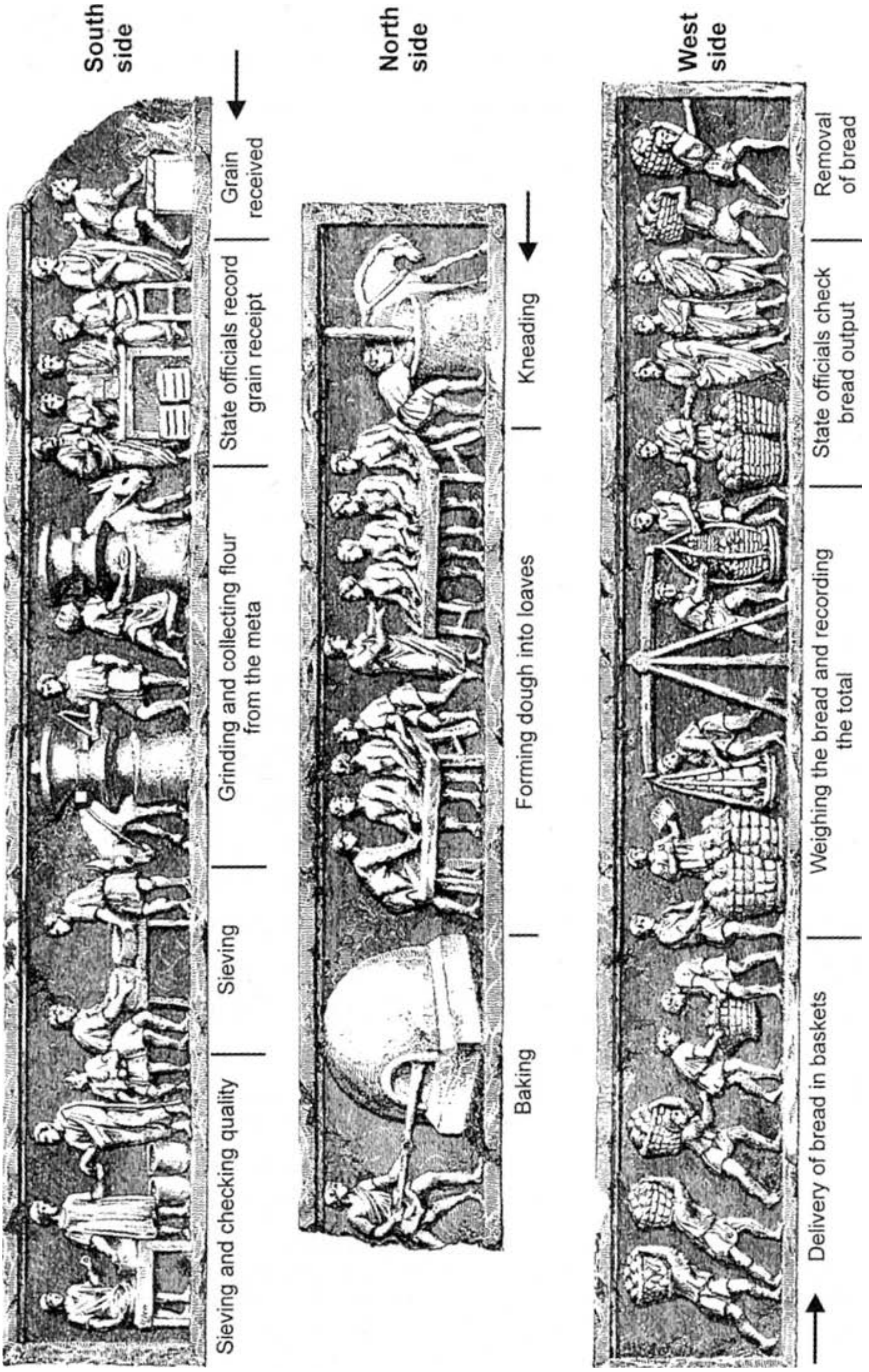

Fig. 13. Drawing of the tomb relief of the baker Eurysaces near the Porta Maggiore in Rome. After Hans Lamer, *Römische Kulture im Bilde* (Leipzig, 1915): Fig. 145).

other chemical changes occur during aging which significantly improve baking properties. Freshly milled, so-called 'green' flour in fact has very poor baking potential, producing baked goods of inferior texture, volume and crumb ('crumb' refers to those parts of the bread other than the crust). Improvements in baking properties accrue gradually over time until they reach a peak and begin to decline.[110] Cereal products containing 6–20% moisture are subject to lypolysis of lipases in the flour, experienced in the bread from such flour as 'off' or rancid odors and flavors. Bleaching tends to inhibit these enzymes.[111] Did the Roman *pistor* age flour? Perhaps we might better ask, could he afford not to, given the commercial desirability of white bread and the Roman penchant for discovering empirically or borrowing such rule-of-thumb solutions to practical problems.

Leavening

The quality which most clearly marks 'bread' from other cereal products, at least for the Westerner, is its light, airy texture, produced by mixing the flour with water and adjuncts and submitting the resulting paste to fermentation. Bread fermentation, whether by means of spontaneous air-borne cells or by inoculation, is primarily an alcoholic, that is, yeast, fermentation produced by species of *Saccharomyces*, *Torulka*, and *Candida* but accompanied in traditional sourdough baking by varying concentrations of such lactic bacteria as *Lactobacillus*, *Pediococcus*, *Lactococcus*, *Streptobacterium*, and *Betabacterium* to produce more or less 'sour' (i.e., acidic) doughs. Sourdough ferments are almost inevitable in doughs for which a sponge is used, as they were by the Romans. In addition to lowering pH, sourdough ferments make the minerals of wheat doughs more available to human digestion and also inhibit spoilage ferments.[112] Yeast fermentation of breads is closely related to that of alcoholic fermentation of wine and beer,

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[110] Pomeranz and Shellenberger (1971): 29.

[111] Troller and Christian (1978): 55.

[112] W. P. Hammes and M. G. Gänzle, "Sourdough Breads and Related Products," in Wood (1998): 201–7. The complete chemistry of sourdough fermentation is conveniently found in Daniel H. Maloney and James J. Foy, "Yeast Fermentations" in Karel Kulp and Klaus Lorenz, edd., *Handbook of Dough Fermentations* (New York: Marcel Dekker, 2003): 43–61. Cf. Peter Stolz, "Biological Fundamentals of Yeast and Lactobacilli Fermentation: Bread Dough," in Kulp and Lorenz (2003): 23–42.

in that sugars in the substrate, dextrins from the starch of flour in this case, are catabolyzed. The difference is that panary (bakery) fermentation is essentially the aerobic phase of alcoholic fermentation, in which sugars are converted to carbon dioxide and water with the attendant production of 673 kilocalories of energy per gram molecular weight of glucose. This energy is available to the yeast cells for metabolic and reproductive purposes. But yeasts, especially those of *Saccharomyces* species, are facultatively anaerobic, i.e., in the absence of oxygen, will continue to metabolize sugars, but in this case the end products are carbon dioxide and ethyl alcohol (ethanol) and only 56 kilocalories per gram weight of glucose. Since something on the order of 90% less energy is available for reproductive purposes, a yeast colony under anaerobic conditions will not exhibit the spectacular growth rate of one under aerobic conditions. And so alcoholic fermentation typically proceeds under both conditions, the initial, aerobic phase when the substrate is oxygenated and a vigorous yeast colony encouraged, and a second, anaerobic phase when this colony is put to work producing ethanol.[113] Obviously the baker is more interested in the aerobic phase, the brewer and vigneron in both phases.

Flour naturally provides amylase, an enzyme necessary to convert starch to dextrin, and is thus an excellent food for yeasts and lactic bacteria. As the fermentation progresses the CO_2 is trapped in the dough structure by gluten and causes the dough to expand or 'rise'. Both ethyl alcohol and yeast itself are potent bacteriostatics; thus bread is inherently more stable than porridge. Lactic acid fermentations of the *lactobacilli* also result in CO_2 and thus have the same leavening effect; in addition the resulting acidity inhibits the organisms which may otherwise lead to 'ropy' bread, 'red' bread, and other spoilages.[114]

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[113] M. A. Amerine and V. L. Singleton, *Wine*: *An Introduction* (Berkeley: U. of Cal. Press, 1977): 66–74; Cedric Austin, *The Science of Wine* (New York: American Elsevier, 1968): 46–48.

[114] P. M. Garman and K. B. Sherrington, *The Science of Food: An Introduction to Food Science, Nutrition, and Microbiology* (Oxford: Pergamon Presss, 1977): 225; Carl S. Pederson, "Processing by Fermentation," in J. L. Heid and Maynard A. Joslyn, edd., *Fundamentals of Food Processing Operations: Ingredients, Methods, and Packaging* (Westport, CT: AVI Pub. Co., 1967): 480–97; Karel Kulp, "Baker's Yeast and Sourdough in U.S. Bread Products," in Kulp and Lorenz (2003): 132–33. On a modern effort to replicate an ancient sourdough pot bread using ancient techniques see Mark Lehner, "Replicating an Ancient Bakery," *Archaeology* 50,1 (Jan.–Feb., 1997): 36.

There are two general methods of beginning these fermentation processes.[115] In one, straight fermentation, the yeast and/or other leavening agents are added directly to the mass of flour and adjuncts before kneading. The other, sponge fermentation, was the norm when doughs were typically leavened by a starter from spontaneous fermentation. In this method 'starter', usually a small quantity of fermented dough from a previous batch, is mixed into cold water and flour to produce a very loose, sticky paste. This 'sponge' is ripened for some hours to allow yeast and bacterial colonization and then is added to the bulk of the flour and other ingredients. Sponge fermentation is the norm where reliable bread yeast is unavailable and/or where sour dough is preferred as a matter of taste. Sourdough sponges, those fermented in part by the above-mentioned lactic acid bacteria (LAB, as they are collectively called) are traditionally taken from a ripened sour and may be 'fed' for months or even years by periodic additions of flour and water.[116] In sourdough fermentation, *Saccharomyces cerevisiae*, the standard baker's yeast today, is too sensitive to the acetic and lactic acids produced by bacterial ferments and the operant yeasts of modern sourdough ferments are therefore *S. exiguus* and *Candida milleri*, far more acid-tolerant. When baker's yeast is added to a standard sourdough ferment it is overgrown and eliminated after only two transfers.[117] In addition to lowering pH, sourdough ferments make minerals of wheat doughs more available and also inhibit spoilage ferments.[118]

It is obvious from examining even such literary evidence as we have that Roman bakers were conversant with both techniques, though of course they were ignorant of the operative organisms. Pliny, for example, is well aware that when the cereals of Gaul and Spain are fermented in brewing beer, the bakers of these countries use the yeast as leaven, and that this leaven gives to their loaves a lighter texture than the Romans can achieve.[119] Pliny's curious phrase,

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[115] Tony Williams and Gordon Pullen, "Functional Ingredients," in Cuvain and Young (1998): 69–80.

[116] Pomeranz and Shellenberger (1971): 41–42.

[117] M. Antonia Martinez-Anaya, "Associations and Interactions of Microorganisms in Dough Fermentation: Effects on Dough and Bread Characteristics," in Kulp and Lorenz (2003): 63–67.

[118] W. P. Hammes and M. G. Gänzle in Edward Wood and Jeane Wood, *World Sourdough Breads from Antiquity* (Berkeley: Ten Speed Press, 1996): 201–07.

[119] *NH* 18.68.

spuma concreta, literally, 'congealed foam,' could refer either to the foamy yeast called barm which forms during the vigorous primary fermentation of beer, barm which is then dried; or, far less likely, the 'foam' after it has flocculated and settled to the bottom of the fermentation vessel to form a thick, viscous sediment, primarily of dead yeast cells. For comparison, in nineteenth-century America, where reliable leavens were not always available, the barm of primary-stage beer fermentations was commonly used.[120]

The likely predominant yeast species of most ancient winemaking, *Saccharomyces cerevisiae, var. ellipsoideus*, was essentially the same as that used in brewing;[121] the difference is that wine fermentation by its very nature must proceed once a year during the vintage, whereas cereal fermentation, because of the dry, stable nature of cereals, can proceed at will; thus beer and ale can be brewed year round, though cooler temperatures are preferred. The Romans contrived an ingenious technique for combining the two. As usual, it is Pliny who explains the process.[122] Millet, for one, he says, is used to make leaven. Millet flour is dipped in must (i.e., unfermented grape juice; must in antiquity was spontaneously fermented, since there are ample yeast cells occurring naturally on the grape 'bloom' to initiate the process), then kneaded and (presumably) dried. Cakes made in this fashion, Pliny assures us, will remain viable a whole year, and doubtless he is right; properly stored, yeast cells are incredibly hardy. Likewise, best fine bran of durum wheat is steeped three days in white must, then kneaded and sun-dried into little leaven-cakes, *pastilli*. When the baker is ready to proceed the little cakes are reconstituted in water and then mixed with emmer flour to create a sponge.[123]

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[120] Pomeranz and Shellenberger (1971): 121.

[121] The reader should note that names of these species have changed repeatedly in the last hundred years and that taxonomic terminology is completely chaotic in mycology. For example, the variety of yeast used in winemaking is now often referred to as *S. cerevisiae*, literally, "Sugar yeast of beer," whereas that used in brewing is sometimes now referred to as *S. uvae*, literally, "Sugar yeast of the grape"! It would seem that some mycologists have been consuming too much of the product of their subjects' labors.

[122] *NH* 18.102–04.

[123] Rackham in his Loeb translation of Pliny's *fervefacere*, ad. loc., says that the *pastilli* are soaked and then boiled with emmer wheat, a careless error which this author would have corrected but for his untimely death; temperatures above 140° will quickly kill any yeast strain capable of leavening bread. André (1961: 67–68) commits the same error. We are reminded that the ancients, whose theoretical knowledge of yeasts and other microbes was nil, habitually compared enzymatic

The sponge is then mixed with bread flour "to make the finest bread." Several oddities appear here. First, what possible advantage besides economy did the use of wheat bran offer over wheat flour in making the yeast cakes? Secondly, Pliny's insistence on 'white' must is odd, assuming he means the must of white grapes, since white varieties ferment no more vigorously than black. Could the ancients have been concerned not to impart some of the black grapes' pigment to this 'finest', that is, whitest bread? But in that case why use bran, even in small quantities? Finally, it is quite odd that Pliny should specify the use of emmer flour in making the sponge. Everything about this passage suggests that Pliny is prescribing a traditional procedure from an ancient source. Use of bran is attested in traditional baking for the making of a spontaneous sour-dough starter[124] and emmer is the traditional grain of Rome, as we have seen. Pliny adds that these yeast cakes are made during the vintage. The Greeks, he continues, mix leaven of this sort in the proportion of 2/3 pounds per "two half-modii" (another odd phrase) of flour.[125]

At other times of the year the baker may be forced to resort to adventitious leavens, as Pliny indicates. For example, barley is soaked in water (in the form of groats?), then kneaded into two-pound cakes which are heated in the ashes of the hearth or in a terra cotta pan until they brown, presumably to facilitate starch conversion to dextrin. They are then kept in terra cotta vessels, presumably uncovered, until they spontaneously sour. When needed, they are reconstituted in water. Back when the ancestors used to make barley bread, Pliny adds, barley flour was 'leavened' with vetch and chickling pea. Everything about this last inexplicable remark suggests that Pliny has confused the making of a composite flour as discussed above with the leavening process; barley flour can only with difficulty be leavened under the best of circumstances, for reasons already discussed,

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processes to physical changes caused by cooking, including boiling. Digestion itself is compared to the 'cooking' of the food in the digestive tract (Greek *pessein* = to ripen (as fruit), to cook, and to digest.) What better analogy could the ancients have found, particularly when enzymatic reactions and fermentation do generate surprising amounts of heat?

[124] Bernard Poitrenaud, "Commercial Starters in France" in Kulp and Lorenz (2003): 198–99.

[125] Not Rackham's 2/3 ounce. André ([1961]: 6)] in his discussion of the passage remarks that Pliny's proportions are much less than those used today but fails to note that Pliny clearly indicates the use of a sponge, which can be 'grown' to any desired proportions.

and these legumes will certainly never have done the trick. "Nowadays," he adds, "leaven is made from flour itself, kneaded before salt is added, boiled down to a kind of porridge, and left to sour. But generally no effort is made to make leaven; rather, a portion of dough reserved from the previous day's baking is used." Pliny redeems himself: perfectly sensible, and doubtless true.

Kneading

The penultimate process in breadmaking is kneading. As previously stated, wheat has the enormous advantage over other cereals of an ability to develop gluten, an elastic protein matrix which traps the carbon dioxide of fermentation and transforms dough from a dense, sticky paste into a light, airy, pliant mass whose texture becomes even lighter when the heat of baking causes these bubbles to expand. Gluten per se, however, is not present in flours but rather gluten-forming proteins, notably glutenin and gliadin. Gluten naturally forms when these proteins are hydrated and mechanically handled, i.e., kneaded. Kneading 'develops' wheat gluten by facilitating hydration, modification of gluten proteins, and interaction of these proteins with other flour components such as lipids. Salt is typically added during the process for taste but also because it improves dough handling, stability, crumb grain, and bread volume.[126]

It is perhaps significant that Cato finds it necessary to give a recipe for kneaded emmer bread[127] The implication is that the typical 'bread' of Cato's day was not kneaded or was kneaded very little; thus the bread of the countryside was primarily a pancake or flatbread.[128] Interesting in this regard is a notice in Festus[129] concerning *panis clibanicus*, a type of pone obtained by spreading dough to bake on

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[126] Pomeranz and Shellenberger (1971): 36–37.

[127] *Agr.* 86. Stephen Hall and Anthony Bryer in "Byzantine Porridge: *Tracta*, *tarchanás* and *tarhana*," in Wilkins, Harvey and Dobson (1995): 44–54, point out that Cato's recipe for *placenta* (*Agr* 76) uses the word *tracta* in two different senses, one 'pastry' but the other as something very much akin to modern *tarhana*, i.e., emmer meal kneaded, with or without a sour-milk product such as yogurt, then shaped into balls and dried for storage, a sort of pasta. Cf. Apicius 5.1.3A and 6.9.13. They suggest the word itself enters Near Eastern languages by way of Byzantium. *Tarhana* is used today to make a quick, hearty soup.

[128] Cf. André (1961): 68–69.

[129] 126,11 M.

the exterior surface of a vessel of terra cotta or metal, in the interior of which coals are placed. Festus describes these pancakes falling into the ashes of the hearth when they are fully baked; they are eaten hot after detaching themselves in this fashion. One is reminded of the johnnycakes and hoecakes which were a regular feature of American pioneer life as well as the various flatbreads of the Near East and India cooked on the sides of traditional ovens.

Such breads doubtless persisted in Rome, especially in rural districts, but the fact that Festus finds them a curiosity worth remarking in the Augustan period assures us that the typical Roman bread of the period was a kneaded, leavened loaf. The mechanics of kneading were too mundane for any ancient author to mention, though a notice in Pliny[130] scolding those in the maritime districts for kneading (*subigi*) bread with sea water "as the majority of persons do in the maritime districts in order to save on salt" (Pliny complains that "nothing else renders the body more susceptible to disease") suggests that salt was added to the flour mass rather than to the sponge. A more germane objection to the use of sea brine as salt, not mentioned by Pliny, is the inclusion of calcium and magnesium salts present in sea water which will have given the bread a bitter flavor; perhaps this is what Pliny means when he refers to 'disease'.

For the kneading process as well as the baking process we have good archaeological evidence. Doubtless in domestic baking and much commercial baking as well, hand-kneading was the norm and was done in about the same way it still is in domestic practice. And Jasny[131] cautions that we should not underestimate the amount of domestic baking done by the ancients, even in a metropolis like Rome. But in the commercial mill-bakeries of Pompeii, Rome, and its environs—and they were numerous—a more efficient technology appears. In August Mau's seminal work on Pompeian daily life we see a plan of a Pompeian mill-bakery[132] located in a converted atrium house on the north side of Insula xiv in Region VI. The mill-bakery itself is located in the former peristyle court of this once-stylish home.

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[130] *NH* 18.68.

[131] Naum Jasny, "The Daily Bread of the Ancient Greeks and Romans," *Osiris* 9 (1950): 227–53. For home baking, see Joan Frayn, "Home Baking in Roman Italy," *Antiquity* 52 (1978): 28–33.

[132] August Mau, *Pompeii: Its Life and Art* (London, 1902): 390–1 and Fig. 224; idem, "Su certi apparechi nei pistini di Pompei," *Mitteilungen des Deustechen archäologischen Institut (Röm)* 1 (1886): 45–8.

The courtyard of the peristyle now serves as the mill and contains four rotary mills of the typical sort. To one side of these in three small side rooms are located (from back to front) a kneading room, the oven room, and a storeroom. The kneading room has large built-in tables and shelves, perhaps for the preparation of sponges and initial dough fermentation, for hand-kneading smaller quantities of dough, as well as scaling and forming of loaves. On the party wall with the oven room is a small opening to allow scaled and formed loaves to be passed to the oven. But the most interesting feature of the kneading room is a cylindrical tufa *mortarium* or mixing basin, [Fig. 14] about 2 1/2' (76 cm) in diameter, in which a vertical shaft once rotated, a shaft from the lower part of which two or three horizontal arms projected.[133] Additionally, around the sides of the *mortarium* holes are cut for insertion of wooden or iron 'teeth', and these holes are carefully located to allow free movement of the rotating arms of the shaft. The working of the device is illustrated in the famous tomb relief Eurysaces [Fig. 13, North Panel] and probably on the sarcophagus of L. Annius Octavius Valerianus as well.[134] Our baker takes his paste mixed with salt and water and places it in the mixer. The central shaft is intersected by a horizontal sweep which is yoked to a donkey who walks around the mortar in the usual way or is operated by two humans on opposite sides. As the spindle rotates the projecting arms of the shaft push the dough at the same time the teeth of the mortar catch and retain it. In short order the paste will have been kneaded into a soft, pliable dough, portions of which the baker scales to weight and forms into loaves of appropriate size and shape and sets aside to rise. Modern commercial kneading machines are based on exactly the same scheme. A curious phrase in Vitruvius' description of the water mill ("at eadem versatione subigitur farina") suggests that the drive shafts of these mills may also have been used to operate such kneading machines at the same time they ground grain. The notion has been credited by a number of scholars.[135] The procedure using animal power is

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[133] Mau (1902): Fig. 223. Cf. Jan Theo Bakker (1999): 9 and Plates 19–20; Bernard Meijlink, "Molino I, XIII, 4" in Bakker (1999): 78 and Plates 41–42.

[134] So Curtis (2001): 358 and Plate 30.

[135] E.g., L. A. Moritz, "Vitruvius' Water-Mill," *The Classical Review* 70 (1956): 193–6. Complete bibliogrpahy in Wikander (1981): 95, though Wikander himself doubts it was in general use and concedes the possibility that it existed only as a "creative idea." Cf. Curtis (2001): 363–64, n. 75.

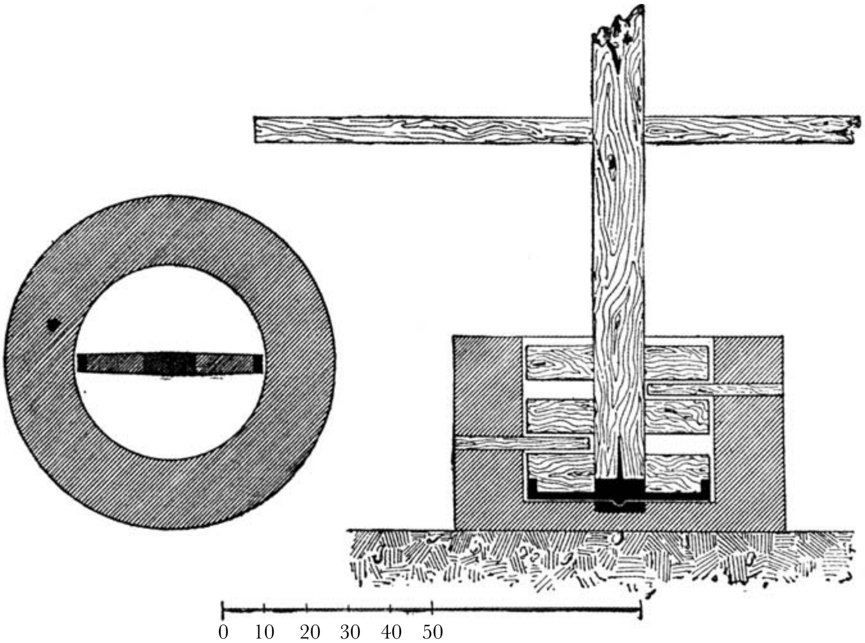

Fig. 14. Plan and section of a Roman kneading machine from Pompeii. (After Mau (1902): Fig. 224).

beautifully illustrated on the tomb relief of Eurysaces previously mentioned,[136] and the cylindrical vertical and horizontal motives which decorate the middle and upper zones of the tomb itself are probably stylized *mortaria* for such machines, inasmuch as a square socket is sculpted into the bottoms of these cylinders, where the bases for wooden spindles of the actual machines would have been inserted.[137]

Some account must also be taken of a curious phrase of Columella's;[138] in speaking of the dry storage of fruits he reports that partially sun-dried figs are trodden "with washed feet, in the manner of flour (*in modum farinae*)" before being stored. Treading, as we shall see, was a standard operation in processing olives and grapes, in which the berries were placed in a trough and trodden by men, barefoot or shod in clogs. The technique for kneading dough had a precedent in Old Kingdom Egypt, and apparently persisted, witness Herodotus' condemnation of Egyptians for kneading dough with their

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[136] Cf. for example, Petrassi (1974): 53.

[137] Brandt (1993): 15–7.

[138] Columella, *DRR* 12.15.4.

feet but gathering dung with their hands.[139] It is impossible not to imagine that this simple, effective technique would have occurred to our miller-baker, given the ancients' penchant for 'borrowing' technologies from one genre to another, and I am confident we should imagine our workers placing masses of dough in stone or wooden troughs, carefully washing their feet, and then treading the mass until it was thoroughly kneaded. Simple, effective, cheap.

Perhaps it is time to place all this activity in a context. [Fig. 15] The Pompeian bakery described by Betty Jo Mayeske,[140] located in Region I.xii.1–2 on the Via dell'Abbondanza, is an excellent example of a well equipped mill-bakery. The building has actually been modified from a large *domus* to accommodate the *pistor's* living quarters in one suite of rooms and a mill-bakery in another to its left. At the front of this latter suite is the milling room with four of our prototypical Pompeian donkey mills. A small room off this larger area may be a stable for housing the donkeys used to operate the mills. Behind this room and connected to it by a small corridor is the bakery proper, a suite of five rooms, the functions of several of which can be deduced by their design. The first room is the *panificium*, the room where flour from the mills, or from storage if our flour has been conditioned, is made into leavened dough, kneaded, allowed to rise, scaled, and formed into loaves. It contains a kneading basin, supports for a table, and evidence for brackets to support a shelf on the wall, doubtless where formed loaves were placed to rest and rise. The table itself is depicted on Eurysaces' tomb frieze,[141] [Fig. 13, North Panel] where we see two such tables with four bakery workers behind each. To their left is the kneading machine, to their right the beehive oven. Another worker scoops kneaded dough from the *mortarium* of the kneading machine, doubtless before handing it over to his cohorts, seen forming the dough into loaves under the watchful eye of a toga-clad figure who may be none other than Eurysaces himself.[142] In the room adjacent to the kneading room of our Pompeiian bakery and connected to it by a short passage is a typical oven. [Fig. 16] It is shaped like a beehive, and here as often enclosed by a hollow brick structure to create a cubical shape. This is the smoke

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[139] Curtis (2001): 117–8.

[140] Mayeske (1988): 149–58 and Figs. 1–13.

[141] Cf. e.g., Petrassi (1974): 53 and Curtis (2001) Pl. 30.

[142] So Petrassi (1974): 54.

Fig. 15. Reconstruction of a Roman mill-bakery. (From Peter Conolly and Hazel Dodge, *The Ancient City*. Oxford (1998): 165. Courtesy of Oxford University Press).

chamber, designed to increase efficiency by retaining heat and also to vent smoke, either directly though the ceiling or by way of a flue through the ceiling. The oven itself is built on a pedestal to bring the fire chamber to eye level.

We may imagine that our oven man (*furnarius*) has kindled in this a fire of wood, the bark of of the flax plant, or charcoal.[143] When this fire has heated the bricks of the oven to the appropriate temperature—and our bakers can judge this intuitively by the amount, type and condition of fuel used—the hot ashes and embers are raked to the sides of the oven or into an ash chamber located at the front of the pedestal, and the loaves are picked up several at a time on flat wooden bread spades or 'peels' (L. *palae*) and placed on the floor of the oven, the larger loaves around the hotter periphery, the smaller in the center. Again, Eurysaces' tomb relief shows us just such a baker, placing a loaf into the oven with a long-handled peel; with a slight update in his fashion statement, he would make a fine *fornaio* in any of Italy's *panetterie*, where the *forno legno* (wood-fired oven)

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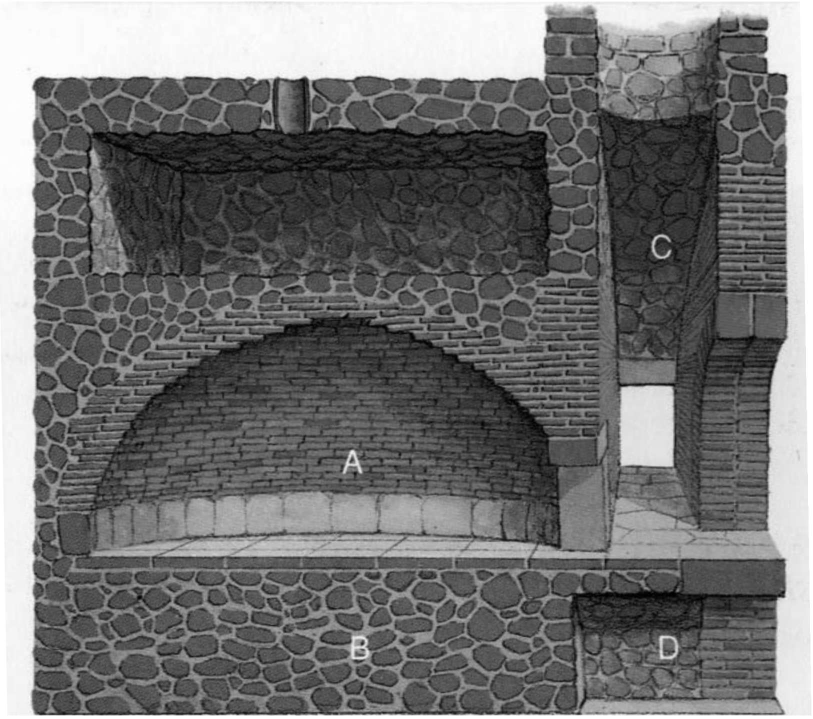
[143] Pliny, *NH* 19.3.18. Mau thinks charcoal more likely in Pompeii.



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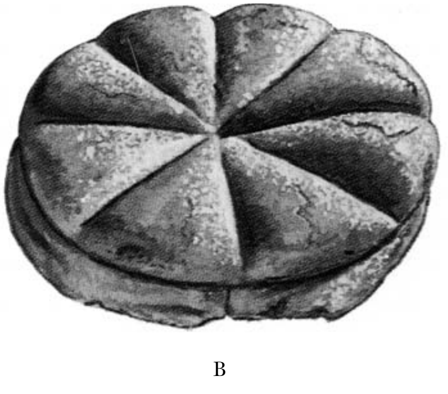

B

Fig. 16A and 16B. A: Cross section of a typical Roman *furnus*, or bakery oven as seen from the side. A pedestal (B) supports the bake chamber (A) below a heating chamber. At the right (C) is the flue. B: A typical Roman *panis quadratus*. The skin is incised before baking to create the eight wedges to make division of the loaf easier. (From Peter Conolly and Hazel Dodge, *The Ancient City*. Oxford (1998): 165. Courtesy of Oxford University Press).

is still the hallmark of quality. At the front of the oven is a small reservoir for water which our baker will sprinkle on the hot surface of the loaves or, perhaps more likely, on the surface of the oven, to create steam. This moisture allows the dough to retain more moisture on its surface which in turn causes the starches in the crust to gelatinize, producing a shiny appearance called 'bloom', and this is no matter of taste or esthetics; a good crust is essential for good 'oven spring', the increase in volume of the loaf in the oven, an increase as much as 30%.[144] At a time when leavening may have been problematic, good oven spring will have been essential for a good crumb. Our baker shuts the door at the mouth of the oven to retain heat and about an hour later uses his peel to remove the crusty loaves and passes them to the storeroom behind the oven. At the end of baking he rakes ashes into an ash pit conveniently built into the pedestal of the oven.

Ancient authors classify three types of bread according to mode of cooking: the *panis clibanicus* previously discussed, a *panis artopticus* cooked in the *artopta*, the movable oven for domestic use;[145] and by far the most common, *panis furnaceus*, bread made in a stationary oven of the type just described. Breads are also classified according to form,[146] the standard form being a round loaf of standard weight (obviously the Roman baker scaled his dough carefully before forming loaves), c. 5" (13 cm) in thickness, with the top divided into eight wedges, a mode still practiced in craft baking today: lines are incised with a knife in the top of the risen loaf, first in the form of a cross, then in the interstices of the cross. Such lines facilitate division of the crusty loaf and assist oven spring. Eighty-one of these so-called *panes quadrati* were removed from an oven at the bakery in Region VII.i.36–37, perfectly carbonized by the intense heat of the eruption.[147] In addition we hear of heavy biscuits called *autopyra*, a coarse dark bread made with branny flour and destined for dogs and slaves;[148]

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[144] Norman W. Desrosier, *The Technology of Food Preservation* (Westport, CT: AVI Pub. Co., 1970): 395; Kulp (2003): 127. For modern comparative techniques, Chris Wiggins, "Proving, Baking, and Cooling," in Cuvain and Young (1998): 120–48.

[145] Pliny, *NH* 18.88; 18.104; Athenaeus 113 a–b. For baking of breads in a *clibanus or sub testu*, Anthony Cubberley, "Bread-baking in Ancient Italy: *Clibanus* and *Sub testu* in the Roman World," in Wilkins, Harvey and Dobson (1995): 55–68.

[146] Cf. André (1961): 69–70.

[147] G. Fiorelli, *Descrizione di Pompei* (Naples, 1875): 171 and idem, *Gli Scavi di Pompei dal 186 al 1872* (Naples, 1872): 172.

[148] Celsus 2.18; Galen, *de Facult. Aliment.* 1.

athletes' bread, kneaded but unleavened and mixed with cottage cheese;[149] *bucellata*, 'jawbreakers', dried biscuits for troops[150] and *artoplites*, a light loaf of finest wheaten flour, baked in a fancy mold.[151] Doubtless forms of 'fancy breads' were also numerous in ancient Rome.

Our prototype bakery has no retail area, though a number of Pompeian bakeries do, located at the front of the shop along the street. Perhaps our baker had standing orders from some of the many retail eating establishments in the town. Or perhaps he sold it in a stall in the marketplace, as we see in a scene from the Praedia of Julia Felix (Reg. II.iv.2,4). Or perhaps his wares were hawked through the streets.[152] We can be sure that in some such ways the urban masses in Rome procured their 'daily bread'.

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[149] Galen, *ibid.* 4.6.

[150] Ammianus Marcellinus 1.17; Seneca *Ep.* 83.

[151] Athenaeus 3.28; cf. Soyer, pp. 37–38.

[152] Mayeske (1988): 154.

CHAPTER TWO

OLIVES

It is somewhat jolting to the modern Westerner, intent as so many of us are on reducing fat in our diets, to confront the fact that in most preindustrial societies obtaining adequate fat content in the diet is often or at least periodically a struggle. Fat functions in a number of physiological processes, not least the development of embryonic and infantile nerve sheaths.[1] In adults fat is primarily a source of energy, that is, of calories. Obtaining a certain minimum level of caloric intake is essential for the daily functioning of the human body, more critical in the short term, in fact, than any other nutritional factor, as we noted in our discussion of cereals. To use a crude analogy, it is pointless to fret about the condition of brakes or suspension of a vehicle if there is no gas available to operate the motor. 'Gasoline' in the human diet comes in the form of carbohydrates and fats, and fats are especially helpful because of their highly concentrated caloric value, calories which are readily stored by the body (as carbohydrates are not) in times of caloric surplus and readily converted to energy when the need arises. Since the quantity of fats obtainable from land and marine animals is limited and those from plant sources more easily found, especially in tropical and subtropical regions, it is hard to overstate the significance of vegetable fats in those regions in the maintenance of human nutrition.[2] In classical Rome we hear of fats obtained from a variety of vegetal sources such as rapeseed and sesame seed, but the fat source *par excellence* from at least the beginning of the second century BCE was undoubtedly the olive. It has been estimated that per capita

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[1] Anthony Kefatos and George Comas, "Biological Effects of Olive Oil on Human Health," in A. K. Kiritsakis, ed., *Olive Oil* (Champaign, IL: American Oil Chemists' Society, 1990): 157–81; Michael I. Gurr, "The Role of Lipids in Human Nutrition," in John Harwood and Ramón Aparicio, edd., *Handbook of Olive Oil* (Gaithersburg, MD: Aspen Publishers, Inc., 2000): 521–63; Gregorio Varela and Baltasar Ruiz-Roso, "Some Nutritional Aspects of Olive Oil," op. cit. 565–82.

[2] G. Frezotti, M. Manni and A. Aten, edd., *Olive Oil Processing in Rural Mills* (Rome: FAO, 1956): 1.

consumption of olive oil in antiquity was 20–25 liters per annum and may have represented one-third of a typical adult's caloric intake.[3] Olive oil is 100% digestible and is thus a highly concentrated source of storable energy. A mere 3.4 oz. (100 g) will provide close to 1,000 calories, all essential edible fats and fatty acids, as well as vitamins A and E. The caloric potential of olive oil is, ounce for ounce, some 18 times greater than that of wine.[4]

Background

The olive tree thrives in the subtropical Mediterranean world; further, it is incredibly hardy and long-lived.[5] It has been conjectured that some trees still bearing today in Italy and Spain were seen by Roman legions in the first century AD. Trees in parts of Israel up to 2,000 years old are called *romi*, meaning they have survived since Roman/Byzantine times.[6] Though the tree is extremely long-lived, it takes some forty years to reach full productivity, and needs careful attention to prevent its reversion to a wild state. Thus the adage that the farmer cultivates a new orchard for the benefit of his grandchildren. Moreover, olive trees thrive in rocky, hilly environments where arable is impossible, and produce, with care, fruit that is healthful and delicious when processed. Since olive fat is an oil at room temperature (i.e., is a liquid rather than a solid or semi-solid),

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[3] M.-C. Amouretti, *Le pain et l'huile dans la Grèce antique* (Paris: Les Belles Lettres, 1986): 177–96. Cf. H. A. Forbes and L. Foxhall, "The Queen of All Trees: Preliminary Notes of the Archaeology of the Olive," *Expedition* 21,1 (1978): 37–47; D. J. Mattingly, "Megalithic Madness and Measurement or How Many Olives Could an Olive Press Press?" *Oxford Journal of Archaeology* 7,2 (1988): 177–95; idem, "Oil for Export," *Journal of Roman Archaeology* 1 (1988): 33–56. Contra: T. W. Gallant, *Risk and Survival in Ancient Greece* (Stanford, CT, 1991): 60–112.

[4] Mattingly (1996): 223.

[5] Mordechai E. Kislev, "The Domestication of the Olive Tree" in David Eitam and Michael Heltzer, edd., *Olive Oil in Antiquity: Israel and Neighbouring Countries from the Neolithic to the Early Arab Period* (Padua: Sargon, srl, 1996 [= *History of the Near East Studies*, Vol. VII]): 3–6; David J. Mattingly, "First Fruit? The Olive in the Roman World," in Graham Shipley and John Salmon, edd., *Human Landscape in Classical Antiquity: Environment and Culture* (London: Routledge, 1996): 213–22; Curtis Runnels and Julie Hansen, "The Olive in the Prehistoric Aegean: The Evidence for Domestication in the Early Bronze Age," *Oxford Journal of Archaeology* 5, no. 3 (1986): 299–308.

[6] Avraham Singer, "The Traditional Cultivation of the Olive Tree" in Eitam and Heltzer (1996): 31.

it is readily metabolized by the human body. It is additionally an excellent source of the fat-soluble vitamins. About its other health benefits we are only now beginning to learn.[7] Little wonder, then, that olive oil was imported in vast quantities to the city of Rome, both from Italy and from the provinces, most notably Spain, and that in the late second century AD the emperor Septimius Severus made a portion of olive oil part of the dole distributed to the urban masses along with wheat in the form of baked bread.

Providing such a staple to a huge urban population geographically removed from its sources in an age of no refrigeration and relatively primitive transportation was no easy task. For one thing, the olive in its natural state contains an aqueous component which the Romans called *amurca*, composing 40–50% of the olive's total weight and intensely bitter. Thus the olive berry plucked from the tree is inedible before it is refined. Further, after the berry is picked, this aqueous solution will render the edible parts of the fruit totally inedible in short order unless removed quickly. This is so because all fats are inherently unstable and are particularly susceptible to rancidity brought about by hydrolytic lypolysis and oxidation. Rendering the oil stable enough that it may be stored over winter and/or shipped considerable distances requires a great deal of skill and empirical knowledge. The fact that traditional culture of the trees results in a bountiful crop only on alternate years places a premium on proper processing and storage.

The cultivated olive tree, *Olea europea*, is thought to be a descendant of the oleaster, *O. sylvestris*, which still grows extensively around the Mediterranean, or of the North African *O. chrysophylla*. Cultivation of the modern species unquestionably began in prehistoric times, probably in Syria and Asia Minor and/or in North Africa; thence it was spread by the Phoenicians to Cyprus, Morocco, Algeria, Tunisia, and elsewhere. Paleobotanical evidence combined with archaeological evidence from the same contexts strongly suggest cultivation in Israel in the Early Bronze Age (c. 3,300–2,200 BCE).[8] Around 2,000 BCE olive trees came to Crete and thence made their way

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[7] Frezzotti (1956): 15–16; Kiritsakis (1990): 9–11; Raphael Frankel, *Wine and Oil Porduction in Antiquity in Israel and Other Mediterranean Countries* (Sheffield: Academic Press, 1999): 36; Curtis (2001): 380–94.

[8] Forbes and Foxhall (1978): 37–47; Nili Lipschitz, Ram Gophna, Moshe Hartman and Gideon Biger, "The Beginning of Olive (*Olea europeea*) Cultivation in the Old World: A Reassessment," *Journal of Archaeological Science* 18 (1991): 441–53.

to the Greek mainland.[9] Greek topography and climate are especially conducive for cultivation; the Greek peninsula has loose, well-drained alluvial soils and sunny weather with occasional periods of drought, which olives can tolerate, but no extended periods of extreme cold, which they cannot.

Evidence of importation of oil as well as of locally made oil flasks suggests cultivation in Etruria from the seventh century BCE, and that certainly agrees with the Roman tradition that it was the Etruscan Tarquinius Priscus who introduced olive cultivation in Rome.[10] There is no definitive evidence that the Etruscans learned oleoculture from the Greeks of southern Italy, but it is not unlikely. Certainly the olive was cultivated in most parts of Italy south of the Po from early on; ancient Italy shares with Greece the advantages of topography and climate in this regard.

The olive berry is a drupe, i.e., a pitted fruit, which consists of a skin or tegument (the epicarp), a fleshy pulp where the bulk of the oil and aqueous solution are located (the mesocarp), and a hard stone or pit (the endocarp) whose oil can only be extracted using solvents. Chemically the fruit is composed, in addition to the 40–50% vegetal water already mentioned, of about 20–25% fat and about 25–40% solid residue. Olive oil is classified as a non-drying oil and its high moisture content is conducive to enzymatic action which leads to the breakdown of glycerides to free fatty acids, experienced as rancidity. The extent of this catabolysis is directly and dramatically affected by the treatment of the berries during harvest, handling, storage, and processing, as well as the lapse of time between harvest and processing. Oil was in antiquity and still is graded by the concentration of free fatty acids in the product, which range from about 0.5% in fine oils to 5% and higher in poorer grades. Oil with acid concentrations over 3% rarely has an acceptable flavor.[11]

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[9] Kiritsakis (1990): 1–4; D. Boskou, "History and Characteristics of the Olive Tree," in Dimitrios Boskou, ed., *Olive Oil: Chemistry and Technology* (Champaign, IL: American Oil Chemists' Society Press, 1996): 1–2; Luciano Di Giovacchino, "Technological Aspects," in Harwood and Aparicio (2000): 17–21; F. R. Riley, "Olive Oil Production on Bronze Age Crete: Nutritional Properties, Processing Methods and Storage Life of Minoan Olive Oil," *Oxford Journal of Archaeology* 21.1 (2002): 63–75.

[10] J. Boardman, "The Olive in the Mediterranean: Its Culture and Use," in Sir J. Hutchinson, ed., *The Early History of Agriculture* (Oxford: Oxford U. P., 1977): 187–89.

[11] Frezzotti (1956): 9–12; Theodore J. Weiss in J. L. Heid and Maynard A.

Oil varies in flavor (unripe, bitter, fruity, sweet, good, or defective), in odor, in color (brilliant green, straw-colored, whitish), and in transparency (limpid, opaque, cloudy; oils which clarify quickly are the inferior grades of oil).[12]

Oil quality is also affected, of course, by the variety of olive tree from which it is produced and by the relative ripeness of the berries. Today there are literally hundreds of olive varieties, and we have every reason to believe that there were numerous varieties in antiquity as well. Columella, for example, lists numerous kinds of olive trees, of which he names ten specifically. Two, the Posia and the Royal, he cautions, are more suitable for the table than for oil, since the Posia has an excellent flavor when new but spoils within the year. Quite an extraordinary statement, incidentally, since it implies that other varieties of oil typically remained or could remain stable for more than a year, despite some modern scholars' comments to the contrary. The Orchite and the Shuttle-olive, he continues, are also better as fruit than as oil sources, while the Licinian produces the highest quality oil, the Sergian the most abundant, and in general, the larger varieties are selected for eating, the smaller for oil production.[13] Unfortunately, identifying these varieties with any modern ones is all but impossible.

Oil quality is also affected dramatically by environments and even micro-environments, and it is interesting to hear Pliny declare authoritatively in mid-first century AD that oil from Venafrum in Campania is the best in Italy,[14] though that of Spain is even more highly regarded.[15]

Processing

Our best sources of information on the actual processing of oil in antiquity are the agronomists, i.e., agricultural writers, especially Cato in his handbook published about 180 BCE, Varro in *Res Rusticae* published in 35 BCE and Columella in his *de Re Rustica* published

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Joslyn, edd., *Food Processing Operations*, vol. II (Westport, CT, 1963): 117–19. Cf. Kiritsakis (1990): 15–21 and D. Boskou, "Olive Oil Composition," in Boskou (1996): 52–83 for the complete chemsitry.

[12] Boskou (1996): 3–5.

[13] Columella, *DRR* 5.8.3–4.

[14] *NH* 13.2; cf Horace, *C.* 2.6.

[15] *NH* 15.1.

between 35–45 CE. All three were gentlemen farmers who owned villa farms in Italy and wrote agricultural manuals, Cato for his son and the other two for other wealthy agribusinessmen, following in a long international tradition. All three have a great deal to say about the olive orchard and its place in profitable mixed farming. Unfortunately, it quickly becomes apparent from reading their manuals that the actual harvest and processing of the olives was let out to itinerant contractors—Cato even describes proper terms for such a contract. Since the manuals are intended for the instruction of the permanent villa staff and particularly the *vilicus*, the bailiff, and his wife, none of our authors treats oil processing *per se*. In that exigency we have recourse to two expedients besides the incidental comments of the authors: first, from their often elaborate descriptions of the processing equipment and from their archaeological remains the process itself may be reasonably inferred. Second, the basic procedures of oil production in the Mediterranean were remarkably conservative right up until the middle of the last century, and we may reasonably assume unless the evidence clearly contradicts us that the basic processes were the same in antiquity as those in, let us say, rural Spain at the beginning of the twentieth century.

Harvesting

Apropos of such parallels, the first step in the processing of olives for oil is, as it always has been, simply deciding when and how to harvest, so much so that I have considered the harvest an integral part of the processing of oil though it might well be considered strictly an agricultural process. As Frezzotti has aptly noted,[16] the simplest technologies in traditional societies are perfectly capable of producing oil of the highest quality, even by modern standards, if the fruit is of the highest quality and is lovingly treated. Conversely, it is possible and sometimes profitable to produce a poor product, even using state-of-the-art scientific procedures and equipment, if the berries are inferior to begin with and the processing shoddy. For example, once the fruit reaches minimum maturity, the earlier and

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[16] Frezzotti (1956): 1. Cf. Kiritsakis (1990): 56–60 and L. Di Giovacchino, "Olive Harvesting and Olive Oil Extraction," in Boskou (1996): 12–13.

quicker the processing occurs the finer the oil but the lower the quantity obtained; conversely, later harvest produces more oil of lower quality. It is here that modern laboratory testing has made a significant impact on maximizing yields while maintaining quality of product.[17] Because olives within a single geographical limit and to a lesser extent within the same orchard and even on the same tree ripen over a very long period—from late October to early January—the ancient farmer must have faced no simple decision. Did he harvest early and hope to sell finest oil at a premium? Did he harvest as late as he could to maximize yield while maintaining a minimal level of quality, knowing that his product was destined for a mass urban market long accustomed to poor quality if not deliberate adulteration? Did he try to find a happy medium? Or did he harvest twice or even more often to target different markets? The ancient agronomists never mention multiple harvests, but some of their comments might be construed as implying as much. On the other hand, the use of contract migrant labor for the harvest would certainly make a single harvest more practical. Cato comments:

> Make green oil in this way. Gather the olives from the ground as soon as possible. If they become foul, wash them and free them from leaves and manure [the ancients used both green and brown manure to fertilize olive trees]. Make the oil the next day after they are picked or the day after that. When the olives are of a dark color begin to pick them. The greener the olives from which you make the oil, the better the oil will be. [But] it will pay the owner best to have the oil made from ripe olives. If there is a frost when you are gathering olives, press after three or four days. Sprinkle these olives with salt if you wish to. Keep the press room and store room as warm as possible.[18]

Cato's advice seems to suggest a single harvest when the bulk of the olives are ripe but not dead ripe. Elsewhere[19] in discussing the terms of the contract with the pressers he specifies 1500 lbs. of Romanic oil, that is, oil from ripe olives destined for commercial sale, and 200 lbs. of *oleum viride*, green oil; perhaps this proportion is to be taken as typical. In the same contract he specifies 50 *modii* of deciduous olives and 10 *modii* of picked olives for preservation as table olives as well as 10 lbs. of anointing oil.

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[17] Frezzott (1956): 1; Kiritsakis (1990): 12–15.

[18] *Agr.* 65 (Brehaut's trans.).

[19] *Agr.* 146.

In general in central Italy the harvest will have begun some time in November; Columella[20] says that December is generally the middle of the harvest, and that certainly agrees with modern practice. Otherwise, the decision as to the exact time of the harvest or harvests must have been a matter of empirical judgment and/or practical necessity. Olives change from bright green just at the point of ripening to a deep purple at full maturity, to black at overripeness, and color is a crude indicator of ripeness and therefore of oil content. Frezzotti[21] thinks that oil content in antiquity was also judged by casting olives onto live embers and judging the brilliance of the flames. I find no attestation of this method in the ancient sources, and Frezzotti may be extrapolating from traditional Mediterranean practice. In any case, the establishment of ideal harvest time is still empirical in most of the Mediterranean, though now assisted by analytical controls.[22] Add to considerations of ripeness practical constraints such as weather, availability of equipment and labor, size of crop, presence or absence of parasites such as the olive fly, oil mill capacity, etc., and we are left with the impression that our ancient *vilicus* probably made a guess, educated by some expensive past experience, and then hoped for the best. Thus Pliny's practical suggestion that the olive harvest must proceed immediately after the vintage.[23]

Cleaning

Before the actual harvest commenced, however, it was the bailiff's duty to see that all necessary equipment was available and in the best possible condition, since the harvesting and processing equipment were the responsibility of the villa owner, not the contract labor. Thus Cato's[24] rather minute listing of necessary equipment and his seeming obsession with good order and absolute cleanliness

> . . . so that the work can be done well. For when the olives are gathered the oil should be made at once to prevent spoiling. Remember that great storms are wont to come every year and shake the olives

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[20] *DRR* 12.52; cf. Cato *Agr.* 31.
[21] Frezzotti (1956): 21.
[22] Suarez in Martinez Moreno (1975): 7–8.
[23] *NH* 18.320.
[24] Cato, *Agr.* 10.

> down. If you gather them quickly and the presses are ready, there will be no loss from the storm and the olives will be of a greener color and better. If they remain too long on the ground or on the floor they will begin to decay and the oil will be rank. A fresher and better oil can be made from any kind of olive if it is made in time.

In modern practice attention is given to preprocessing tasks just as carefully as Cato recommends. All equipment is repaired as necessary and thoroughly cleaned. Absorbent fabric disks used in pressing are reconditioned or, if new, conditioned. Pressing equipment, storage containers, and general premises are vigorously cleaned, since olive oil is so susceptible to off odors and flavors.

The actual ancient harvest was effected in several ways, all influenced by the fact that the olive berry is quite delicate and, once bruised, susceptible to enzymatic fermentation and autolysis. In discussing the terms of his contract, Cato makes it clear that contract laborers will hand-pick olives for oil from trees or will beat the trees with canes to fell the olives, using ladders provided by the owner. Deciduous olives, which are much more subject to bruising and decay, are to be gathered by separate laborers known as *leguli*, and kept separate to be made into table olives. As the olives destined for oil are gathered they are roughly cleaned of twigs and trash and measured by the *modius* (1 peck / 8.8 L). Cato's injunction that 2/3 of the required 50 contract laborers be pickers (*strictores*) is an accurate reflection of the predominance or at least preference of this method;[25] picking the fruit as opposed to beating it down keeps it in peak condition and doesn't damage the tree. Elsewhere he warns the *vilicus* to be vigilant since it is not in the self-interest of the harvesters to gather the olives in the way most advantageous to the owner. Specifically, it is much faster and easier to beat olives from the trees and gather them from the ground, but olives immediately begin to decompose in contact with any solid surface, particularly if they are bruised in falling.[26] Today precisely the same rules of thumb apply. As late as 1975 the typical method of harvest was still 'beating down' (Spanish *vareo*), a method which inevitably leads to greater bruising of fruit and tree. Hand picking, on the other hand, allows fruit to be picked at the height of ripeness and in perfect condition, but is far more time-consuming.

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[25] *Agr.* 144.

[26] *Agr.* 64.1.

Ancient pickers probably worked in the same ways as their modern counterparts, who climb wooden ladders and use the right hand as a comb to pluck the olives while holding with the left the olive tray into which they fall. Alternately, they may have used special combs for the purpose, as they sometimes did for wheat. Olives are then placed in small baskets or bags slung from the pickers' shoulders. When full these are passed to a porter, who empties them into larger receptacles such as baskets, bags, or trays. Empties are then passed back to the pickers. Additionally, in relatively flat terrain olives may be felled, by shaking the twigs or striking them with long canes, into a special cloth net spread under the tree. The nets are then pursed to collect the olives.[27]

Today, when olives are frequently transported many kilometers to large processing facilities, method of packing is critical, since olives bruise so easily, especially when stacked in sacks, and bruising invariably results in inferior oil unless processing begins immediately. Obviously, this will have been far less a problem on the ancient villa, where processing equipment was located on premises and where transport was doubtless by hand in relatively small increments. But what of the smallholder who surely could not have afforded his own equipment? Unfortunately our sources fail us here.

Cato also says nothing about cleaning the berries except his terse injunction about removing twigs and manure at the orchard. But, again, some sort of systematic cleaning is certainly implied. Today fruit, especially the deciduous fruit, invariably comes to the mill contaminated with dirt, stones, leaves, twigs, and weeds. The fruit is sieved to remove gross impurities but some remain and not only do they adversely affect oil aroma and flavor, but they also contribute to wear and tear on machinery. Thus the olives must be thoroughly washed and simultaneously sorted to eliminate rotten berries and those attacked by the olive fly.[28] Since even minute quantities of spoiled fruit can ruin a pressing, some such process must be envisioned for antiquity. In fact in the case of deciduous olives, which he recommends only as table olives, Columella prescribes a thor-

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[27] Frezzotti (1956) 25–28; Suarez in Martinez Moreno (1975): 7–8; L. Di Giovacchino, "Olive Harvesting and Olive Oil Extraction," in Boskou (1996): 14–17; idem, "Technological Aspects," in Harwood and Aparicio (2000): 23–25.

[28] Frezzotti (1956): 33–35; Suarez in Martinez Moreno (1975): 4–15; Di Giovacchino in Harwood and Aparicio (2000): 26–27.

ough washing in a cauldron of very hot, though not boiling, water before the olives are processed and stored.[29] Doubtless a similar process was used for oil berries as well.

Warehousing

Another problem that the modern olive processor shares with his ancient prototype is that of warehousing fruit prior to milling.[30] Obviously the ideal would be for fruit to be milled and pressed within hours of its arrival at the plant, as both Cato and Columella assert. But often the berries arrive from the harvest faster than they can be processed and thus must be stored for several days. In this case Columella recommends that the olives be stored in a loft supported on arches, like the granaries we examined in our last chapter, containing a number of bins to store daily pickings separately. The floor of this loft is to be paved or tiled and sloped toward channels to allow the vegetal water (*amurca*) to drain away, since this solution is "most deleterious to the oil." On the floor of the bins boards are set on edge at one-foot intervals in the fashion of floor joists. Above these at right angles is placed a 'floor' of closely woven reeds; this platform allows air to circulate freely under the berries and the *amurca* to drain off. Channels for the *amurca* carry it to special vats (*dolia*), a separate vat for each bin since *amurca* is useful and that of different grades has specific uses.[31] Archaeological evidence suggests the pressroom floor itself might be used for this storage, the minimum requirement for such a facility being no more than a suitable pavement so the *amurca* could be drained and washed. Floors apparently for this purpose made of concrete occur at several sites, and one made of mosaic tile at one site. At a Via Tiberina villa, a platform built at one end of the pressroom and faced with concrete was probably for such preprocessing storage. Nothing like Columella's sophisticated system appears in the archaeological record, but that is hardly surprising since such bins were largely of highly perishable wood and reeds.[32]

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[29] Columella *DRR* 12.52.21.

[30] Kiritsakis (1990): 58–59; Di Giovacchino in Boskou (1996): 18–19.

[31] Columella, *DRR* 12.52.2–3.

[32] J. J. Rossiter, "Wine and Oil Porcessing at Roman Farms in Italy," *Phoenix* 35 (1981): 355.

Cato is most emphatic, and Columella seconds him, in warning against what would seem to have been a common ancient practice at this stage. He cautions that pressmen prefer to keep the olives a long time in the bins, since they thereby become soft and easier to mill and press. Apparently some owners also accede in the practice in the mistaken belief that the oil quantity also increases in storage, to which Cato very sensibly replies that "the more quickly you get [the olives] pressed the better it will pay you, and the same number of *modii* of olives [if pressed fresh] will yield both more and better oil."[33] Both statements perfectly sound, though the amount of oil drained away in the vegetal water was probably negligible, such that 'more' here is a relative term. Columella, citing this passage of Cato,[34] explains quite handily the apparent discrepancy in the presumed and actual amounts of oil obtained from stored fruit:

> Cato says that the olives become shrunken on the storage floor and less in volume [through loss of the *amurca*]. Accordingly, when a farmer puts under cover the quantity required for pressing [up to 100 *modii* according to Pliny, *NH* 15.23] . . . he disregards the original quantity brought in and completes the shortage [due to the shrinkage] from another heap similarly set aside, and thus the stored olives *seem* to yield more oil than fresh ones.

Warehousing is every bit as stubborn a problem today—indeed, more so, given transport times and the huge quantities processed at centralized mills. For comparison, a modern authority recommends storage in depths of no more than 4"–5" (10–12 cm) in aerated vats; otherwise various catabolyses occur which render the fruit a brown mush resembling manure.[35] Suarez mentions a "very ancient" practice to retard or stop fermentations by adding salt to the heaps. This salt is today often added as brine which has the additional effect of cooling the mass and thus further retarding fermentation.[36] Cato's reference cited above to the frost-bitten olives to which salt is added makes it clear that the practice was known to the ancients as well, though it is unclear whether he means for the salt to be added before or after pressing. Columella says that salt is added to olives after a very brief pressing, before they are pulped, two *sextarii* (c. 2 pints/.95 L)

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[33] *Agr.* 64.2.
[34] *DRR* 12.52.
[35] Frezzotti (1956): 30–33.
[36] Suarez in Martinez Moreno (1975): 11–13; cf. Cato, *Agr.* 65.

of salt per *modius* of olives, and then carefully pulped.[37] The effect will have been the same.

In any case it is obvious that the ancients knew perfectly well that minimal storage time and rapid processing were essential to maintain quality of product. The processing itself took place in the press room (*torcularium*) [Fig. 17]. Cato's treatise contains a detailed account of the construction of the pressroom, mills, presses, and other equipment necessary for olive processing:

> [An olive orchard of 240 iugera (c. 160 acres/65 hectares) should have] 5 oil presses fully equipped including the pulping mills, a bronze cauldron to hold 30 amphorae (c. 216 gal./813 L.), a cover for the cauldron, 3 iron hooks, 3 water pitchers, 2 funnels, a bronze cauldron to hold 5 amphorae (c. 36 gal./140 L.), a cover for it, 3 hooks, a small vat for water, 2 amphorae for oil, 1 half-amphora measure holding 50 [?], 3 ladles, . . . 100 dolia, 12 vats, 10 dolia for wine-press refuse [?], 10 for oil dregs, 10 for wine, 20 for grain, 1 vat for lupines, 10 seriae, a vat used for washing, 1 tub for bathing, 2 vats for water, separate covers for all storage jars large and small. One donkey mill, 1 hand mill, one Spanish mill, 3 harnesses for the mill asses, . . . one [mortar and] pestle to separate olive pits, 1 *modius* measure and 1 half-*modius* measure.[38]

Brehaut in his note on the passage explains some of the more esoteric elements.[39] The vats mentioned are flat vessels of stone or earthenware to hold the oil after it is removed from the pressroom to be separated from the amurca. The dolia of smaller type, *seriae*, are used according to Varro[40] to transport olives from storage to the pulping mill. These are large vessels perhaps as much as a half-dolium (c. 100 gal./c. 420 L.) which are also used as storage vessels for wine[41] and to pack hams for salt curing.[42] One of the handmills may have been used to grind the salt used in treating the oil and in pickling olive relish and table olives as well as additives for wine. Brehaut offers no explanation for the "Spanish mill" nor does Moritz, and I can add nothing. The pestle to separate olive pits is used to separate the pits from the press refuse, since this was considered

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[37] Columella, *DRR* 12.52.10.

[38] Cato, *Agr.* 10.2–4. For the archaeology, see especially Rossiter (1981): 353–60, and the bibliography p. 361.

[39] Brehaut, *ad loc.*

[40] *RR* 1.55.5.

[41] Cato, *Agr.* 13: *seriae vinariae.*

[42] Cato, *Agr.* 162.

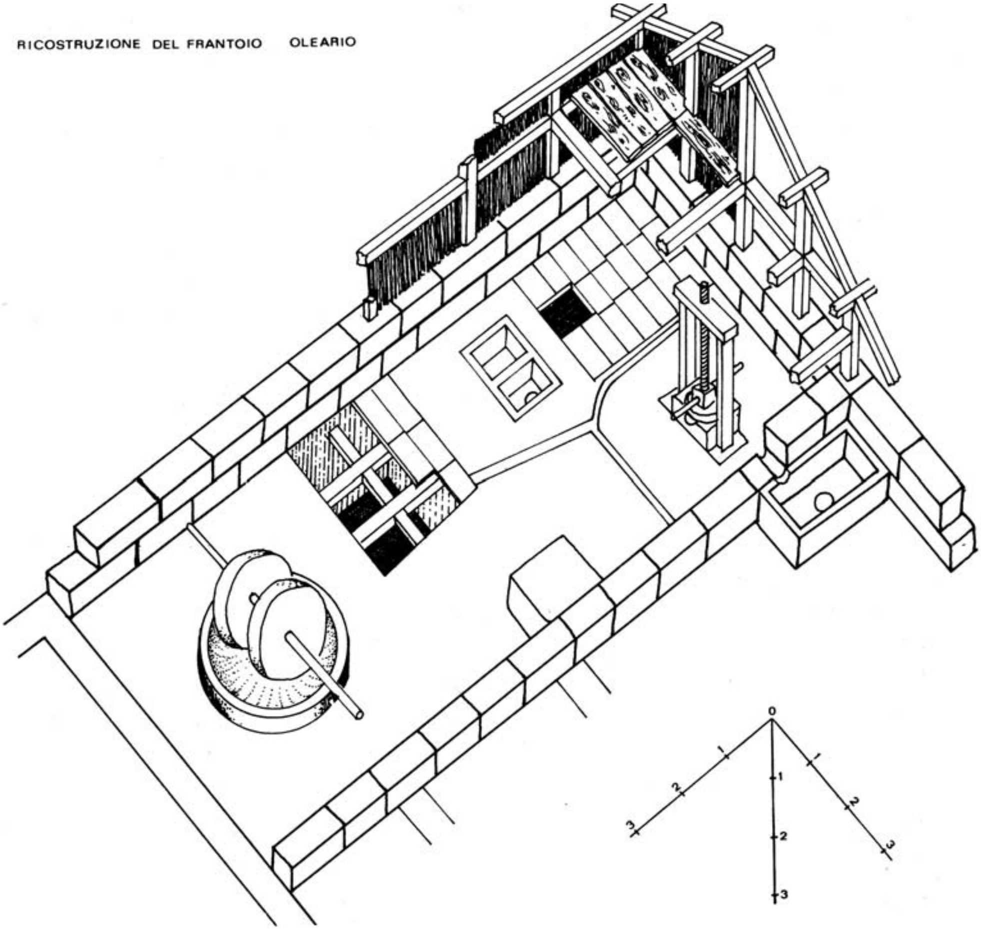

Fig. 17. Press room (*torcularium*) of a Roman villa rustica set up for processing olives. To the left, an olive mill (*trapetum*) for milling raw olives to paste. To the right a screw press situated in a reservoir (*lacus*) which delivers the raw oil and vegetal water to settling tanks where oil and water are separated. (From A. Maffei and F. Nastasi, edd., *Caere e il suo territorio da Agylla a Centemcellae* (1990): Fig. 137. Courtesy of the Instituto Poligrafico e Zecca dello Stato, Rome).

essential before the refuse was used to manure olive trees. Cato's description of the pressroom and its equipment has now been supplemented by archaeological remain of such buildings.[43]

Pulping

Suarez[44] divides the technical processes which follow in modern processing into four: paste preparation, in which the vegetal structure of the fruit is broken down via milling; malaxation, i.e., the process of physically opening oleaginous cells and achieving partial separation of solid and liquid components of the drupe; radical separation of solid and liquid states by way of filtration, pressure, and/or centrifugal force; and liquid-phase separation of oil and vegetal water by decantation (racking) or centrifuging. Again, the technical processes in antiquity were essentially identical, though the equipment used to effect them was less sophisticated; indeed, centrifugal force was never used for separation of oil and solids or oil and amurca.

The first two of Suarez' technical processes were typically combined in antiquity. Columella[45] specifies four methods of pulping olives, in order of preference: the oil mill (*mola olearia*), the pulping mill (*trapetum*), the clog and trough (*solea et canalis*) and the olive grater (*tudicula*). Unfortunately, he gives few specifics and our discussion of the last two for which there is no confirmed archaeological evidence is necessarily speculative. We will discuss the four in the order of their apparent evolution. The simplest method would seem to be the 'clog and trough' method, in which a trough is filled with olives, treaders don thick wooden clogs, step into the trough and proceed to tread the olives in the same general manner as their analogs in the winery and the bakery, the clogs being necessitated by the relative toughness of the olives' flesh and the sharpness of the pits.

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[43] E.g., A. Carandini et al., *Settefinestre. Una villa schiavistico nell'Etruria romana*, vol. II (Modena: Edizioni Panini, 1985): Figs. 354–55.

[44] Suarez in Martinez Moreno (1975): 6; cf. Kiritsakis (1990): 61–70; Di Giovacchino in Boskou (1996): 19–51; idem in Harwood and Aparicio (2000): 28.

[45] *DRR* 12.52.6–7. Cf. White (1975): 226–9. Frankel [(1999) 4; 57–8] finds evidence in the Levant for the crushing of olives in mortar and pestle, and it is reasonable to assume that smallholders in the Roman world will have resorted to the same simple expedient. This may, in fact, be the primary or secondary purpose the mortar and pestle of Cato's reference at *Agr.* 10.2.4 previously cited.

That this interpretation of the terms is reasonable is suggested by notices in the lexicographers, especially Hesychius, and by a part of the Rondanini relief which apparently shows the very operation, as well as by comparative practices in other parts of the ancient (and modern) Mediterranean, especially ancient Israel.[46] But comparative archaeological evidence suggests that rectangular troughs could also be used with simple rollers to pulp olives.[47] In Greece, cylindrical rollers were used, in this case to pulp olives spread out on a hard, flat surface.[48]

Columella tells us that the olive grater (*tudicula*) resembles a threshing sledge (tribulum) set on end and says that it accomplishes the task reasonably well except that it becomes clogged if even a few too many berries are grated at once. From this White[49] posits a type of large box-grater with the interior surfaces of the four sides studded with flints after the fashion of the threshing sledge. That the operation is essentially one of grating is suggested by the apparent etymological derivation of the name of the device from *tundere*, 'to bruise, bray'. About the exact operation of the device White astutely declines to speculate.

Neither Cato nor Columella specifically describes the operation of the pulping mill (*trapetum*), for reasons adduced already, but in his exquisitely detailed description of a press room for his prototype olive orchard, Cato is particularly careful in his description of this mill, perhaps, as Brehaut conjectures, because it was a device relatively new to Roman agronomy at that time. [Fig. 18] A number of these mills have actually been recovered by archaeologists, and it is also quite astounding how much pulping mills still used in many areas

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[46] A. Louis, "Aux Matmala et dans les ksars du sud. L'Olivier et les hommes," *Cahiers des Arts et Traditions populaires* 3 (1969): 41–66. But Brun (in Tchernia and Brun [1999]: 73 and Fig. 89) thinks it more likely that the Rondanini relief shows both olive processing and winemaking and that the treading here is treading of grapes, since the presence in the same scene of a pulping mill would make the treading of olives unnecessary.

[47] David Eitam, "The Olive Oil Industry at Tel Miqne-Ekron," in Eitam and Heltzer (1996): 172.

[48] Forbes and Foxhall (1978): 39–41.

[49] White (1975): 227. Frankel [(1999): 74] follows J. P. Laporte ["La *tudicula*: Machine antique à écraser les olives et les massues de bronze d'Afrique du nord," *Bull. Archéologique du comité des travaux historiques et scientifiques* 10–11 (1974–75): 167–74] who sees the implement as a bronze, reactangular object, elliptical in profile at its short ends, with knobby projections on both sides, a sort of upright rasp.

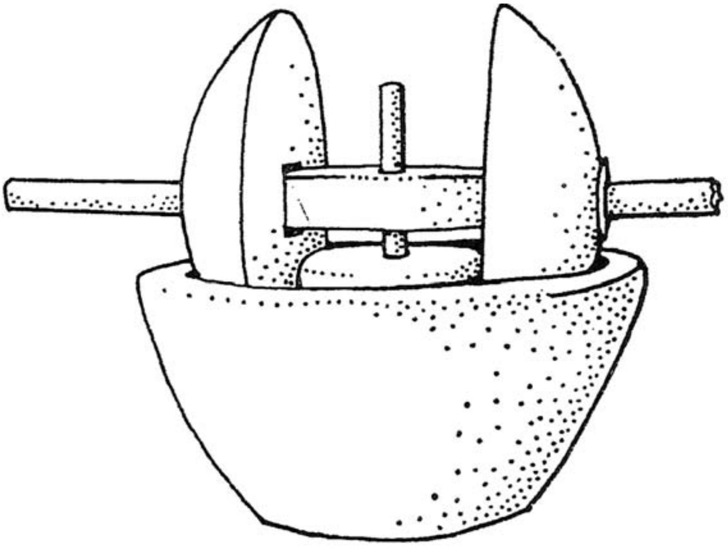

Fig. 18. The pulping mill (*trapetum*). Raw olives are placed in the mortar and the hemispherical millstones are turned by men or donkeys. Olives are pulped by the rotation of the millstones as well the friction of the stones against the mortar. (From White (1975): Fig. 56. Courtesy of Cambridge University Press).

of Spain and Italy at the middle of this century resembled their ancient prototype.[50]

The *trapetum*[51] consists of a hemispherical stone basin or mortar with a heavy stone pillar rising vertically from its center to the height

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[50] Cf. Frezzotti (1956): 45 and Figs. 27–28. The only significant structural difference in the Italian type is the shape of the basin and millstones, which resemble more the *mola olearia*. The modern analog has a horizontal stone disk encircled by an outwardly flaring metal flange. The ancient *trapetum* millstones were truncated hemispheres to fit into the stone bowl; the modern millstone is cylindrical. In Spain the millstones are truncated cones, Cf. Carlos Gomez Herrera, "Mechanical Properties of Ground Olive Pastes," in Martinez Moreno (1975): 18–19; Jose Alba Mendora, "Milling, Malaxation" in Martinez Moreno (Rome, 1975): 25–26; Di Giovacchino in Harwood and Aparicio (2000): 21 and Fig. 2.5. Di Giovacchino finds evidence that stone mills actually produce a product superior to that of the more cost-effective crushers of continuous centrifugation plants often used today. For the archaeology: Lin Foxhall, "Oil Extraction in Classical Greece," in Marie-Claire Amouretti and Jean-Pierre Brun, edd., *La production du vin et de l'huile en Mediterranée* (Paris, 1993 [*Bulletin de correspondance hellénique Supp. XXVI*]): 183–200; Mattingly (1996): 229. Greek crushing stones are different from Roman, not lens-shaped but flat disks the edges of which are curved to form a segment of an arch. For the *trapetum* in Israel: Nahum Sagiv and Amos Kloner, "Maresha: Underground Olive Oil Production," in Eitam and Heltzer (1996): 277–81 and Figs. 3 & 4. Here, too, a semi-lenticular *orbis*.

[51] Cato, *Agr.* 20–22.2 At *Agr.* 22.3–4 Cato scrupulously records the cost of the

of the top of the mortar. Into the top of this pillar is driven an iron pivot, secured to the pillar with wedges and molten lead. The pivot supports a perpendicular, that is to say horizontal, axle to which are attached on opposite sides two truncated hemispherical millstones or 'edge-runners'. They are slightly smaller than the hemispherical basin to fit rather snugly into it, having their flat sides toward the pillar. When the axle is turned on the pivot, the millstones travel around the mortar and simultaneously rotate on their axles. Olives are brought from storage in the *seriae* and fed into the center of the mill in the gap between the millstones. The stones are then turned by donkeys on opposite sides. As the centrifugal action of the millstones forces olives outward they are pulped by the friction as well as the rotational friction of the millstones.

Both Cato and Columella[52] say that the gap between the outer surface of the millstones and the inner surface of the mortar is carefully adjusted such that the flesh of the olive is thoroughly macerated but the pit is not broken "which," says Columella, "spoils the flavor of the oil." This is odd. Modern olive millers in fact *prefer* to break the pits since they provide more friction in pulping and also create a better filter bed in pressing, allowing the oil to flow more readily. Nor do pits in fact spoil the flavor, though a number of modern scholars have accepted the ancients' prejudice as fact. On the other hand, a cracked pit will most definitely spoil the flavor of an unpitted table olive in storage. Were our authors reasoning by analogy? Might they even be transferring to olive pressing empirical knowledge from winemaking, where the grape seeds are high in bitter tannins which the ancients avoided? There is simply no good evidence that either the *trapetum* or its successor, the olive mill, could be operated without crushing the stones, despite the literary evidence.[53]

In any case it seems clear enough that the *trapetum* was, or became, the standard device on the villa farm of Cato's day, and its operation is clear both from its design and from modern comparative practice. After adjustment, olives are poured into the mill from above, into the 'hopper' formed by the space between the millstones' inte-

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trapetum, the setting up of the mill, cartage, and the axles, as well as the cost of replacement millstones. Such mills, he says, may be procured as Suessa and Pompeii, the replacement millstones at Rufinum (in the territory of Nola) and at Pompeii. Cf. White (1975): 227–9.

[52] *DRR* 12.52.6.

[53] Cf. Mattingly (1996): 229.

rior flat surfaces. The axles, which extend beyond the outer convex surfaces of the millstones, form two sweeps. Two donkeys attached to these by harnesses or two men slowly walk the stones around the mortar as the olives are macerated. When the millers judge the olive pulp to be sufficiently broken down, the millstones are lifted out of the mortar and the pulp and exuded liquids extracted.[54] Modern millers learn to judge the quality of the paste by observing when large, black, shiny fragments of skin are no longer visible. With modern analogs of the *trapetum*, a normal load can be milled in 40–60 minutes.[55] The ancient *trapetum* will hardly have been as efficient as motor-driven mills of today, and ancient processors may have needed a finer paste in any case since, as previously mentioned, the ancients had no analog to modern malaxators which thoroughly break down the cell walls of mesocarp tissue to permit release of oil and initiate the process of oil-water separation. Perhaps we should think in terms of several hours for the pulping operation.

Though Varro[56] specifically equates the term 'olive mill' (*mola olearia*) with the *trapetum*, Columella's notice makes it clear that by his own time the two were distinct. Though none of the agronomists gives a description of the olive mill, the archaeological evidence is unambiguous; the developed olive mill was a large, shallow, flat-bottomed mortar from which a tall shaft projected around which pivoted a horizontal axle/sweep on opposite ends of which cylindrical millstones (as opposed to hemispherical or truncated hemispherical ones) were attached. The sweep projected beyond one or both of the millstones in the same way as that of the trapetum and doubtless for the same reason, namely for the application of force. The mill is known from sarcophagus reliefs and is still the standard form in many parts of the world [Fig. 19].[57]

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[54] Blümner, *Technologie und Terminologie der Gewerbe und Künste bei Griechen und Römern, vol. 1* (2nd ed., Leipzig, 1912): 339 and Fig. 119; 34 and n. 3.

[55] Frezzotti (1956): 47.

[56] *DRR* 1.55.5.

[57] White (1975): 228–9; Carandini II (1985): 26–27 and Figs. 31–35; Raphael Frankel, "The Trapetum and the Mola Olearia," in Amouretti and Brun (1993): 477–81. Frankel submits that Columella's term *mola olearia* is more likely the horizontal mill found at Volubilis in Morocco and in large numbers in the Guadalquivir Valley in southern Spain which closely resembles a "true mola", i.e., a grain mill (Frankel's Fig. 1, F) because this mill is more easily tentered per Columella's recommendation. Whether Frankel is right or no (and I find his argument unconvincing) he performs a valuable service in reminding us that there is no dichotomy

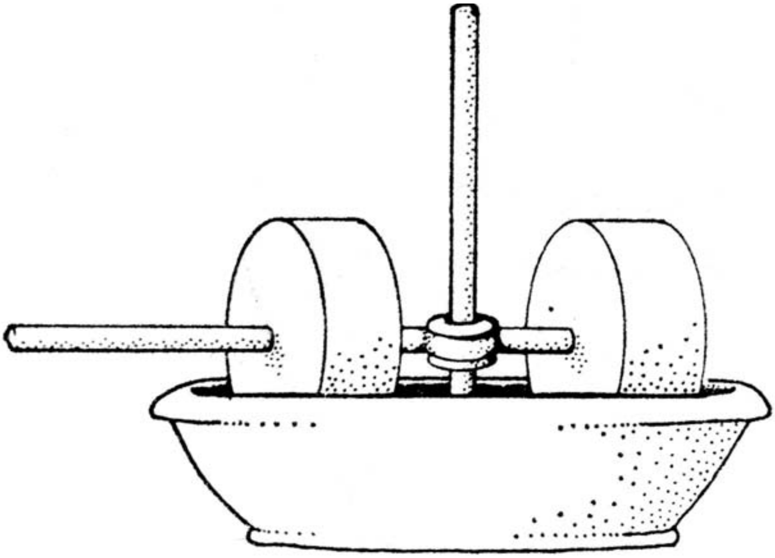

Fig. 19. The developed olive mill (*mola olearia*), in which the hemispherical millstones of the *trapetum* have been replaced with the more practical cylindrical millstones. The operation is essentially the same. (From White (1975): Fig. 58. Courtesy of Cambridge University Press).

But why the development? Columella is explicit here; he says that the mill can easily be raised or lowered to suit the size of the olive pit and thus prevent crushing of the kernel.[58] Surely of equal importance is the simple fact that the millstones need not have been cut so precisely to fit the mortar nor will wear have ever really made them less effective, since they could simply be lowered as they wore, unlike the hemispherical millstones of the trapetum.

Pressing

Again, Cato[59] gives us a marvelously detailed description of the presses where the next step occurs, the complete extraction of oil and *amurca*

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in pulping mills but a variety of styles, ranging from the 'true' *trapetum* with concave mortar and lenticular crushing stones to a concave mortar with discoid stones or stones with only the rims convex, to the round, flat-bottomed mortars with true cylindrical crushing stones.

[58] *DRR* 12.52.6.

[59] *Agr.* 3.5–6.

from solid tissue. From this description, from archaeological remains, and from modern reconstructions of the presses[60] as well as from comparative practice we can gain an excellent idea of the operation.

> For 120 iugera (80 acres/32 hectares) of olive orchards there should be 2 presses if the orchard is a good one, closely planted and well cared for. There should be good pulping mills (*trapeta*), one for each press, of slightly different size so that if the [larger] millstones become worn they can be changed from one mill to the other. Also, for each press, rawhide press ropes, 6 levers and 12 crosspieces, press-basket ropes of rawhide and 2 pulley-blocks [per beam] of the Greek style, worked with fiber ropes, the upper pulleys being 8 finger-breadths in diameter and the lower 6. You will raise the press beam faster if you are [only] willing to make pulleys; [with the blocks] it will be lifted more slowly but with less labor.

Many of the details of this description are conjectural (technical terms used to describe ancient equipment are notoriously slippery) but the general notion is clear. We have a *torcularium* with two *trapeta* for pulping the olives and two large lever presses nearby for pressing the resultant pulp. This of course implies that the previously mentioned 240-iugera orchard will have had 4 of each machine, though Cato has mentioned 5 of each; perhaps there is a spare of each in case one of the others breaks down at this critical juncture. The press beams, mortised into the masonry wall of the pressroom, are huge beams, up to 50' long (16 m), massively heavy (Forbes estimated over 1,550 lb or 525 kg)[61] so that their dead weight provides a significant portion of the pressure needed to completely extract the oil. Besides the simple niche, some press beams had as their fulcrum a pair of slotted piers across which was a heavy lintel. The advantage of the system is that wooden balks can be placed above and below the press beam so that it is more nearly level with the top of the press stack, in which position it develops the greatest force. As the press stack shrinks with the exudation of liquid, the press beam can be lifted and balks from below repositioned above and pressure reapplied. This procedure can be repeated several times as the press

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[60] Most notably that of Hörle, reproduced conveniently in Brehaut, Fig. 37. Cf. White (1975): 230. Frankel [1999): 61–137] has the best general discussion along with excellent illustrations.

[61] Cf. Brun in Tchernia and Brun (1999): 99, where the dead weight of the press beam of a reconstructed beam-and-winch press at Beaucaire, Provence, weighs c. 2 1/2 tons.

stack grows shorter.[62] In either case, the ends of the beams opposite the fulcrum, where maximum force is developed, are harnessed by ropes to windlasses by means of which the beams are drawn down with all the massive force which the windlass's mechnanical advantage permits.[63] Elsewhere[64] Cato describes a pressroom with four such presses (presumably for our 240-iugera orchard), two on opposite sides facing each other. Massive timber frames for the presses are built into the fabric of the walls and floor. Front posts carry crossbeams upon which are mounted the windlasses. The windlass may be turned with fixed handspakes, though Brehaut[65] thinks the six levers inventoried were used in working the windlass, presumably by inserting them into sockets in the windlass wheel. This sounds reasonable; such levers would have exponentially increased the torque developed by the windlass. The beam is so massive that it must be lifted mechanically as well. Thus a block-and-tackle arrangement is prescribed to facilitate lifting, rather than the simple pulleys which are faster but require far more force (A pulley, of course, offers no mechanical advantage but simply redirects motion, whereas multiple pulleys, that is, a block-and-tackle, create increasing mechanical advantage as the number of pulleys is multiplied).

Cato's beam press represents one permutation of this machine, albeit a standard one which is still used in many areas of the Mediterranean. But it is in fact one of four main types of presses which are attested, along with numerous permutations, namely the wedge press, the lever or beam press with a winch (Cato's type), the lever press with a screw, with or without a counterweight, and the screw press.[66] The wedge press is cited in no texts; in fact, we have only two paintings, one in the House of the Vetii at Pompeii and the other from Herculaneum. The paintings are so similar in style and content it is probable they are by the same artist. They

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[62] Drachmann (1932): Figs 40–41; Raphael Frankel, "Western Galilee: Oil Presses" in *Excavations and Surveys in Israel* 4 (1985): Fig. 2; idem, "Some Oil Presses from Western Galilee" *BASOR* 286 (1992): Fig. 7; idem, "Oil Presses in Western Galilee and Judaea: A Comparison," in Eitam and Heltzer (1996): 199 and Fig. 1; Mattingly (1988): 188–90; idem (1996): 229–30; Mattingly and Hitchner (1993): 439–41; Jean-Pierre Brun, "Pressoirs et Chais," in Tchernia and Brun (1999): 48–107 (especially good for the archaeology and iconography).

[63] Drachmann (1963): 110–15.

[64] *Agr.* 18.

[65] Brehaut, p. 9, n. 7.

[66] White (1975): Figs. 60–66.

depict two vertical spars solidly fixed in the earth over a stone press table with a depression to hold the olive pulp or herbs to be pressed and a spout to one side to conduct the liquid expressed to a receptacle. Above the mass to be pressed is a press board, a single plank in this case, and above this alternating tiers of conical wedges and additional planks, the uppermost of which is directly under a massive crossbeam between the two spars. Erotes are depicted on either side, driving in the wedges with sledge hammers and thus exerting increasing pressure on the mass. Pompeii was famous for its perfumeries, and perhaps the expression of essential oils from aromatic herbs is what is depicted here; we have no evidence that culinary olive oil was expressed in this way, but it is not improbable.[67]

At some unknown point a refinement was introduced to the conventional beam-and-winch press [Fig. 20A0–F3].[68] The disadvantage of the lever is that it is extremely difficult to exert a constant pressure using it unless a ratchet and pawl mechanism is built into the windlass. The screw is a simple machine which does not have this disadvantage and has considerable mechanical advantage as well. The screw itself dates to the generation of Archimedes (300 BCE) and by the time of Heron of Alexandria (first century CE) there were screwcutters available. The screw was introduced to Italy at the end of the first century BCE. At first the screw simply replaced the windlass to haul down the press beam [Fig. 20C2–D4]. The screw was fixed in the floor such that it could freely rotate. The end of the press beam was forked to straddle the screw and a fixed nut threaded on the screw placed over this fork. The screw was turned by handspakes and the nut forced the beam down.[69] Forbes cites a

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[67] Forbes III (1965): 144; Raymond Billiard, *La Vigne dans l'Antiquité* (Lyons, 1913): 444–45; D. J. Mattingly, "Paintings, Presses and Perfume Production at Pompeii," *Oxford Journal of Archaeology* 9,1 (1990): 71–90, who makes a convincing case that these wedge presses are to be associated with production of high-quality, low-viscosity olive oil for use as a base for perfumes and therefore to be connected with Heron of Alexandria's reference (Heron 2.4) to a "fourth power, the wedge, used in machines for perfumes." He also challenges the well known reconstruction of a direct-screw press from Pompeii (VII.4.24 = Mattingly's Fig. 11) and argues cogently that the entirely reconstructed supersturcture is wrong, the location, the orientation, the scanty remains of the original timbers all being better interpreted as elements of a wedge press.

[68] Mattingly (1988): 188–90; idem (1996): 229–30; Mattingly and Hitchner (1993): 439–41. For a Greek example, S. C. Bakhuizen, "Torcula Graecanica: A Note on the Archaeology of Olive and Grape Pressing," in M. Gnada, ed., *Stips Votiva: Papers Presented to C. M. Stibbe* (Amsterdam: Allard Pierson Museum, 1991): 1–6.

[69] Drachmann (1963): 115–26.

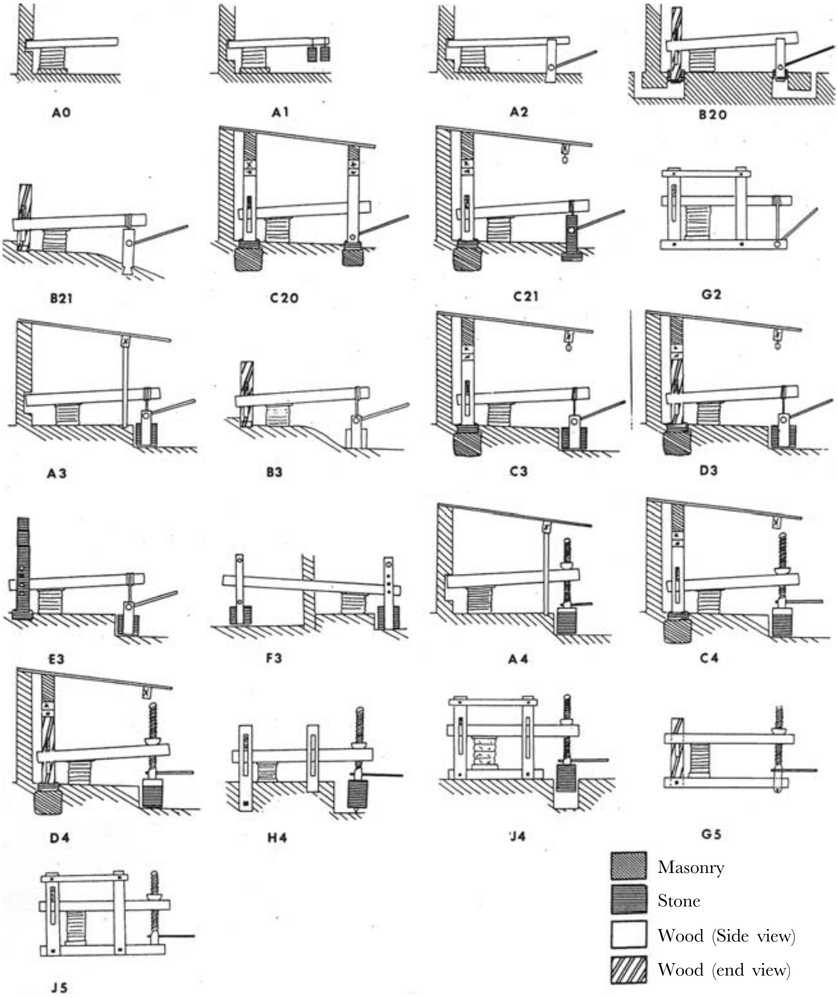

Fig. 20. Typology of Roman presses. A0: Lever press; A1: lever press with counterweight; A2–F3: Lever-and-capstan presses; A4–J5: lever-and-screw presses, with and without counterweights. (From Brun (1986): Fig. 28. Courtesy of CNRS Éditions).

modern example of this same device at Finis near Aosta. Alternately, the screw is used to draw up a stone weight or a chest filled with stones [Fig. 20H4–J4]. This latter device is described by Hero and is still used in many parts of the Mediterranean.[70] The advantage of this so-called lever and counterweight press is that once the weight has been lifted from the ground it will continue to exert constant pressure on the press stack as it shrinks, whereas the lever and winch press and the lever and screw press must be periodically ratcheted or screwed down as this happens.

Obviously this is simply a modificaion of a lever press, but true screw presses were also used by the ancients beginning from c. 50 CE, and are described by Heron and Pliny. In one type two screws at opposite ends of a short horizontal beam go through them and are dovetailed into a massive press bed. As the two screws are turned simultaneously the pressure increases on boards and frails. This appears to be a refinement of the wedge press. Alternately, one screw has a nut which is actually cut into a solid press beam, and both are fixed to the press bed by two stout uprights, after the fashion of the modern copying press. The press lid, *tympanum*, is drawn down by turning the screw, *cochlea*, which is forced downward by the fixed nut.[71]

The process using the standard, Catonian press will have gone thus: olive paste from the pulping mills is loaded into press baskets or frails [Fig. 21A], loosely woven of some organic material such as rush or esparto grass.[72] If Brehaut's conjecture is correct, they may have been reinforced with the "press-basket ropes" which Cato includes in his inventory. Beneath the press beam lies the press table itself. The press beam is mechanically raised and held in position by belaying the rope used to lift it; alternately, a wooden post is

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[70] Drachmann (1963): 126; Forbes III (1965): 142–43; Frankel (1999): 76. J. J. Rossiter and E. Haldenby ("A Winemaking Plant in Pompeii Insula II.5," *Echos du Monde Classique/Classical Views* 33, n.s. 8 [1989]: 229–39) have interpreted the physical evidence from a *torcularium* at Pompeii in light of a passage from Ulpian's *Digest* (19.2) as a combination beam-and-winch and beam-and-screw press, a sort of transitional apparatus.

[71] Drachmann (1963): 126–35; Forbes III (1965): 142–43.

[72] White (1975): 88–91. Frayn ([1979]: 135) explains Columella's curious phrase "sparto malleato" as a reference to an apparent practice of hammering Spanish esparto flat before weaving it into certain articles, but she makes no conjecture as to why Columella forbids the practice for olive frails. For modern practice, Kiritsakis (1990): 67; Di Giovacchino in Harwood and Aparicio (2000): 26–29. Esparto grass is still common for frails.

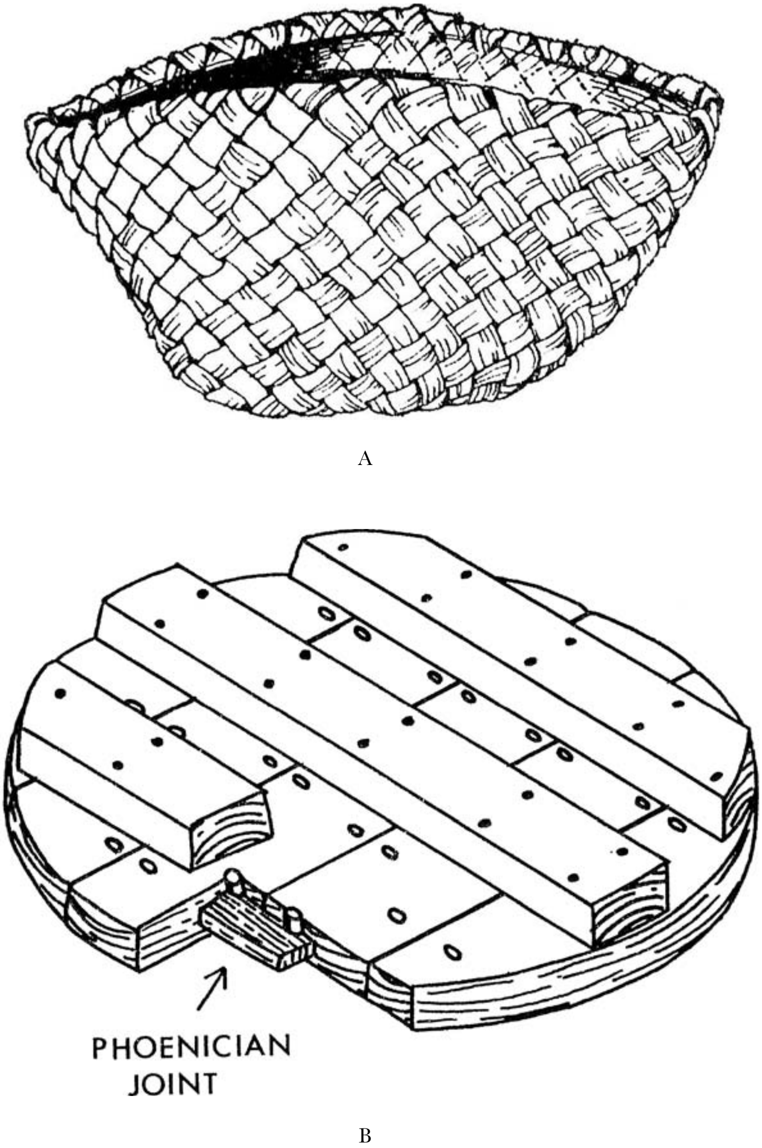

Fig. 21A. A Roman frail (*fiscus*) in which olives and grapes were placed to be pressed. Fig. 21B. A press board (*orbis*) as described by Cato, showing the Phoenician joints with their mortises and tenons. (22A from White (1975): Fig. 29. Courtesy of Cambridge University Press. 22B from Eitam and Heltzer (1966): Fig. 3. Courtesy of Sargon Press).

planted in the ground under the end of the beam, its upper end forked to receive the resting beam, as we see in a bas-relief from the Palazzo Rondanini at Rome.[73] Upon the press table the baskets are stacked, with circular press boards (*orbes*) [Fig. 21B] between each one. The size of the press baskets may be judged by Cato's prescription of press boards four feet in diameter and six fingers thick.[74] Heron describes an alternative to frails called the *galeagra*, which Drachmann[75] reconstructs from the garbled text of Heron as a lattice of half-lapped boards arranged on the press bed in a tic-tac-toe pattern, into the middle of which the olive paste is placed. On top of this is placed a square board which receives the direct pressure from the press (the technical term is 'follower'). A chock or series of chocks, smaller than the hole in the lattice so that the press beam can drive it toward the bottom of the lattice before the press beam strikes the lattice's side, is placed between this board and the press beam.

The press table is constructed within a *lacus* (vat) in such a way that exuded oil and *amurca* are trapped. The *lacus* is lined with terra cotta or lead. Cato astutely prohibits bronze or iron for this purpose;[76] not only do metals such as iron and copper impart their own taste to oil, but they also tend to react with lipids to promote

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[73] Brun in Tchernia and Brun (1999): 74 and Fig. 98.

[74] Cato *Agr.* 14.2; 18.9. At *Agr.* 18.9 Cato says of the press board, "Make it four feet across and six fingers thick, with side joints in the Punic style, and use in it evergreen oak dowels, and when you have fixed them tightly in place, fasten them in place with cornel-wood pins." Brehaut (p. 41, n. 24) explains "side joints in the Punic style" (*Punicanis coagmentis*) as "the ancient equivalent of the modern half-lap and tongue and groove." They are in fact, as we now know from the hull construction of ancient ships, butt joints fitted with mortises and tenons. Mortises are carefully aligned and cut along the length of abutting boards. Then rectangualr or tapering pieces of wood—essentially double tenons—are fitted into one board and the abutting board driven down over the opposite tenons projecting from it. The "dowels" to which Breahut refers (*subscudes iligneas*) are in fact these tenons. Holes are then drilled through both boards and tenons, into which cornel-wood treenails are driven. When these treenails are cut off flush with the surfaces of the boards, a very tight, durable joint is formed which can withstand tremendous force, witness the intact survival of such joints in ship hulls submerged for two millennia. The term "Punic style" doubtless refers to the famous incident during the First Punic War when Romans making a dramatic effort to construct a fleet *ab ovo* kidnaped Punic shipwrights and forced them to divulge their techniques. Cf. A. W. Sleeswyk, "Phoenician Joints, *coagmenta punicana*," *International Journal of Nautical Archaeology* 9 (1980): 243–44; Samuel R. Wolff, "Oleoculture in Phoenician North Africa," in Eitam and Heltzer (1996): 132–33 and Fig 3.

[75] Drachmann (1963): 126. For modern pressing (grapes in this case) using a reconstructed galeagra, cf. Brun in Tchernia and Brun (1999): 101–2.

[76] *Agr.* 66.

hydrolytic lipolysis and rancidity. Lead, on the other hand, is nonreactive, a fact the ancients had obviously discovered. Alternately, channels lead from beneath spouts at the front of the circular press beds to a common channel between two presses, and thence to settling tanks.

The actual pressing is effected by leverage. Several men, one assumes, lower the massive beam onto the stacked frails capped with a press board. The sheer weight of the beam causes oil and *amurca* to exude from the frails and to pool in the *lacus*. The pressmen then use pry bars inserted into notches at one or both ends of the windlass to wench the beam down until the virgin oil flows. As the first oil is exhausted, increasing pressure is exerted until the olive pulp has expressed the majority of its liquid component.[77]

During the pressing process maintaining cleanliness and purity are even more critical than in storage and pulping, since the oil is here most vulnerable to taints. Thus in speaking of the duties of the pressroom overseer Cato insists that he watch the contract pressmen closely to ensure that the work proceeds as cleanly as possible to avoid tainting. Presumably this also explains his injunction to restrict access to the pressroom and storeroom to the least possible number of persons.[78] The overseer must also ensure that the pressmen keep the presses clean and handle the olives properly. Cato's insistence that the overseer prevent the pressmen from cutting wood must refer to careful prohibition of the building of warming fires in the pressroom during this chilly season, the fumes from which would certainly taint the oil.[79] Columella advises that pressrooms and storerooms be kept warm since, if oil freezes as happens on rare occasions, it

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[77] Again, the fundamentals today are often remarkably similar, though the motive force is different. Most popular today is exudation via powerful centrifuges, but also popular is the hydraulic press, a piston contained within several columns which is forced upward by hydraulic pressure to press against an architrave above. The olive pulp is still typically placed in frails, often still of esparto grass or other natural fibers though nylon is popular as well. The frails are stacked between disks to form "cake towers' which are placed under the press. Alternately, the paste may be spread on absorbent fabric disks or diaphragms, often with a hole in the middle to be threaded over a central perforated tube on a portable cake tower. Materials in both cases must be fairly coarse, on the order of small rope, to allow the oil to exude freely. Press disks today are smaller than Cato's recommended 4', on the order of 1 1/2' to 3' (40–90 cm) in diameter. Cf. Frezzotti (1956): 59–65; Juan M. Martinez Moreno, "Oil Extraction," in Martinez Moreno (1975): 37–38.

[78] Cato, *Agr.* 66.

[79] Cato, *Agr.* 67.

becomes rancid; but he insists that the heat be natural (i.e., siting the pressroom and storeroom to take advantage of exposure to sunlight) since, in his opinion as well, smoke from fires will spoil the oil.[80] Columella also advises that superior oil and ordinary oil not be pressed in the same frails, since the used frails, soaked in oil and vegetal water, can also impart off flavors and aromas. Further, after each day's pressings the frails must be washed out immediately two or three times in very hot water, then submerged under running water or in a lake or pond of the purest available water (presumably this will prevent fermentation of the *amurca*), afterwards beaten with rods to remove dirt and lees, washed again, and dried.[81]

The agronomists are particularly chary with details of the second and third pressings, so our reconstruction is especially tenuous here. Obviously, how much residual oil there may have been left in the pomace from the first—what today would be called the virgin—pressing will have depended upon the efficiency of the presses and upon the standards the overseer demands in maintaining quality at the expense of quantity. Columella[82] compares the oil of the first pressing to *lixivium*, the free-flow grape must from the treading of the grapes. That might be taken to mean the free-flow oil from the *trapetum*, the pulping mill, which is the process analogous to the treading of grapes, were it not that Columella specifies that this oil "of far superior flavor" is instead pressed with minimal pressure. For comparison, today a single pressing operation is possible because of more efficient hydraulic pressure but it also produces oil of poorer quality, and therefore multiple pressings are still the norm. Today the first pressing, equivalent to first and second pressing in antiquity, represents about 85% of total yield and is superior in color, character, aroma, and acidity.[83] Doubtless in antiquity after the first pressing, however thorough it may have been, the press cakes, the compacted pomace left from the pressure of the presses, were removed from the frails and restructured in some way to permit release of more oil. Columella's analogy invites us to think of the hatchets which were used in winepressing to restructure the press cakes from that process. Before the second pressing is effected today the press

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[80] *DRR* 1.6.18.

[81] Columella *DRR* 12.52.22.

[82] *DRR* 12.52.11.

[83] Cf. Frezzotti (1956): 77–78.

cakes are often recrushed in the pulping mills.[84] I find no explicit evidence that this was done by the ancients, but such a procedure is not unlikely. We also hear of the soaking of press cakes in hot water, a procedure that would certainly increase yield but would simultaneously partially emulsify a portion of the oil and *amurca* and result in an oil of dramatically lower quality and stability. Something like this is effected today by the use of solvents, but the result is oil suitable for industrial use only. Surely this procedure will have been used in antiquity for a third pressing only, if at all. And there is some advantage in less than 100% extraction of oil; oil pomace with some residual oil may be used today as animal feed high in proteins and amino acids, but completely exhausted pomace is devoid of nutritive value and is considered a waste product suitable only as fuel.[85] In any case, our ancient pressmen will have repeated the steps of the first pressing twice more, reconstructing the cake between each pressing.

Concerning the capacity of these pressrooms Cato mentions 1,200 *modii* of olives,[86] and Brehaut reasonably suggests that this figure represents the daily capacity of the four presses of Cato's prototype 240-iugera orchard, given three pressings of 100 modii each per press.[87] Brehaut surmises that the product will have represented about 3 tons of oil given Pliny's formula of 3 Roman pounds per *modius*, and estimates that the oil will have filled 3 to 4 of the 100 *dolia* prescribed for the storeroom. Both are optimistic since they are based on the gross weight of the olives, not the final product. Assuming, perhaps optimistically, that the Roman presses will have been able to render 80% of the liquid components of the olives, 1,200 *modii* of raw olives should render about 720 *modii* of oily must, i.e., the oil/*amurca* admixture, 5,400 Roman pounds. But some of the *amurca* will have exuded in the receiving bins; furthermore, the *amurca* represents about

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[84] Frezzotti (1956): 80–82; Kiritsakis (1990): 80–85.

[85] Cesare Curola, "By-products," in Martinez Moreno (1975): 78–87.

[86] Cato, *Agr.* 144.5.

[87] Brehaut, *ad. loc.* n. 13. For attempts to estimate the capacity of presses in Roman North Africa, see R. B. Hitchner and David J. Mattingly, "Ancient Agriculture. Fruits of the Empire—the Production of Olive Oil in North Africa," *National Geographic Research and Exploration* 7,1 (1991): 36–55; Mattingly (1988): 177–95; idem, "The Olive Boom. Oil Surpluses, Wealth and Power in Roman Tripolitania," *Libyan Studies* 19 (1988): 21–4; idem, "Olea mediterranea?" *Journal of Roman Archaeology* 1 (1988): 153–61; idem, "Maximum Figures and Maximizing Strategies of Oil Production? Further Thoughts on the Processing Capacity of Roman Presses," in Amouretti and Brun (1993): 483–98.

twice the gross volume in the oily must of the pressings as the oil. One *dolium* of oil per press per day is therefore probably more realistic, not to speak of more practical for racking purposes. Varro clarifies (?) in this way:[88] "... *hostus* is the name given to the oil yield from one *factus* ('making'), that is, the amount of unprocessed olives processed at one time. Some give this as 160 *modii*, others only 120 *modii*, depending upon the size and number of presses used."

Separation of Oil

Both Cato and Columella give us good descriptions of the storeroom or oil cellar (*cella olearia*), [cf. Fig. 22] and we have excellent archaeological evidence as well. Its most prominent feature is undoubtedly the three rows of *dolia*, the huge terra-cotta vessels of some 125–200 gallons (475–750 L) capacity along a long wall of the storeroom and destined to receive the three pressings in succession.[89] Cato's list of equipment for the cellar includes 100 of these storage jars as well as lids for them, 14 oil vats, 2 large seashells and 2 small ones (for racking, that is, decanting the oil), 3 bronze skimming ladles, 2 amphorae for oil, 1 water pitcher, 1 half-amphora measure holding 50 (?), 1 sextarius for oil, 1 small vat, 2 funnels, 2 sponges, 2 earthenware pitchers, 2 jars of 1/2 amphora each, 2 wooden skimming ladles, 2 sets of bars and keys, 1 set of scales, a 100-pound and other (smaller) weights. The *cella olearia*, like the *cella vinaria*, is to be located in proximity to the pressroom for convenience and should be sited facing north and as far from kitchens, baths and other sources of foul odors as possible. Since smoke and soot are deleterious to the oil's aroma, Columella suggests that both press room and oil cellar be built in the lee of the wind so that furnaces will be least necessary to warm the rooms. In this storeroom are effected two separate processes, though in effect they overlap: separation of oil and amurca, and clarification and conditioning of oil. The liquid obtained from pressing is not olive oil; it is an oleaginous liquid consisting of oil, water, and solids from pulp tissue. Perhaps the most

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[88] *DRR* 1.24.3.

[89] Cato, *Agr.* 13.2; Columella *DRR* 12.52.11. For the role of the storeroom in general in ancient subsistence farming, Hamish Forbes and Lin Foxhall, "Ethnoarchaeology and Storage in the Ancient Mediterranean: Beyond Risk and Survival," in Wilkins, Harvey and Dobson (1995): 69–86.

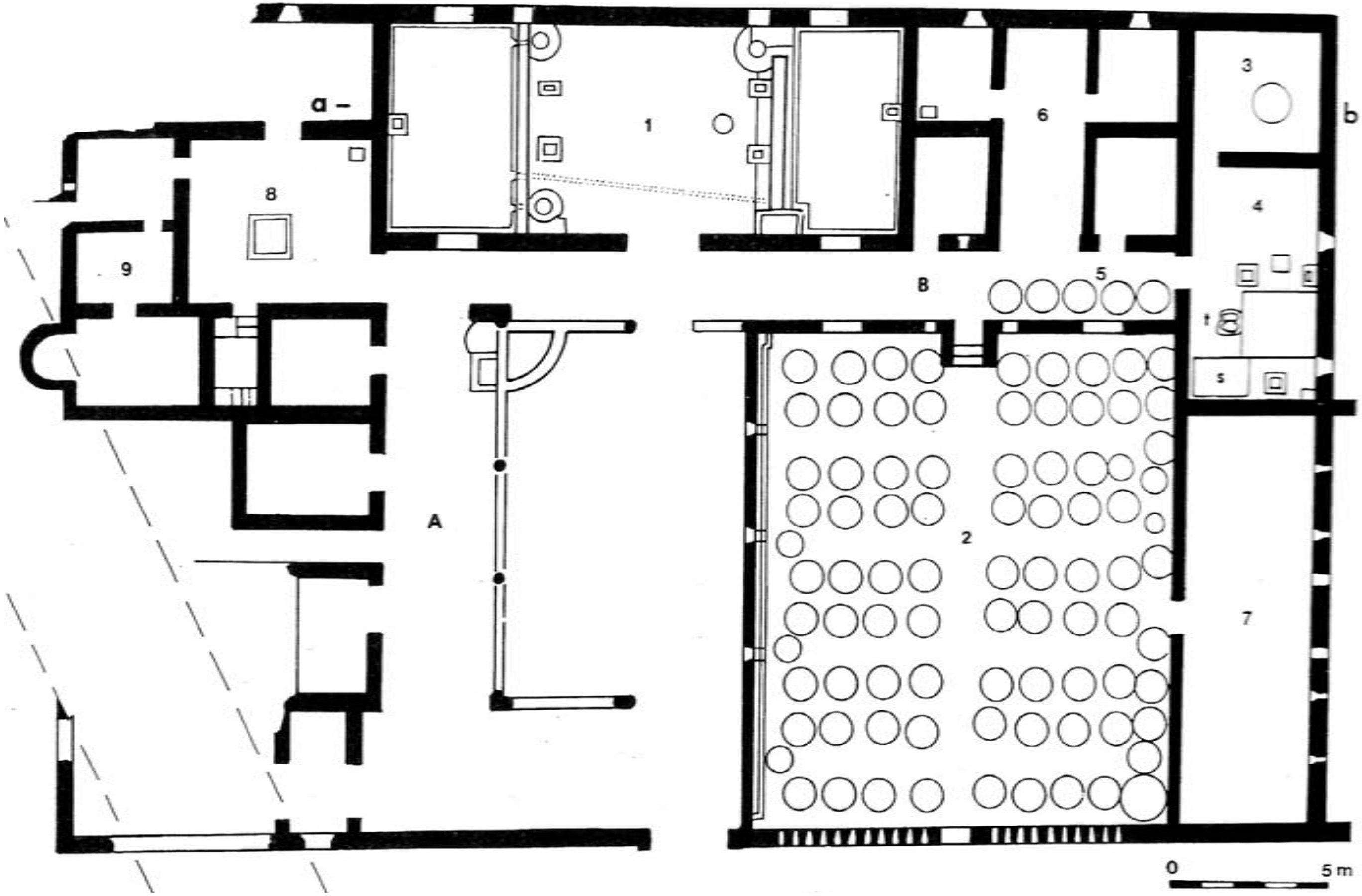

Fig. 22. Plan of the villa rustica of the Villa della Pisanella at Boscoreale showing wine presses (1), wine cellar (2), oil mill (3) and oil presses (4), oil cellar (5), slave quarters (6) and granary (7). (After Pasqui, 1897).

critical step in the production of excellent olive oil is the rapid and complete separation (via decanting or racking) of the aqueous element, the *amurca*, called today the 'black water', from the oil and solids, since vegetal water, as we have seen, begins to ferment almost immediately and will quickly ruin the flavor of oil. Secondly, the solids suspended in the oil must be allowed to precipitate so that the oil becomes clarified, though speed here is not so critical.[90] The simplest method to effect the first step and the one used exclusively by the ancients relies on the unequal densities of oil and water, i.e., the fact that "oil and water don't mix." Oil is considerably less dense than water and quickly collects at the top of a mixture of the two, as anyone who has mixed a vinaigrette will know. The oil may then be simply decanted (racked) from the top of the mixture or, alternately, the water drained from the bottom, to another vessel where further separation can proceed. In places where traditional methods are used today it is recommended that the oil be racked from black water after no more than eight hours to prevent a decline in quality, and racked a second time after 24 hours.[91] The ancients were well aware of this critical time factor. Cato[92] recommends that the racking begin as soon as possible after the oil from the press tables has been drained into the lacus; in fact, a leaden basin (*cortinam plumbeam*) is actually placed in the *lacus* and an attendant uses a shell (the traditional 'scoop' for this process) to take up the oil, being careful not to take up any *amurca*, and transfers it to the leaden vat; then (presumably after a brief period when oil and *amurca* are again allowed to separate) the attendant transfers the oil to a second receptacle, in this case a *dolium*.[93] As the oil is skimmed the *amurca* is drained from the *lacus* and the leaden vat into separate storage vessels, for this *amurca*, so harmful to the oil, is a valuable commodity in antiquity, used by them as everything from insect repellent to furniture polish. Ironically, today the foul-smelling black water is considered a nuisance and a possible pollutant, though experiments have

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[90] Cf. Frezzotti (1956): 72, 87–90; Enrique Muñoz Aranda, "Decanting," in Martinez Moreno (1975): 49–50.

[91] Muñoz Aranda in Martinez Moreno (1975): 49–50.

[92] *Agr.* 66.

[93] Readers should be aware that many translators, using the analogy of winemaking, call the vegetal water, that is *amurca*, lees, which it manifestly is not. The lees refer to the solid precipitate of both oil and wine clarification; there simply is no analogue to *amurca* in vintaging, and the use of the term 'lees' for this component is deplorable.

been done using it as a culture medium for yeasts, as an antibiotic, and as fertilizer.[94]

Thus far, Cato; a villa at Stabiae has an interesting refinement, a system for channeling oil from the press bed to an embedded dolium in the pressroom floor, but more typically the archaeological evidence suggests it was channeled into a sunken rectangular reservoir (e.g., at Posta Crusta, Foggia; Vicovaro, Room G, Lazio; Monte Canino, Ager Capenas; and Scalea, Calabria).[95] This tank effected the first separation of oil and amurca, which could then be racked from one smaller container to another. At Camerelle, Castrovillari, and at Pareti, Buccino, dolia were found within the collection tanks beside the presses, perhaps as a substitute for Cato's leaden vessel. Walls of these tanks are typically lined with concrete, and less often the floors, understandably, thinks Rossiter, since *amurca* collected here is used elsewhere to 'proof' the storage jars, as we will see. Sometimes there is a second tank next to the collection tank or a partition in the same tank (perhaps Columella's *structile gemellar* at 12.52.10). The purpose is obvious: oil and amurca separate in one tank and the oil is ladled to the other where it settles again. Meanwhile the *amurca* is decanted from the first tank, which is then cleaned. Existing tanks of this sort date from the second half of the first century BCE at the latest, and may be a recent innovation Columella felt obligated to describe.

About this same time a truly momentous innovation appears. Coarseware ceramic tubs have been found in many ancient sites; these have spouts at their bases, positioned over holes in the floors of pressrooms leading to drains. Obviously the spout was plugged until oil and water separated, then the plug removed and vegetal water drained away leaving the pure oil.[96] But these tubs have insufficient capacity for even moderate-scale production. Thus, at a number of villa farms there are series of tanks fitted with outlet pipes or sluices leading from one settling tank to another. At Granaraccio, Ager Tiburtinus, the outlet is near the bottom of the tank, obviously to drain away the heavier *amurca*, exactly as is done today. This

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[94] Carola in Martinez Moreno (1975): pp. 78–87.

[95] Rossiter [(1981): 356–58] has produced an excellent compendium of the archaeological evidence, as well as a complete bibliography (Appendix B, p. 361).

[96] Forbes and Foxhall (1978): 46 and Figs 17–18. For the use of byproducts of olive pressing, including amurca, see Marie-Claire Amouretti, "Les sous-produits de la fabrication de l'huile et du vin," in Amouretti and Brun (1993): 464–7.

obviates the necessity of aerating the oil in racking, a practice which promotes oxidative rancidity. How widespread this innovation may have been it is impossible to say at this point. But at a number of sites the laborious task of ladling oil from settling tanks to storage jars is facilitated by small platforms or flights of steps inside the settling tanks.

The traditional racking procedure prescribed by Cato and Columella compensates in thoroughness for anything it lacks in technical sophistication; along the floor of the cellar are our three rows of dolia, each row consisting of some 30 of these massive containers. Excavations reveal that these jars were not commonly embedded in the earth as were those for wine, since strict temperature control for oil is not as critical as for wine.[97] The first row receives the highest-quality first pressing of each day, the middle the ordinary oil of the second pressing, and the third the 'commercial-grade' oil of the third pressing. When these respective oils have stood in the first dolia on each row "a little while" (unfortunately Columella is no more specific) the oil handler uses his ladle to rack it from the *amurca* and lees into the adjacent *dolia* in each respective row, where it is allowed to separate and precipitate again until the procedure is repeated.[98] Simultaneously the *dolia* are emptied of amurca and solids and thoroughly scrubbed and dried to receive the pressings of succeeding days and rackings. Columella[99] tells us that this cleaning of storage vessels during and after the processing of oil is the responsibility of the bailiff's wife. Cato is somewhat more specific about the timing of each racking:[100] "If possible, rack the oil twice a day, for the longer the oil stands on its *amurca* and with the fragments of pulp in it, the worse it will be." Columella adds that "the more the oil is aerated in being racked . . . the clearer it becomes and the more the lees are separated." Partially true; true enough that frequent rackings promote clarity, but Columella's use of the term 'aerated' is most unfortunate if deliberate (and I suspect it is, since the purifying effect of air is a commonplace in Greek and Roman rational medicine), since aeration actually promotes oxidation and thus rancidity in oils.[101]

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[97] Rossiter (1981): 359.

[98] Columella, *DRR* 12.52.11.

[99] *DRR* 12.52.16.

[100] *Agr.* 64.2.

[101] Cf. Frezzotti, pp. (1956): 87–90. For comparison, in traditional modern racking,

Clarification

After the oil has been racked for the last time it is also stored in the *dolia*. Ninety *dolia* represent a potential volume of some 28,000 gallons (107,912 L) of oil from a single orchard, quite an impressive number. The *dolia* themselves had to be carefully treated to reduce porosity and therefore prevent oxidation. Cato[102] recommends that new *dolia* be treated in a rather ingenious way. They are to be kept filled with *amurca* for seven days, topped up each day to maintain fullness. Afterwards the *amurca* is drained and the vessels dried. The day before the *amurca* is drained, gum arabic is soaked in water for a day, then diluted. Gum arabic, obtained from the sap of a North African tree, *Acacia senegal*, dissolves easily in water but forms an impervious, mucilaginous barrier when dry. The vessels are heated over a slow fire till moderately warm (i.e., not as hot as for pitching wine vessels) to open the pores of the clay body, then the gum is poured in and rubbed into the pores of the internal wall of the vessels. Cato recommends four pounds of gum for each "50-quadrantal vessel," i.e., dolium. The use of *amurca* here might seem suspicious, given its deleterious effect on oil, but in fact it is but one more example of the ancients' ingenious use of this product. The *amurca* will have saturated the clay body of the unglazed terra cotta and will have left its residue when dry, a residue which must have been effective in repelling vermin and doubtless contained enough residual oil to provide a sort of 'primer' for the sealant. The gum arabic will then have provided an impervious barrier, not only to outside air, but to the tainting odors and bitterness of the *amurca* as well. Gum arabic is obviously used here in preference to the more

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the oil is typically racked first at 1 to 3 days, a second time 2–3 days later, and a third 5–6 days after this, but this is after the oil and lees have been separated from the amurca, usually by a rapid centrifugation. The lees themselves are re-pressed to extract any residual oil, sometimes combined with the press cake. Oil is not necessarily clarified only after it is completely limpid, though the reverse is true; opaque oil of an amber color may be clarified, i.e., free of lees in suspension. In fact, high-grade oils with super-low acidity may be opaque, though technically clarified, for months, whereas poor-grade oils of high acidity tend to become limpid (and also clarified) far more quickly. Indeed, a slight opacity in freshly processed oil is one indicator of high quality.

[102] *Agr.* 69.

common pitch because it is less volatile and does not impart the resinous flavor and odor of pitch to the oil.

After the oil has been clarified it is capped and sealed and stored until the oil merchant comes to negotiate for it, or to claim it if he has previously contracted for it. But the conscientious vilicus' concerns are not quite over; even in the sunny Mediterranean on Cato's prototype Campanian orchard there are sudden cold spells in January after the oil is pressed. Once the oil has been capped for storage, with the lids prescribed in Cato's catalog of equipment, and the rims have been plastered to effect air-tight seals, the storeroom can safely be warmed with fires. But Columella[103] adduces a worrisome scenario: if the oil freezes in cold weather on its lees (i.e., before clarification is complete and the vessels are sealed), toasted salt must be added to melt it and thus prevent putrefaction. Hydrolytic rancidity of oils and fats may be pronounced in olives subjected to freeze injury, either before or after harvest.[104] Salt, of course, will have lowered the freezing point of the oil by raising its density. On the other hand, salt is a proagent in oxidative rancidity;[105] our vilicus is between a rock and a very hard place. Thus in hard freezes *nitrum*, i.e., natron (sodium carbonate) is baked and pulverized and mixed with the oil. Natron is, of course, another salt; one wonders if the ancients had discovered that it produced less pronounced oxidative rancidity. As a footnote, cool but not freezing temperatures are not deleterious to oil quality and in fact have both a preservative and clarifying effect (i.e., help the oil to 'fall bright'). In modern storage facilities oil is kept in depots out of direct sunlight where a temperature of c. 58°F (14–15°C) is considered ideal. Provided containers are tightly sealed, light and air in the storage depot are not harmful.[106]

How the oil *negociant* may have operated we are not told by the agronomists, but no doubt he sampled the oil and rated it empirically and doubtless also kept his eyes and ears attuned to learn the degree of care taken by the villa in harvesting and processing the

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[103] *DRR* 12.52.12–16.

[104] M. A. Joslyn, "Enzymes in Food Processing," in Heid and Joslyn (1967): 255.

[105] John T. R. Nickerson, "Preservatives and Antioxidants," in Heid and Joslyn (1967): 32.

[106] Cf. Frezzotti (1956): 89; and Angelo Cucirachi, "Final Operations," in Martinez Moreno (1975): 60–70.

crop. Even today in the analysis of oil quality it is the empirical analysis of so-called organoleptic (sensory) elements of color, odor and taste, the oil's *frutado*, that prevail over the chemical analyses unavailable to the ancients. Today trained tasters are always used to classify both raw fruit and finished oils.[107]

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[107] Cucirachi (1975): 60–70. For analytical methods, Maria Teresa Morales and Maria Tsimidou, "The Role of Volatile Compounds and Polyphenols in Olive Oil Sensory Quality," in Harwood and Aparicio (2000): 393–458.

CHAPTER THREE

WINE

About the processing of the third element of the Mediterranean Triad, namely the grape, we are in the fortunate position of having a relative abundance of information. This is so for a number of reasons, not least the fact that viticulture became such a prominent part of Roman agribusiness (villa farming), not only in Italy but in the western provinces and North Africa as well. Cato, Varro, Pliny, Columella, and other agronomists are at pains to describe in some detail the business of vinification and inevitably we are told in the process much about the technology as well. Once again it is clear that the grittiest work of the vintage was done by contract labor, but minute details of such things as the modification of wines to produce a more marketable product make it clear that refinements of the process were very much under the purview of the vigneron and his bailiff. Then, too, it was Roman agronomists who introduced commercial viticulture to much of Europe, most notably to Gaul, modern France, and there is a continuous tradition of methods which leads right back to Cato.[1] Thirdly, in addition to being staple food—and it is critical that we come to appreciate products of alcoholic fermentation as the vital foods they are in preindustrial societies—wine has always been at the heart of classical social institutions, from dining to religion. One can scarcely read a classical author without happening upon incidental references to the role of wine in these institutions. Moreover, by its nature viticulture leaves

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[1] For the transmission of viticulture and viniculture to France, cf. Jean-Pierre Brun and Fanette Laubenheimer, edd., "La viticulture en Gaule," *Gallia* 58 (2001): 1–260; Germany: Karl-Josef Gilles, "Römischer Weinbau an Mosel und Rhein," in Peter Herz and Gerhard Waldherr, edd., *Landwirtschaft im Imperium Romanum* (St. Katharinen: Scripta Mercaturae Verlag, 2001 [= *Pharos: Studien zur griechisch-römischen Antike* 14]): 57–76; Britain: A. G. Brown, I. Meadows, S.D. Turner and D. J. Mattingly, "Roman Vineyards in Britain: Stratigraphic and Palynological Data from Wollaston in the Nene Valley, England," *Antiquity* 75, No. 290 (2001): 745–57; Roman Egypt: Clotilde Ricci, *La coltura della vite e la fabbricazione del vino nell'Egitto greco-romano* (Milan: Cisalpine-Goliardica, 1924); Kai Ruffing, "Wein und Weinbau im römischen Ägypten (1.–3. Jh. n. Chr.)" in Herz and Waldherr (2001): 57–72.

significant physical remains, more and more of which are accessible to the archaeologist. We might mention by way of example the impressive hill in the environs of Rome today called Monte Testaccio, 'Clay-Pot Hill', a mound some 160 feet high composed of discarded terra cotta vessels, prominent among them millions of wine amphorae, many of them bearing tags or impressions with details of the wine's character and provenience. And we are now in the happy position of having excavation reports from a number of Italian and provincial villa farms which incorporate vineyards, press rooms and wine cellars.

Finally, the mystique of vinification has always exercised a grip on the human imagination quite nonpareil, and modern researchers are as fascinated as were their ancient counterparts. More's the pity, then, that the most detailed study of Italian viticulture, that of Raymond Billiard,[2] is now over 90 years old and rather dated.

As they were for most of their food processes, the Romans were debtors for their expertise in viticulture to a long succession of predecessors.[3] The grape thrives in regions with warm-to-hot, dry summers but dies at winter temperatures below 0°F (−18°C), and thus thrives in the Mediterranean. *Vitis vinifera sylvestris*, the wild ancestor of the species of grape responsible for most of the world's ancient and modern wine production, *V. vinifera*, is thought to have originated in central Anatolia. There is still no proof that Paleolithic man knew 'wine' (spontaneously fermented grape juice) though it is not unlikely that he did. Recent evidence suggests that actual viniculture began in the upland Transcaucasia (modern Georgia, Armenia and Azerbaijan) during the Neolithic. Residue in distinctive jars from Godin Tepe, in the middle Zagros Mountains of Western Iran and dating to c. 3100–2900 BCE, were analyzed using the latest analytical tools which showed the presence of tartaric acid and calcium tartrate, indicative of grape juice, either as such or as wine or vinegar. But the distinctive form of the jars, with narrow necks and clay

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[2] Raymond Billiard, *La Vigne dans l'Antiquité* (Lyon: H. Lardanchet, 1913), now partially superseded by André Tchernia and Jean-Pierre Brun, *Le vin romain antique* (Grenoble: Glénat, 1999).

[3] Daniel Zohary, "The Domestication of the Grapevine *Vitis vinifera* L. in the Near East" in Patrick E. McGovern, Stuart J. Fleming and Solomon H. Katz, edd., *The Origins and Ancient History of Wine* (Amsterdam: Gordon and Breach, 1995): 23–30; H. P. Olmo, "The Origin and Domestication of the Vinifera Grape," in McGovern, Fleming and Katz (1995): 31–43.

stoppers to minimize exposure to air, as well as the presence of tree resin, specifically from terebinth trees, as an antioxidant, as well as the archaeological context in which the jars were found, collectively leave little doubt that the jars held wine. Jars from Haji Firuz Tepe in the northern Zagros Mountains dating to c. 5400–5000 BCE were subjected to liquid chromatography and were found to have contained resinated wine as well.[4] The fact that the words for wine in Ugaritic, Hebrew, Greek, and Cypro-Syllabic derive from Hittite **wiyanas* strongly suggests that viniculture (making of wine) and viticulture (growing of wine grapes) were mediated to Levantine cultures by the Hittites.[5]

We know quite well that viticulture had reached the Aegean area in the early Bronze Age, perhaps directly from Crete and ultimately from Syria and Egypt. Certainly wine was already a staple food there by Homeric times. By the seventh century BCE, Greek wines were being exported as far as the Rhone valley in Gaul by way of the Greek *entrepot* Massilia, modern Marseilles. By the fifth century BCE viticulture itself was practiced in Greek colonial areas such as Sicily and southern and central Italy. The Romans apparently learned the new art from the Etruscans, and by the mid-third century BCE viticulture on a commercial scale is well attested in Roman territory. After the Punic Wars and with the beginnings of large-scale importation of wheat to feed the growing urban masses, expansion of viticulture in Italy was very nearly explosive, and expansion scarcely paused as Rome extended her hegemony to all parts of Europe and North Africa.

Biochemistry

The reasons for the enormous success of wine as food are perhaps self-evident, but they bear repeating. Wine is a remarkably stable liquid with enormous food potential. In addition it has pleasant psychotropic qualities when drunk in moderation, has significant bacteriostatic and bactericidal powers as a medicament, and can itself

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[4] Patrick E. McGovern, *Ancient Wine: The Search for the Origins of Viniculture* (Princeton: Princeton U.P., 2003): 1–84. This is the best source for the prehistory of wine, with particular emphasis on molecular archaeological evidence.

[5] Frankel (1999): 35.

be used in its natural state and after modifications as a preservative for other foods.

Wine is the product of the alcoholic fermentation of grape juice by yeasts, most notably by *Saccharomyces cerevisia*e (formerly *S. cerevisiae* var. *ellipsoideus* and *S. uvae*). This fermentation is defined as "enzyme-catalysed reactions, by which molecules, usually sugars, are broken down without the aid of oxygen or oxidized inorganic molecules."[6] Wine fermentation is thus the same chemical process as that of beer and breads. Fermentation proceeds, with the simultaneous production of CO_2, until available sugars are exhausted or ethyl alcohol concentration reaches 14%, at which point yeast cells are rendered inactive by their own waste product. These yeasts are simple, single-cell fungi which typically reproduce by a process called budding and can thereby colonize with spectacular speed in an aerobic environment. Yeast cells thrive on sugars, and an enzyme in the yeast cells called zymase metabolizes sugars such as glucose, dextrose, maltose, and/or sucrose into ethanol (ethyl alcohol) and CO_2.[7] Significantly, the reproduction of the yeast of alcoholic fermentation is so explosive that the growth of other, pathogenic, organisms during fermentation is severely inhibited; in other words, yeasts simply overgrow other microflora. Additionally, many yeasts are capable of producing biocins, natural toxins that kill competing organisms. Further, alcohol and other fermentation byproducts, especially phenols, are all bacteriostatic.

Wine is important nutritionally almost exclusively as a source of carbohydrates, though it contains trace amounts of vitamins C and B. The critical role of carbohydrates in preindustrial diets has been previously discussed. The medical benefits of wine's many other constituents such as the phenols alluded to above are only now even beginning to be appreciated, much less understood. In that regard, despite their obvious ignorance of causation, the ancients were far ahead of us. With due caution for the hazards of the effort, Tchernia[8] has made an attempt to estimate the average consumption of wine in Rome. His estimate of some 27 oz (.8 L) per adult per day is

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[6] Muller and Tobin (1980): 178.

[7] Gaman and Sherrington (1977): 223–25.

[8] André Tchernia, *Le Vin de L'Italie romaine. Essai d'Histoire économique d'après les amphores* (Rome: École française de Rome, 1986 [= *Bibliothèque des Écoles françaises d'athènes et de Rome* 261]): 41–56.

consonant with comparative studies from the fourteenth to eighteenth centuries. This amount would deliver some 550–700 calories. It is interesting to note that a man of average weight can metabolize about 117 g of ethanol per day, regardless of physical activity or other foods consumed, and this is the amount of alcohol delivered by just over one liter of wine of a concentration of 10% alcohol.[9] Thus, if Tchernia's estimate is even close, his hypothetical Roman adult is consuming close to the maximum amount of wine he can effectively utilize as an energy source. Additionally, it has been experimentally demonstrated that wine mixed with contaminated water will quickly destroy typhoid and other pathogens.[10] Since Romans habitually mixed wine with water, usually in a 1:3 to a 1:1 ratio, this is no small consideration.

The physical properties of grapes are very similar to those of olives, and therefore the physical processes utilized on them are remarkably similar. Specifically, the grape is a berry composed of an epicarp, the skin; a mesocarp, the pulp; and an endocarp, in this case seeds or pips. And as with olives, the mesocarp is the primary focus of the processor, skin and pips only secondarily. Thus the processes used in separating the physical components of the grape are very similar and often identical to those for the olive. The physical processes are in fact so similar that it is notoriously difficult to type agricultural installations for wine or olive oil production, particularly in the incomplete archaeological contexts we usually encounter.[11]

Chemically, however, the grape is quite different from the olive, containing essentially no fats; it is the aqueous part of the pulp which provides the nutritive value. This grape juice, or must, is composed of 70–85% water, 15–25% carbohydrates in the form of sugars, plus various trace elements such as organic acids, phenolic compounds, nitrogen compounds, carbonyl compounds, and inorganic salts derived from the soil.[12] Grape sugars may be preserved in two ways:

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[9] R. Passmore, "The Energy Value of Alcohol," in C. F. Gastineau, W. J. Darby and T. B. Turner, edd., *Fermented Food Beverages in Nutrition* (New York: Academic Press, 1979): 221.

[10] Vernon L. Singleton, "An Enologist's Commentary on Ancient Wines," in McGovern, Fleming and Katz (1996): 75.

[11] Jean-Pierre Brun, "L'Oléiculture et la viticulture antiques en Gaules: Instruments et installations de production," in Amouretti and Brun (1993): 307–41.

[12] A more detailed account of the chemical components of must and wine and their effects will be found conveniently in Philip Jackisch, *Modern Winemaking* (Ithaca: Cornell U. Press, 1985): 40–60.

by concentration to increase the density of the solution, and by alcoholic fermentation. The Romans used both extensively, though the product of the former process was used as a condiment and preservative and thus will be treated in a later chapter. The product of the latter process is, of course, wine.

Wine in a broader sense can be made from any number of natural products containing sugars, and frequently was in other parts of the ancient world. But the ripened fruit of *vitis vinifera* has an extremely high sugar content (ripe wine grapes are so sweet when eaten that they are cloying to the taste), and the 'bloom' of the wineskin, its grayish, powdery coating, is composed in part of colonies of yeasts of the *Saccharomyces* genus and others, and thus when the skin of the grape is broken a spontaneous fermentation will quickly begin. The grape, in short, is the ideal fruit for alcoholic fermentation.[13]

Processing of grapes can thus be conveniently divided into physical and chemical processes. Physical processes include picking, pulping—in this case by treading—and pressing. Chemical processes are fermentation, clarification, and aging, during the latter two of which the product, now wine, may be modified both physically and chemically.[14]

Harvest

Obviously, successful fermentation depends upon adequate sugar concentration which depends in turn upon harvest of the grapes at peak ripeness. In addition to numerous 'rules of thumb' to gauge the ripeness of the berries, Pliny[15] indicates the empirical nature of the process: harvest "when the grape shoot droops down to the stem" or "when, after removal of a grape from the cluster, it leaves a gap." Columella, Palladius and Deiophanes[16] all give the sensible advice to taste the grapes for sweetness, but taste is subjective. Others rec-

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[13] Modern winemakers leave nothing to chance, of course; indigenous yeasts in the musts are killed and carefully selected strains of *S. cerevisiae* are introduced to influence the character of the final product. Such yeast culture is strictly a product of Pasteur's modern research. It is interesting to note a recent trend back to spontaneous fermentation among a small group of artisinal winemakers, on the theory that indigenous yeast strains add subtle flavors which simply cannot be reproduced in the laboratory.

[14] Cf. Curtis (2001): 372–80.

[15] *NH* 18.74–75.

[16] Columella, *DRR* 11.2; Palladius 10.11; Deiophanes in *Geop.* 5.45.

ommend judging by color. To all of these factors should doubtless be added the exigencies of weather, availability of contract labor, presence or absence of molds, etc. [17]

The vintage in ancient Italy normally occurred around August in the north and mid-October in the south, though it could be prolonged in southern regions until mid-November. Billiard[18] laments the fact that so many ancient authorities advise harvest when grapes are dead ripe, a "deplorable practice" by modern standards since at this point much of the acid content of the grape so necessary for a balanced product is gone, a fact which necessitated the rather alarming degree of modification suggested by ancient geoponics as compensation. But in the absence of pure cultured strains of wine yeast, all organoleptic considerations give way to the singular necessity of promoting a rapid colonization of wine yeasts to the exclusion of all others and the need to achieve alcohol level sufficient to inhibit secondary fermentations. To put it bluntly, sulfur dioxide and cultured yeast strains have given us moderns the luxury of criticizing ancient viticultural practices.[19] On the other hand, Tchernia[20] thinks there was a gradual shift in the Empire from taste for sweet wines to drier ones, reflected in a tendency to advance the date of harvesting.

Modern vintners know that berries are best gathered on a dry day because they readily absorb water which dilutes their sugar concentration and flavors.[21] Likewise the ancient geoponics advise that the harvest (*vindemia*) should not be conducted too early in the morning, to avoid dew on the fruit. But in this Mediterranean context, our vintner is advised to avoid midday hours as well, when the grapes are too hot.[22] Billiard[23] notes that this would be a serious problem because excessive heat will have impeded the spontaneous fermentation our ancient wine maker relied upon.

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[17] For comparative modern methods, cf. M. A. Amerine, et al., *The Technology of Winemaking (4th ed.)* (Westport, CT: AVI Pub. Co., 1980): 77–91.

[18] Billiard (1913): 428–30.

[19] On the difficulties of preserving wines vinified using ancient techniques at an experimental *cella vinaria*, cf. André Tchernia, "La vinification au début de notre ère et le goût des vins romains," in Tchernia and Brun (1999): 118–9.

[20] André Tchernia, "Le vignoble italien du 1$^{\text{er}}$ siècle avant notre ére au III$^{\text{e}}$ siècle de notre ère: répartition et évolution," in Amouretti and Brun (1993): 286.

[21] Rodney Boothroyd, *Home Winemaking: Techniques and Recipes* (New York: Schocken, 1986): p. 33.

[22] Cato, *Agr.* 25; Pliny, *NH* 18.74.

[23] Billiard (1913): 430–33.

Today grapes are harvested by hand with knives or shears or (increasingly) with mechanical harvesters. In manual harvesting, shears are preferable because the harvester is less likely to pull the clusters and thus break the skin of the grapes, an action which may lead to oxidation of the must. In antiquity contract laborers using billhook knives cut the grape clusters and others carried them to the processing plant in baskets [Fig. 23]. Cato says that 40 such billhooks (*falculae vineaticae*; cf. Billiard, Fig. 138) were suitable for the vineyard of 100 iugera[24] Vintage baskets (*corbulae fiscinae/fiscellae*) were firmly woven of osiers, vine shoots, or twigs from tree prunings. They held about 3 *modii* (c. 7 gals./26 L.).[25] When harvesting vines trellised on trees, we are told, workers attached these baskets to their necks with cords in order to free their hands. When these baskets were filled they were passed to porters on the ground, who emptied them into wooden trays (*lintres*) or into larger baskets of 10-*modius* capacity (*torcularia vinaria*) which were then mounted as panniers on donkeys and thus conducted to the pressroom.[26] At the processing plant grapes were sorted into two classes, some to be used as table fruit, the bulk destined for the cellars. For obvious reasons only the finest, unblemished grapes were retained as table grapes.[27]

The Winery

From Cato's elaborate descriptions as well as from archaeological evidence we have an excellent idea what the pressroom (*torcularia vinaria*) must have looked like on a typical villa farm. It is important to remember, however, that much simpler methods were used and may even have prevailed on subsistence farms. Rossiter, for example,[28] points out that wine making on a small scale was carried out in a portable treading tub and seems to have involved no pressing

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[24] Cato, *Agr.* 11; cf. Columella, *RR* 12.18.

[25] Cato, *Agr.* 31; 37; Varro, *RR* 1.22; Vergil, *Georg.* 1.5.259–66; Columella, *DRR* 12.18.

[26] Cato, *Agr.* 11.4–5; Columella, *DRR* 12.18. Cf. White (1975): 56–59 and Fig. 18.

[27] Billiard (1913): 433–34.

[28] Rossiter (1981): 48–9. An excellent review of the archaeology in the rest of the Empire, especially the western Mediterranean basin, cf. Brun in Tchernia and Brun (1999): 77–90.

Fig. 23. A vintage scene. From a Christian sarcophagus from the Lateran Museum at Rome. (After Billiard (1913): Fig. 137).

of the grapes. But *torcularia* for commercial production have been excavated from various parts of Italy, and excellent examples are found in Campania, especially at the Villa della Pisanella at Boscoreale, the famous Villa of the Mysteries near Pompeii, a villa at Gragnano and one in the city of Pompeii itself, all of which had elaborate processing equipment. The central feature of such facilities is a concrete treading vat.[29]

This certainly points toward an evolutionary development. In the early Mideast where vinification was developed, vineyards were modest and rain infrequent so that no special vintaging building was necessary. Spouted tubs, so small that their use as treading vats has been questioned, are found from Bronze Age Crete, Arkhanes, Gournia, Mallia, Petras, and Kato Zakro. Black-figure vases of satyrs conducting the vintage are unambiguous, however; the tubs are large enough for one person to work at a time.[30] A Greek red-figure crater in the National Museum in Athens even shows a satyr treading in a large wicker basket.[31] Alternately, a flat area was simply enclosed by low stone walls, the grapes thrown in and trodden. Must ran into a channel in the floor and was ladled from it into various vessels to be taken to the cellar to ferment. Such simple, open-air facilities figure on a Greek bas relief in the Naples Museum (Billiard, Fig. 143) and are still functional in parts of Syria and Palestine. But such installations are less efficacious in cooler and wetter climates; thus the development of the *torcularium*.[32] [Cf. Fig. 17]

The dimensions of the *torcularia* are naturally proportionate to the size of the vineyard, as are the number of presses. Vitruvius[33] proposes this rule: "If the press is not a screw press but a beam press, the pressroom must be at least 40' × 16' (11.8 × 4.7 m), sufficient to permit the press to be operated with ease." If a second press is installed, he notes, the room is to be extended 24' (7 m) in width. Cato, who knows only the press beam in his day, suggests a pressroom 66' × 36' (19.5 × 10.6 m).[34] The *torcularium* should be between

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[29] The pertinent bibliography is conveniently listed in Rossiter (1981): Appendix A.

[30] Albert Leonard, Jr., "'Canaanite Jars' and Late Bronze Age Wine Trade," in McGovern, Fleming and Katz (1995): 233–54.

[31] Brun in Tchernia and Brun (1999): Fig. 43.

[32] Billiard (1913): 436; Brun in Tchernia and Brun (1999): 68–9.

[33] Vitruvius, *de Arch.* 6.6.9.

[34] Cato, *Agr.* 18.

the cellar and the kitchen so that one can easily make boiled musts; it should also be well lighted from above so that animals and dirt cannot intrude, whitewashed with lime, airy and roomy so there will be no danger of asphyxiation from the huge volume of carbon dioxide produced in fermentation.[35]

Treading the Grapes

It was to the *torcularium* that grapes destined for the vintage were brought and dumped into a treading vat (*lacus*) [Fig. 24].[36] Free-run must (*mustum lixivium*), that is, must which flowed spontaneously from the bruised grapes, was customarily mixed with the must of treading (*mustum calcatum*) and that from the press, but it might also be decanted into separate vessels to be fermented unmixed, since it was regarded as of superior quality. In the same way, *mustum calcatum* was sometimes kept apart from the must from the pressings.[37] About the details of the treading itself there is considerable variation in our sources, as one might expect. The basic purpose of the procedure is simply to break the skin of the berries and begin separating skin, pulp, and solids. Unlike the olive, the grape is easily crushed using simple friction. Cato says that grapes that are sorted and graded are taken to the *torcularia* for treading (notice that he locates the process in the pressroom itself),[38] the must from this treading then being directed immediately into the large, pitched fermentation jars, *dolia picata*, or into a holding reservoir (*lacus vinarius*) and thence to the *dolia*.[39] Columella[40] has the must from treading flow into a reservoir (*lacus musti*) but also says it can be directed to fermentation vats. Pliny[41] has must from the treading and pressing flowing into the same reservoir, and thence to the dolia[42] or into wooden casks.[43]

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[35] Florentinus in *Geopon.* 6.1; Lucretius, *DNR* 6.5.805–06; cf. Billiard (1913): 437.

[36] Also *forus* and *linter*. Cf. White (1975): 130–32;147–49; 164–65.

[37] Columella, *DRR* 12.77; Pliny, *NH* 14 (11); Florentinus in *Geopon.* 6.16; cf. Billiard (1913): 442.

[38] Cato, *Agr.* 25.1; 112.3.

[39] Cato, *Agr.* 113.1.

[40] Columella, *DRR* 12.27.1; 12.19.3; 12.41.1.

[41] Pliny, *NH* 14.59,83.

[42] *NH* 14.133.

[43] *NH* 14.132.

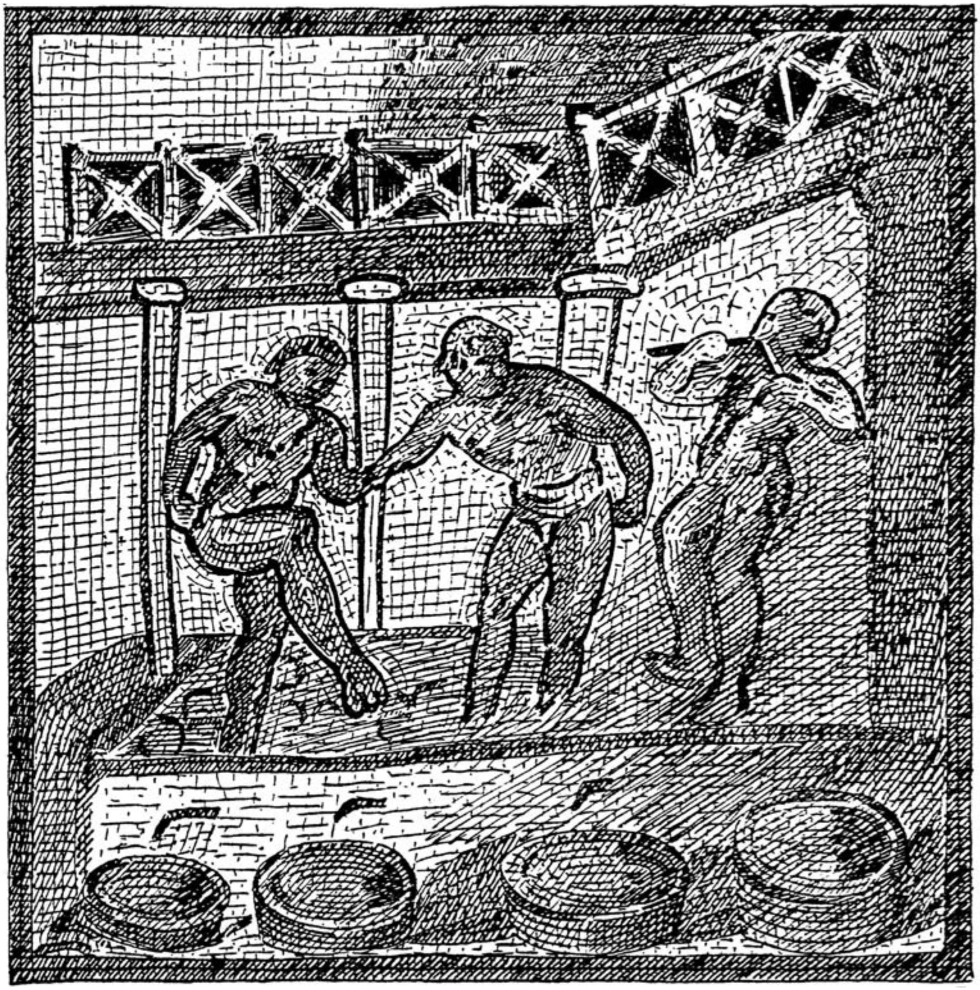

Fig. 24. Treading the grapes in a treading vat (*lacus*). Based on a mosaic found at Saint-Romain-en-Gal, now found at the Louvre Museum. (After Billiard (1913): Fig. 148).

Palladius, writing in the fifth century AD, omits all reference to pressing and thus implies that the must comes from treading alone. He describes an elevated platform from which must flows into two reservoirs on a lower level and then via terracotta gutters or pipes to dolia or wooden casks.[44] Curtel[45] had thought that Cato's remark about treading in the press room was a confusion of treading with pressing, but Rossiter's excellent review of the archaeological evidence confirms Drachmann's suggestion[46] that the treading regularly took place on the press bed, i.e., the concrete-lined platforms over which the presses were mounted. Thus there were no separate treading reservoirs nor need there have been; raised curbs on the sides of the press beds created a rectangular reservoir (*lacus*) serviceable for both treading and pressing. This will be the feature of the *torcularium* to which Varro and Columella refer by the term *forum*.[47] Where the press bed was circular rather than rectangular (e.g., at Granaraccio), the treading still took place in the pressroom, but in a separate basin close by the presses.[48]

The process of treading (*calcatio*) is virtually timeless. Treaders (*calcatores*) tread the grapes with naked feet.[49] Needless to say they are required to maintain strict bodily cleanliness and are enjoined from letting fall during the process any food or sweat[50] and are forbidden to tread if they have wounds on their feet, not for hygienic reasons but since wine thus made could not serve for religious libations.[51] A strong cadence is provided by rustic airs played on the double flute (shawm) or the *syrinx*.[52] Frequently this 'march' becomes an actual dance,[53] called in Greek *epilénion*, a sort of pantomime of the tasks of the vintage. The dance might be accompanied by a chant,[54] itself called *epilénion*, in Latin *celeuma*.[55] The bruised pulps of the grapes consist of a viscous mass on which it is easy to slip; in order to

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[44] Palladius 1.18; cf. Rossiter (1981): 346–48.

[45] G. Curtel, *La Vigne et le Vin chez les Romaines* (Paris, 1903): 107.

[46] Drachmann, *Ancient Oil Mills and Presses* (Copenhagen, 1932): 87.

[47] Varro, *RR* 1.54.2; Columella, *DRR* 11.2.71.

[48] Rossiter (1981): 349–51; Billiard (1913): 438–40.

[49] Virgil, *Georg.* 2.5.1ff.

[50] Apuleius in *Geopon.* 6.11.

[51] Pliny, *NH* 14.23.

[52] Calpurnius, *Egl.* 10.5.44.

[53] Theocritus, *Idyl.* 7.5.24 writing in the 3rd c. BCE.

[54] Oppien, *de Venatione* 1.5.127 writing at the end of the 2nd c. CE.

[55] Martial, *Epigr.* 4.64.5.21–22.

maintain equilibrium, *calcatores* support themselves on crutches or curved staffs or hold to cables which hang from the ceilings or horizontal beams or even lock arms with others.[56]

Pressing

At this point, as noted, the free-run must (*lixivium*) may be transported directly to fermentation vats or may be reserved to be mixed with the must of treading or of first and second pressings, though this last does not appear to have been standard procedure. It is important to remember that treading alone will extract some 80% of potential must and that this was considered the highest quality must, as it still is today. Then again, pressing equipment cannot have been cheap.[57] Thus at one end of the economic spectrum our wealthy villa farmer will have been faced here again with the choice between quality and quantity. At the other end, the subsistence farmer may have had no such choice since he had no access to pressing equipment at all, though we needn't overestimate the economic hardship this will have posed. For what it is worth, Cato says that grape pulp and skins, the *marc*, are to be placed under a mechanical press, in this case the standard beam press, to extract more must, though it is unclear whether he means for this must to be mixed with the *mustum calcatum* or, as Columella and others advise, be stored separately as inferior product.[58] Cato also implies a second pressing. Varro also implies two pressings and is the first to explicitly recommend separate storage of treading must and must of first pressing.[59] He further recommends mixing the remaining pomace with water to provide a drink for the farm hands in winter. Columella[60] also advises two pressings and separate storage. Pliny[61] has musts from treading and pressings flowing into a common reservoir.

Concerning the presses themselves we need say little here, since wine presses were identical to olive presses in all particulars and seem to have been introduced to Rome contemporaneously [Cf.

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[56] Billiard (1913): 440–41.
[57] Cf. Rossiter (1981): 346–48.
[58] Cato, *Agr.* 23.4.
[59] Varro, *RR* 1.54.2–3.
[60] Columella, *DRR* 12.36.1; 12.37.1.
[61] Pliny, *NH* 14.59; cf. Rossiter (1981): 4–48.

Fig. 20]. In fact, not only are the same *types* of presses used for both, but sometimes the same presses and installations are used successively, and presses are also used for other kinds of alimentary oils such as sesame and nut oils as well as for cheese and wool.[62] We should mention in passing, however, a very simple type of wine press attested in Egyptian art, namely the bag or torsion press. The marc is wrapped in a flexible bag of some permeable material to which metal loops are attached at each end. One of these loops is attached to a stationary frame and through the other ends is passed a stick which is gradually rotated by several men until the torsion wrings the liquid from the bag.[63] The procedure will be familiar to anyone who has wrung out a sopping towel by twisting its ends in opposite directions. The wine extracted falls into a reservoir. We have no attestation for such a device in Rome, though its use there is not unlikely.[64]

To reiterate, presses attested in Rome for wine making as for olive pressing are of four types: the wedge press[65] the lever and windlass press,[66] the lever and screw press[67] and the screw press.[68] Cato's description of the pressing technique is positively cryptic: "Press [the marc] every day. Divide into equal parts the must from the second pressing after the cutting up [of the pomace] and put one part into each storage jar."[69] From that unpromising beginning, Billiard has synthesized this procedure. A quantity of marc which can be handled in a single pressing (*factus* or *pressura*) is put by the pressmen (*factores*) onto laths of lattice work (*regulae*), or into large press baskets or frails (*fisci*) made of osiers, brambles, esparto grass, or rushes, dense enough to contain the marc but porous enough to allow the must to exude. Between these frails or lattices are placed wooden *tympana* or *orbes* of the sort described in the last chapter, four feet

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[62] Jean-Pierre Brun, "Discrimination entre les installations oléiculture et viniculture," in Amouretti and Brun (1993): 511–37.

[63] Billiard (1913): 442–44; Brun in Tchernia and Brun (1999): 49 and Fig. 42.

[64] For expression of olive oil, the torsion press is still attested in parts of Corsica which knew no other as late as the beginning of the nineteenth century. Cf. Antoine Casanova, "Types de pressoirs et types de productions à partir de l'exemple de la Corse à la fin du XVIII^{e} siècle," in Amouretti and Brun (1993): 361–65.

[65] Billiard (1913): 445–52.

[66] Billiard (1913): 453.

[67] Billiard, 453–55, citing Pliny, *NH* 18.74.6.

[68] Billiard (1913): 453–55, citing Pliny, *NH* 18.74.7 and Palladius 4.10.

[69] Cato, *Agr.* 23.3, Brehaut's translation.

(1.2 m) in diameter. The press beam (*prelum*) is lowered and the lever-men (*vectiarii*) crank the windlass in the case of the standard beam press, the screw in the case of screw presses. The must flows from the interstices of the frails and collects in the reservoir (*lacus*) of the press bed, whence it is conducted or decanted in one of the ways described above to the settling vats or fermentation vats (dolia) in the cellar.[70]

Pressing often demanded considerable time. When the day did not suffice, the process continued into the night. This fact explains Cato's recommendation[71] of beds for workers as well as bolsters and lamps. Excavations of *villae rusticae* such as that at Boscoreale alluded to earlier confirm Cato's remarks; clustered about both olive and grape press rooms are cubicles which can only be bedrooms.[72] Pliny[73] says that on a well appointed villa one pressing (*pressura*) ought to produce 20 cullei (2400 gal./9085 L).

A number of artistic representations show must flowing from the treading vat through spouts into jars placed around the perimeter. But we should not necessarily assume that this is free-run must; the *lacus* of the treading vat served as a mixing tank as well as a settling tank for impurities. Several archaeological sites in Italy demonstrate this system, most notably the Villa della Pisanella at Boscoreale where must from a second press reservoir was conducted by an underground lead pipe to the treading *lacus*, but where alternative outlet pipes led to dolia embedded in the pressroom floor. Obviously these cannot have been fermentation vessels; Rossiter thinks they may have been for successive storage of marc. The *lacus* itself is fitted with a spout which will have been plugged until lees, stems, and other impurities had settled to below its level. Then it was unplugged and the must conducted by a gutter to sunken dolia in the cellar for fermentation.[74] Similarly at Pompeii, Regio II, Insula V, must from the press bed flowed through a channel to one rectangular *lacus*, connected in turn by an overflow spout to a second *lacus* and thence by a covered gutter along a wall to dolia in an adjoining fermentation gallery. Further, there are parallels at Room 41 of the

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[70] Billiard (1913): 451. For the *lacus*, White (1975): 157–60.

[71] Cato, *Agr.* 13.

[72] Billiard (1913): 455–56.

[73] Pliny, *NH* 18.317.

[74] Rossiter (1981): 351–53.

villa at Grotta del Malconsiglio, Sybaris, at Sette Finestre, Ager Cosanus (where a filter over the plughole evidently trapped dross), at San Giovanni di Ruoti, Basilicata, and at Guidonia, Lazio.[75]

A single pressing is not sufficient to completely extract all the potential must; therefore, when all the must of the first pressing has stopped flowing, the pomace was removed from the press bed and extracted from the frails or lattices. It was then hacked apart with hatchets (*circumcidere*),[76] put back on the press in the same way as before and pressed again. But the resulting product should not be thought of as inferior; indeed, it was valuable in its own right. The must of the second pressing (*tortivum mustum circumcidaneum, vinum circumcisitum, mustum tortivum*)[77] was rich in tannin from the crushing of stems and seeds, as was obvious to the ancients; this wine was kept separate according to Varro[78] "because it tastes of iron." That this tannic product could be useful in correcting the acid deficiency we suspect in ancient wines appears to have been known to ancient winemakers as well; Varro recommends that it be equally apportioned to the free-flow wine and wine of first pressing.[79] When we recall that Varro had recommended separate storage of free-flow and first-pressed must to maintain quality, it becomes evident that the product of the second pressing is not an adulterant here but an additive to *improve* quality.

As must filled the treading lagoons and press reservoirs, workers will have hastened to empty it and transport it to the cellar. These workers may have been among the pressmen (*torcularii, factores*) or may have constituted a separate group of workers, perhaps called *capulatores* as for olive pressing.[80] In any case workers, perhaps so named or perhaps called *haustores*, if named separately, placed a jug or pail (*hama, urceus*) under the foot of the pedestal of the *lacus* and

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[75] Grotta del Malconsiglio: E. Galli, *Atti Grecia* (1929): 46–98; Sette Finestre: A. Carandini and T. Tatton-Brown in K. S. Painter, ed., *Roman Villas in Italy* (London: British Museum Occasional Papers NS 24, 1980): 9–43; San Giovanni di Ruoti: A. M. Small in Painter (1980): 91–109; Guidonia: C. Caprino, *NS* (1944–5): 39–51.

[76] Columella, *DRR* 12.36.

[77] Cato, *Agr.* 23; Varro, *RR* 1.54; Columella, *DRR* 12.36.

[78] Varro, *RR* 1.54.

[79] Cf. Billiard (1913): 456.

[80] The latter formed a separate guild in Rome with their own *schola* situated in Rome's third Augustan region and inhabiting a quarter of the fifth region called the *vicus Capulatorum.* The name derives from the ansate vessel, *capis* or *capula*, with which oil was decanted.

filled these pails to be transported to a reservoir in the cellar. Overflow from the *lacus* fell into a tiled trough and was returned to the reservoir.[81] Alternately, the overflow fell into a tiled gutter or pipe and was conducted thence by gravity to a *lacus* in the cellar. In either case workers filtered the raw must through a sieve of osier or rattan (*colum* or *saccus vinarius*),[82] conical in shape, which retained gross impurities [Fig. 25] Thence the wine made its way to the fermentation vats, the dolia.

Fermentation

Odd as it may sound to modern sensibilities, the fermentation process, the *cuvage* (L. *fervere*), was not a distinct step in the vintning process. Today must is typically treated with sulfur dioxide at the rate of several parts per million in order to kill native yeasts present on the skin of the grape, yeasts which appear there as grayish 'bloom', as well as any spoilage organisms which may be there. Then the modern wine maker pitches a strain of pure *Saccharomyces cerevisiae* which has been cultured in the lab. The strain he uses will depend of the grape varietal(s) he is using and the style of wine he aims at. Our ancient vintner knew perfectly well that there were organisms on the skin of grapes which caused the spontaneous fermentation of musts, but he had only the vaguest of notions what they were and his wine making descendants were no better off, of course, until Pasteur placed yeast culture on a scientific basis. Thus we may expect that for the ancients, fermentation began spontaneously, perhaps even as grapes were transported to the treading vats; grapes will have been exposed to a warm sun as they waited in baskets for transport, and many of the clusters will have been broken in the process of harvesting. Transporting and treading will have extended this time, as did pressing, all factors eminently conducive to yeast reproduction. Additional fermentative species will have derived from contact with winery equipment. If spontaneous ferments studied today may be taken as indica-

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[81] Billiard (1913): 456–57.

[82] Cato, *Agr.* 11; Columella, *DRR* 9.15. Brun (Tchernia and Brun [1999]: 73 and Fig 87) interprets these baskets as decanters and remarks that they must have been thoroughly pitched to make them waterproof, but I think Billiard's interpretation is more likely, given the ancient testimonia.

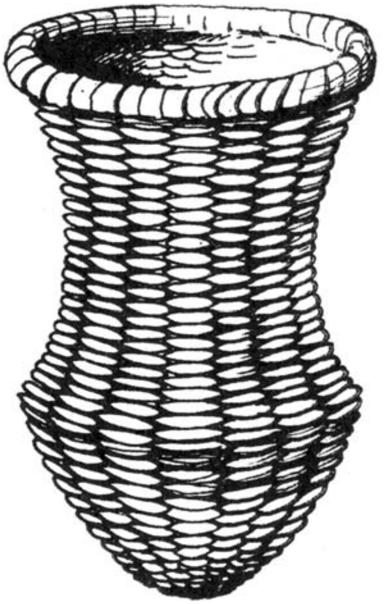

Fig. 25. The wine strainer, *colum*, used for straining gross impurities such as grape seeds, skins and twigs from the must before the must is conducted or decanted to fermentation vats. (From White, 1975, Fig. 31. Courtesy of Cambridge U. Press).

tive of their ancient prototypes, there is a progressive pattern of yeast growth initiated by various species of *Kloeckera, Hanseniaspora, Candida, Metschnikowia and Saccharomyces*. But the initial colonies of the 'wild' yeasts, which are much less tolerant of ethanol, are generally overgrown by *S. cerevisiae* after 2–4 days.[83] There may well have been certain advantages to spontaneous fermentation, in the absence of persistent spoilage organisms. Today the most troublesome of wild yeasts are the so-called apiculate yeasts of the *Kloeckera* and *Hanseniaspora* species, inevitably present on grape bloom and in the air of the vineyard. *Hanseniaspora* species produce about twice as much acid as *S. cerevisiae* and give wine a sharp, cidery taste regarded as a defect in modern wines.[84] But the increase in acidity and stability of wines so fermented may have been worth any perceived loss of organoleptic

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[83] G. H. Fleet, "The Microbiology of Alcoholic Beverages," in Brian J. B. Wood, ed., *Microbiology of Fermented Foods* (London: Blackie Academic and Professional, 1998): 222–4.

[84] Cedric Austin, *The Science of Wine* (New York: American Elsevier Pub. Co., 1968): 33–34.

quality for our ancient wine maker. In any case, by the time our must arrived at the cellar it will have been undergoing a vigorous fermentation.

We have every reason to believe that the vast majority of ancient fermentations proceeded in this way and that most such fermentations were perfectly effective. But what if things went awry for our ancient vintager? Was he completely at the mercy of ambient microflora? We have intriguing if inconclusive evidence that he was not. Columella[85] says that on an estate where wine habitually 'sours' (*acescere*) the raw must should be taken directly from the treading tanks before pressing, should be supplemented with 1/10 part water, and should be boiled until reduced by this same 1/10 part. Columella's use of the term *acescere* for souring would immediately suggests an acetic fermentation but for two facts. First, *Acetobacter* and *Gluconobacter* species, the operant organisms in vinegar production, almost always operates only after yeast fermentation has subsided. Secondly, they are most often ambient in fermentation vessels, not on grape bloom, a fact the ancients knew perfectly well and used to their advantage in the deliberate production of vinegar, as we shall see later. This suggests that Columella uses the term in a generic sense for any infectious fermentation, and the logical culprits here are various wild spoilage yeasts. Given that fact, his recommendation to boil the must is perfectly sound, since boiling must long enough to reduce it by 10% would certainly be enough to sterilize it. Our vintager would then need to pitch a yeast culture, of course, since boiling will have killed all microbes, including *S. cerevisiae*. Among numerous additives recommended for defective wines[86] is that of wine lees (*faex*, *limus*), an amalgam of insoluble precipitates, autolyzed wine yeasts, inert bodies, silicaceous and other inorganic sediments, and refuse. But the bulk of the amalgam is composed of spent yeast cells. Billiard[87] thinks the yeast cells in lees from a vigorous fermentation might well improve a weak spontaneous fermentation, though he acknowledges that one risks thereby the introduction of infectious microbes from the lees, for which reason the practice is frowned upon today. But in a situation where the must stands a high likelihood of infection in any case, pitching even this impure yeast culture makes perfect

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[85] Columella, *DRR* 12.26.

[86] Columella, *DRR* 12.30; Pliny *NH* 14.24.1; Palladius 11.14.

[87] Billiard (1913): 503–04.

sense. Ambient yeast strains, including wild spoilage strains, are incredibly tenacious and can survive in a specific microenvironment for generations. Once a year's vintage had spoiled, our ancient vintager had every reason to believe that successive vintages were likely to spoil as well, and to take all available countermeasures. It is obvious that boiling must will have had a devastating effect on the volatiles in must that contribute so heavily to wine's bouquet and aroma, but we must remember that the primary goal of the ancient vintager was to produce a stable, minimally potable product.

Again, the fermentation process for wine is essentially the same alcoholic fermentation as for grains, though the fermentable sugars are different. Wine yeasts need certain nutrients in order for reproduction and enzymatic action to proceed, most notably nitrogen, phosphorous and sulfur. Today's vintager takes no chances but supplements these elements by means of yeast nutrient. We have no direct evidence that the ancients understood this concept, and certainly they hadn't a clue to the chemistry involved. But it is an interesting question how many of the prescribed additives listed in literary sources may have had this effect.

After yeast cells have used such nutrients in an initial, 'bulking-up' phase, they then begin the primary, aerobic fermentation in which sucrose is catalyzed to glucose and sucrose and the latter to water and carbon dioxide gas. During the secondary, anaerobic stage of fermentation the byproducts of metabolism are alcohol and CO_2.[88]

1. $C_6H_{12}O_6$ + $6O_2$ » $6\ CO_2$ + $6\ H_2O$
(Sugar) (Oxygen) (Carbon Dioxide) (Water)
2. $C_6H_{12}O_6$ » $2\ C_2H_5OH$ + $2\ CO_2$
(Sugar) (Ethanol) (Carbon Dioxide)

During the primary phase of fermentation yeast must bud vigorously and rapidly in order to inhibit the growth of spoilage organisms; it should then have a high tolerance for its own 'waste product', ethanol, to the level of 10–14% by volume, until the concentration of the latter inhibits or kills it, and it should then rapidly precipitate and form a compact yeast sediment so that the wine can be decanted from it without unduly roiling it. Good wine yeast has an optimum

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[88] Those wanting a more complete explanation may consult P. Ribéreau-Gayon, D. Dubourdieu, B. Donèche and A. Lonvaud, *Handbook of Enology, vol. 1* (Chichester: John Wiley and Sons, 1998): 51–74.

effective temperature range of 68°–77° F (20°–25°C); above about 95°F (35°C) it dies and below 59°F (15°C) it is sluggish or dormant. But avoiding radical fluctuations in temperature seems to be more important in producing a vigorous ferment than the specific temperature of fermentation, at least within these parameters. Primary fermentation lasts from three to ten days; secondary fermentation lasts one to five months, depending on yeast nutrient, sugar content of must, and temperature of fermentation.[89]

To ensure a robust primary fermentation today, many winemakers make a yeast starter from a smaller quantity of fermentable, to be pitched into the bulk must at the appropriate time. This is roughly equivalent to the 'sponge' of panary fermentation previously discussed. But it should be remembered that the modern winemakers start out with a sterile must. We have no attestation for the use of wine starter culture in antiquity, for the simple reason that fermentation in most cases if not all began, literally, when the grape came off the vine. That this fermentation could nonetheless be vigorous, if not explosive, is suggested by Varro[90] who quotes Fundanius to the effect that cellar floors should be sloped to a reservoir because primary fermentation often bursts not only *dolia* used in Italy but even the wooden butts (*orcae*) used in Spain.

Chaptalization

Achieving sufficient alcohol levels to ensure biological stability in a wine is a function of sufficient total sugar content of a must as well as yeast vigor. Obtaining musts with sufficient fermentable is not likely to have been a problem often in this warm Mediterranean milieu, particularly when grapes were apparently harvested dead ripe. But it is clear from literary evidence that this was a problem on occasion. Today's wine maker knows precisely how much fermentable sugar his grapes will yield simply by checking the specific gravity of a sample of grape juice; because sugar is much denser than water or ethanol, the specific gravity of a must is an excellent indicator of total fermentable available. Though Archimedes had long since discovered the principles of specific gravity, it would be several cen-

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[89] Muller and Tobin (1980): 178–79.
[90] Varro, *RR* 1.13.6.

turies before the invention of the precursor to the modern hydrometer. It was Synesios, sixth-century CE commentator on Democritus, who first mentioned the *hydroscopium*, a true hydrometer composed of a cylindrical vessel, graduated and weighted at the bottom with a small, conical weight.[91] Apparently the instrument was used exactly as the modern hydrometer and was capable of determining minute differences in density. The fact that none of the agronomists mentioned this instrument suggests that it was used only rarely, if at all, by ancient winemakers. In the absence of such an instrument, they doubtless resorted to empirical evidence from tasting the ripe fruit and/or the must to estimate fermentability of must. Even today winemakers rely heavily on taste to complement technical evidence in this regard.

Today deficiencies in total sugars in musts are corrected by the addition of sucrose, a process, still highly controversial in some quarters, known as chaptalization.[92] Since yeast easily converts sucrose to glucose and fructose, this does not appreciably affect the taste or quality of the final outcome. Cane sugar was only just known to the ancient Romans as an exotic from Persia, and was far too precious for this use, as was honey, an expensive commodity in ancient Rome, as we shall see. Thus, grape concentrates, *defrutum* or *sapa*, were universally used and were ideal from a technical standpoint. Thus Cato's recommendation:[93] "if necessary put *defrutum* boiled down from free-run must (*mustum lixivium*) into the must; add a fortieth part of the concentrated juice . . . per *culleus*." Elsewhere we find the prescription for wine too low in fermentables because of the dilution of too much rain; it should be corrected by the addition of 'cooked wine', *vinum decoctum*.[94] Since wine per se will have had little if any residual sugar in it, our sources apparently refer to grape concentrates by this same term. According to Columella, when must to be chaptalized has been removed from the press vat it is cooled and clarified for two days (in the settling tanks?) and *defrutum* is added on the third day[95] at the ratio of one sextarius per amphora of wine.[96]

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[91] Synesios, *Epist.* 15.

[92] Boothroyd (1986): 50–52; Tchernia in Tchernia and Brun (1999): 114.

[93] Cato, *Agr.* 23.2.

[94] Palladius 11.14; cf. Columella, *DRR* 12.19.

[95] Columella, *DRR* 12.21.2

[96] Columella, *DRR* 12.20.1.

There are two considerations for the wine maker here, neither, perhaps not surprisingly, mentioned by ancient sources: first, sugar in high concentrations will itself inhibit yeast reproduction and metabolism and so in making wines of higher alcohol concentration must today be added in stages; second, sugar's high density causes it when poured into a fermenting must to sink quickly to the bottom of the solution; thus the mixture must be vigorously stirred.[97]

The final technical consideration at this phase of the process is the maintenance of optimal fermentation temperature, especially critical since fermentation itself produces tremendous heat, often enough in a large winery. This is particularly challenging in a Mediterranean climate, needless to say. Today special cooling systems are used. But the Roman vintager found a simple, efficacious solution by embedding his fermentation vessels, dolia, in the ground. Rossiter thinks the primary function of embedded jars in cellars was to stabilize temperatures, insulating against heat loss during fermentation and maintaining a steady, cool temperature (optimum is 50°F/10°C) during winter months when wine is maturing.[98] These sunken jars are such a typical feature of ancient cellars that they may be used with caution as a typology; sunken dolia are indicative of a wine cellar whereas freestanding dolia suggest an oil cellar instead.[99]

Thus far considerations of biological stability. Though color, polyphenols and tannin content are largely esthetic factors in wine, tannin contributes secondarily to biological stability because of its antioxidant properties, and tannin is more concentrated in red wines. It follows that a red wine is *ipso facto* more stable. It is a common misconception that white wines derive exclusively from white grape varietals and red from red varietals, when in fact, with the exception of a few red varietals whose juice is also red, grape juice is light in color for both; it is therefore perfectly easy to make white and rosé wine from red grapes. The red color, in fact, derives from the skin of the grape. Additional tannin and polyphenols (including

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[97] Boothroyd (1986): 51–52.

[98] Rossiter (1981): 359, n. 39.

[99] Rossiter (1981): 353. Jean-Pierre Brun ("Discrimination entre les installations oléicoles et vinicoles," in Amouretti and Brun [1993]: 532–4) cautions that archaeological evidence shows cases where oil was stored in dolia above ground, semi-interred and totally interred, so that this distinction can only be used for typing with great caution and in conjunction with other archaeological and archaeobotanical evidence.

flavanoids and nonflavanoids) derive from exposure of the must to stems and seeds. Thus in modern wine making, must is left in contact with skins, and sometimes stems and seeds, for a period of time, often several days, during which the 'cap', the mass of these solids which floats to the top of the must, is periodically stirred back into the mixture to increase extraction of colorants, phenols and tannin.[100] Billiard, relying as he does almost exclusively on literary evidence, logically deduces that must was transported directly from press reservoirs and/or treading reservoirs to the cellar and there filtered and allowed to ferment out of contact with these solids. Thus he concluded, again quite logically based on his evidence, that ancient wine was fundamentally different from modern. But this is perhaps not so, or at least not so for the high classical period when wine making had become an art and a huge industry rather than a cottage craft. This period is better represented by Rossiter's archaeological evidence where, it will be remembered, must goes from treading and/or press reservoirs to one or more 'settling' reservoirs in the cellar. It is logical to assume that here must remained in contact with grape solids. If so, these 'settling' tanks may have served multiple purposes. First, they may have been agitated periodically just as their modern counterparts to maximize extraction of colorants and tannins; simultaneously they will have served as primary fermentation vats. This latter does not expose must to infection as much as might be supposed, since primary fermentation produces such massive quantities of CO_2, so much denser than air that it will float over the surface of the must like a protective, anaerobic cap and will effectively inhibit aerobic spoilage organisms. It is during secondary fermentations that the vast majority of infections occur anyway.[101] Thus the same danger of asphyxiation that attaches to those entering grain silos or dolia to be cleaned applies to cellars during primary ferment, especially if partially underground, and sealed off as they are in winter from cold winds. Pliny cautions, "Going into

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[100] Cf. Richard P. Vine, Ellen M. Harkness, Theresa Browning and Cheri Wagner, *Winemaking from Grape Growing to Marketplace* (New York: Chapman and Hall, 1997): 105–06.

[101] For comparison, modern traditional ale production utilizes open slate vats for primary fermentation, at least in many parts of Yorkshire where traditional ale is produced. References to 'dark wine' by the ancients may be just that, since tawny wines darken as they oxidize and are exposed to heat (cf. Tchernia in Tchernia and Brun [1999]: 133–4) But references to 'blood-red' wine (*vinum sanguineum*) can hardly be made to anything other than a hearty red.

the cellar where the wine vats are can be fatal. A good test is to let down a lamp; if it goes out, it means danger."[102] We can then imagine a scenario in which primary fermentation and extraction of derivatives proceeded for perhaps a day or two before the solids were allowed to precipitate or, alternatively, before the wine was decanted/conducted to a secondary reservoir where precipitation of gross particulates occurred. Only then will the wine have been conducted to the cellar for filtering and secondary fermentation in the dolia.

Cellaring

This cellar was a masterpiece of rational design; on that the literary and archaeological evidence are in accord. The wine cellar, *cella vinaria*, was part of the larger storage magazine along with that for oil vats (*cella olearia*) and for storage vats for concentrated musts (the *defrutarium*).[103] Such a disposition economized time, work, and supervision. Fine wine is delicate and, like its counterpart in the *cella olearia*, highly susceptible to off-odors; thus the ancients go to some lengths to describe the proper disposition of the *cellae*. Vitruvius[104] says that windows should face north since the heat of the southern exposure will 'turn' the wine. Columella[105] advises building the wine cellar at ground level, facing north and situated as far as possible from baths, bakehouse, smokehouse, and all sources of fetid odors. The tendency of wine to assume off-odors even prompts Columella[106] to advise burning incense in the cellar, though we may question the advisability of this expedient.

As to size, the ancient authors advise a cellar proportionate to the size of the farm, and preferably big enough to accommodate more than one vintage since wine improves with age and, more importantly, since correct timing of the sale of the vintage to the *negociant* can double the price.[107] Rather astonishingly, Cato[108] advises a number

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[102] Pliny, *NH* 33.63.

[103] Columella, *DRR* 1.6; cf. Billiard (1913): 463–65, who incorrectly takes the *defrutarium* to be the place for production of cooked concentrates. For an experimental reconstruction of a *cella vinaria*, cf. Brun in Tchernia and Brun (1999): 91–105.

[104] Vitruvius, *de Arch.* 6.6.

[105] Columella, *DRR* 1.6; cf. Pliny, *NH* 14.27.1.

[106] Columella, *DRR* 12.18.28.

[107] Varro, *RR* 1.13.

[108] Cato, *Agr.* 11.

of dolia sufficient to receive five vintages from his prototype hundred-iugera vineyard, a quantity of some 800 *cullei*, i.e., on the order of 115,600 gallons (4,375 hectoliters)! The floor is composed of a deep bed of sand or, to judge by the comment of Fundanius cited by Varro above, of a pavement sloped to a reservoir at one side to recover leaking wine or that from burst fermentation dolia. Judging by the archaeological sites explored by Rossiter, the former arrangement was used exclusively, and Varro may be recording a curiosity.

The crowning glory of the cellar was, of course, its huge fermentation and storage vessels, the terracotta dolia, so typical of ancient bulk storage of liquids throughout most of antiquity [Fig. 26A].[109] Wooden butts, *cupae* [Fig. 26B], occurred sporadically, particularly in late antiquity, but were never typical in central and southern Italy.[110] On the other hand, they gradually supplanted dolia in Gaul and the western provinces, where they were used as fermentation vats in much the same way as their modern counterparts, the *foudre*, a butt laid on its side and stabilized on either side with wooden chocks (*podia*).[111] Dolia were the ancient equivalent of modern *foudres*, enormous round, pot-bellied jars with a flat base, a large mouth, and walls as thick as 2 1/2" (6–7 cm). Billiard cites an example from the Musée Borély at Marseilles 5'2" (1.58 m) high, 4' (1.22 m) in diameter, and 12'6" (3.8 m) in circumference; another reposing at the entrance of the Maison Carrée at Nîmes 6'3" (1.9 m) high and 14'6" (4.45 m) in circumference, with a capacity of 208 gallons (8 hectoliters). Columella speaks of a standard dolium of 1 1/2 *cullei*, about 206 gallons (780 L), and Palladius of one of 200 *conges* capacity,

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[109] Cf. Billiard (1913): 465–68; White (1975): 144–7 and Fig. 40. Their terra cotta covers were *opercula*. Size of dolia varies enormously, the commonest extant examples holding 36 amphorae (216 gal.). A fragment of a sarcophagus conserved at Ince Blundell Hall, Liverpool, dating from the 3rd c. CE, shows sale of wine. Nine embedded dolia are shown, covered with circular lids formed from planks held together with two transverse planks which seem to have functioned as handles as well. But surely this scene depicts a wine wholesaler, after the sealed dolia have already been breached, since we see two workers filling an amphora from one of the dolia on the left, and the negociant and a customer at the right. Cf. Brun in Tchernia and Brun (1999): 76 and Fig. 94.

[110] For what it is worth, a 'cooking pot' from Monastaraki on Crete from the Middle Minoan II period contained residue of a resinated wine as well as lactone derived from oak, suggesting it had been aged in oak barrels. Cf. McGovern (2003): 261–63. Cf. White (1975): 141–3, who says *cupae* were interred like dolia and used as vats as well as for storage. I cannot detect the source for this argument. For the extension of the use of the *cupa* in Italy and elsewhere, Tchernia (1986): 285–92.

[111] Brun in Tchernia and Brun (1999): 58–9. For *podia*: Palladius 1.18.

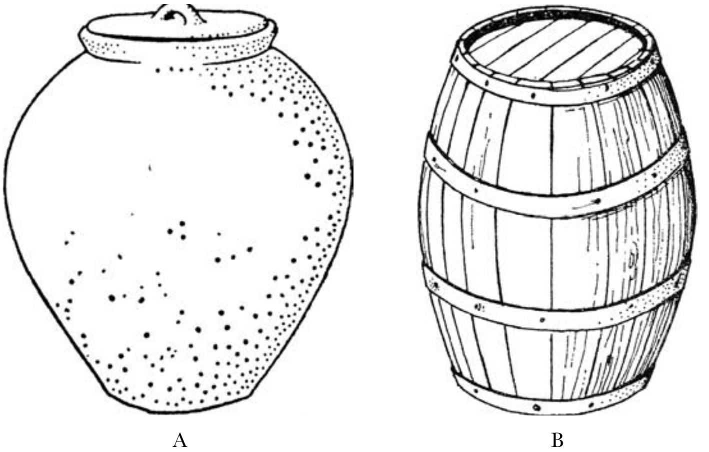

Fig. 26A. The standards fermentation and wine storage vessel, the terra cotta *dolium*, showing its terra cotta lid (*operculum*). Fig. 26B. The Roman wine barrel (*cupa*) which became standard in Gaul and perhaps other northern provinces. (From White (1975): Fig. 144 and 141. Courtesy of Cambridge University Press).

some 165 gallons (625 L).[112] No wonder Diogenes the Cynic could be said to have lived in a *pithos*, the Greek equivalent of the *dolium*, and that Athenians driven to straits by the overcrowding caused in that city by the Peloponnesian War resorted to the same device!

The clay body of clay vessels mixed with the right grog can be made largely impervious to liquids.[113] But these huge dolia, which may well have been underfired because of their bulk, were too porous to be used for liquid storage as they came from the potter, and thus they were pitched. The process (*picatio*) [Fig. 27] is described in some detail by Columella[114] and needn't detain us here except in regard to several particulars. First is the question whether pitching was effective in making the vessels, and the amphorae in which wine was ultimately sold, waterproof. Conventional wisdom has been that only

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[112] Cato, *Agr.* 23;69; Columella, *DRR* 12.18; Palladius 10.11.

[113] For example, 17th c. Staffordshire pottery designed for potting butter for commercial sale in London was made of a coarse, unglazed clay which was nonetheless impervious to water in order to prevent dealers increasing the vessels' weight before sale by soaking them in water. Cf. Peter Brears, "Pots for Potting: English Pottery and Its Role in Food Preservation," in Wilson (1991): 51.

[114] Columella, *DRR* 11.2.70; 12.18. Cf. Carolyn G. Koehler, "Wine Amphoras in Ancient Greek Trade" in McGovern, Fleming and Katz (1995): 323–37.

Fig. 27. Pitching of vessels (*picatio*). At right, a worker boils pitch; at left, another worker swabs the interior of a terra cotta *seria* (half dolium) with the pitch which will make it waterproof. (From the Seasons Mosaic, Vienne. After Billiard (1913): Fig. 149).

glass containers and cork stoppers are truly airtight—that the ancient vessels cannot have been well sealed and must therefore have promoted gradual evaporation and oxidation, making ancient aged wines far more like marsala or sherry than claret or chardonnay. Billiard, however, cites his own experiment to prove the efficacy of the treatment.[115] A small amphora of some 1200 cc capacity lost, when unpitched, some 250 cc, or about 20% of its volume, in less than 10 hours. The same vessel after being pitched in the ancient fashion lost no measurable quantity after 24 hours. Admittedly, a short time, but certainly in accord with a mountain of ancient testimony that fine wines were kept five, ten, twenty, even a hundred years. Given even minute rates of evaporation these last cited must have been little more than a thick syrup after twenty years. In the absence of clear evidence to the contrary I think that we must assume that pitching was a highly effective sealant. About the ancient method of 'corking' wines I will have more to say later.

The second issue is the question of resinous taste in the wine imparted by the pitch. Since resins are soluble in alcohol, Koehler thinks that resinated wines, that is, wines with a distinctly resinous taste, began as a fortuitous result of the necessity of pitching vessels to seal them. "Since Pliny follows his recommendation to use Bruttian pitch for coating wine vessels with an enumeration of the flavors of pitch from other regions, he implies it would have made a difference in the taste of wine (*NH* 14.25.127–28)." Not *would* have, but *could* have, in my opinion. Pliny clearly favors Bruttian pitch because its taste is less assertive, whereas Spanish pitch, for example, is said to have a bitter, acrid, astringent quality which makes it easy to detect; therefore this pitch is interdicted. Even pitch used as a preservative in wine the ancients were at pains to add in concentrations below the taste threshold, as Koehler herself acknowledges.[116] Modern resinated wine such as Greek *retsina* is made by dissolving a considerable dose of pine resin—on the order of 1% by volume—in wine. Any resin that may have leached into ancient wine from container walls will have been in the range of parts per million. On the other hand, a form of Roman *retsina* was apparently popular. Martial in one of his literary 'gift tags' (13.107) mentions a wine from Vienna,

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[115] Billiard (1913): 474–78. Cf. M. H. Callender, *Roman Amphorae* (London: Oxford U.P., 1965): 45; Brun in Tchernia and Brun (1999): 106–7.

[116] Koehler (1995): 323–37.

capital of Gallia Narbonensis, called *picatum*, obviously a wine in which the resinous flavor was considered desirable, for which reason Martial mentions the vintner by name.[117]

Billiard cites further evidence that pitch has a bacteriostatic function as well. Certainly the ancients went to considerable lengths to make such vessels as sterile as possible before filling them. In September, a month before the vintage, all new vessels were thoroughly scoured with brine or sea water and allowed to dry for a minimum of fifteen days. Old vessels small enough to be so handled were inverted over fires until the old pitch melted and ran out and then were scraped and similarly scoured. They were then repitched by allowing pitch to liquefy over a fire and then by running the pitch into the belly of the vessel laid on its side, which was then rotated and manipulated so that the pitch covered the entire inner surface. Dolia, particularly if embedded as was typical, could not be moved; workers had to crawl into them with lamps to liquefy the old pitch, which was then laboriously scraped off before the application of new pitch. As a footnote, Pliny cautions those who descend into dolia for the purpose to exercise extreme care "since the force of the lees is so great that they kill those who enter the dolia,"[118] clearly a reference to the danger of residual CO_2.

Form and size of the dolia were not without influence on the stability of the wine. Our ancient wine maker preferred those with narrowed mouths and smaller overall size.[119] Anatolius[120] says that vessels which are too open promote loss of bouquet and the attack of 'diseases', both perfectly true; even today identical wines aged in tuns are demonstrably inferior in bouquet to those aged in butts.[121] And ullage, unfilled air space at the top of a liquid container, promotes any number of aerobic infections, most notable *Acetobacter*. The greater the ullage, the greater the chance of infection.

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[117] T. J. Leary, "Martial's Christmas Winelist," *Greece and Rome* 46,1 (April 1999): 36. On attempts to 'reconstruct' the taste of ancient wine, Alain Carbonneau and Rocco Rotunno, "Reconstitution du vignoble de Pompéi," *Pallas* 52 (2000): 135–40 (reconstruction of a Pompeian vineyard using ancient techniques); and Michel Bouvier, "Recherches sur les goûts des vins antiques," *Pallas* 53 (2000): 115–33, and idem, *La saveurs du vin antique: vins d'hier, vignerons d'aujour'hui* (Paris: Éd. Errance, 2001).

[118] Pliny, *NH* 23.31.1; cf. Billiard (1913): 474–78.

[119] Pliny, *NH* 14.27.2.

[120] Anatolius in *Geopon.* 6.3.

[121] Cf. Billiard (1913): 470.

The loss of one of these monsters must have been significant in itself, not to speak of the loss of some 200 gallons of wine. Thus we find this type vessel equipped with hoops of lead or oak or vineshoots, all designed to deaden blows.[122] If the vessel did crack, it was rejoined at the cracks with lead clamps and sealed with wax, resin, sulfur, or plaster, and cracks were disguised with crushed powdered tiles, mixed with water and luted on.[123] Obviously, embedded dolia were largely protected from incidental blows, another advantage of this system.

Other vessels were occasionally substituted for the dolia, particularly in northern Italy and the western provinces. The most significant was doubtless the wooden barrel, *cupa* (whence our English *cooper*). *Cupae* were apparently much like our own barrels, composed of wooden staves (*laminae, tabulae*) retained by hoops. Unfortunately, Pliny, our main literary source on barrels, uses the term *dolium* when he clearly refers to wooden casks, causing considerable confusion. Note, for example, *Natural History* 18.236, where he advises repair of dolia in winter months "by scraping the staves and making new ones."[124] Perhaps *cupae* were an innovation in northern Italy in Pliny's time. Elsewhere[125] he attributes wooden barrels to the Alps and says one sometimes sees them exploded in times of bitter cold. Billiard suggests that in central and southern Italy casks were sometimes used for transport of wine only, whereas in the Alpine regions they were vessels of choice.[126] Other villas made resort to cement wine cisterns, sunk into the subsoil of the cellar.[127] In this regard Pliny[128] reports a vintner who, faced with a shortage of vessels, poured the new wine into *piscinae*, presumably decorative pools but perhaps literally fish ponds.[129] The cellar was, of course, also equipped with a variety of other vessels and utensils, all kept scrupulously clean. *Seriae*, for example were smaller jars which correspond to modern casks. Columella gives their capacity as seven *amphorae*, i.e., 48 gallons (183 L).[130] In addition there were *seriolae* corresponding to our kegs or firths. Dolia were typically arranged in ranks and files in the cellar, sometimes

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[122] Cato, *Agr.* 39.
[123] Billiard (1913): 469.
[124] Cf. Billiard (1913): 472.
[125] Pliny, *NH* 14.27.1.
[126] Billiard (1913): 478–84.
[127] Cato, *Agr.* 67.
[128] Pliny, *NH* 18.74.9.
[129] Billiard (1913): 472–73.
[130] Columella, *DRR* 12.28. Cf. White (1975): 185–8.

at ground level (*supra terram*), but typically embedded in the sand (*defossa, demersa, depressa*), usually to about 2/3 their height. Dolia were typically ranged in two or three ranks, after the same fashion as the olive jars.

From the foregoing it will be evident that there was a variety of arrangements for the initial chemical processes of wine making, but that in general must was conducted from treading vats or pressbeds to reservoirs, either in the pressroom or the cellar, where it was perhaps kept in contact with skins and seeds for several days for extraction of color and tannins and underwent at least the first stages of a primary fermentation and was chaptalized as needed, and was then separated physically from grape solids in one way or another before being conducted to storage vessels for the cuvage. Cuvage includes, as we use the term, perhaps the remainder of primary fermentation, certainly the secondary ferment, and overlapping these processes clarification and the beginning of aging.

In the primary fermentation vessels[131] foam as well as gross impurities are brought to the surface of the seething must and are skimmed twice a day.[132] As the fermentation subsides, Cato advises,[133] elm-twig brooms are to be used to brush thoroughly the inner sides of the storage jars so that dregs do not adhere to them. Doubtless the duration of primary fermentation varied widely, depending on exterior factors such as ambient temperature as well as intrinsic factors such as temperature of must, sugar concentration of must, and vigor of yeast culture, but Pliny estimates an average of nine days.[134] Cato[135] avers that after some thirty days the wine has finished rejecting all the impurities it has held in suspension, by which he seems to suggest a terminus for both primary and secondary fermentation. During this phase the dolia are covered with terracotta lids (*opercula*), pitched in the same fashion as the dolia, but not sealed to allow excess carbon dioxide to be emitted.[136] Today during the secondary ferment, vessels are fitted with a fermentation lock, a simple device which allows CO_2 from the secondary ferment to bubble through a liquid

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[131] Cf. Billiard (1913): 485–86 and Forbes III (1965): 122–23 (the latter very unreliable).

[132] Cato, *Agr.* 26. The skimmer is the *trulla.* Cf White (1975): 192–3 and Fig. 53.

[133] Cato, *Agr.* 152.

[134] Pliny, *NH* 14.25.3.

[135] Cato, *Agr.* 26.

[136] Macrobius, *Sat.* 7.12.15. Cf. White (1975): 179–80.

medium, usually simply water, while preventing air from coming in contact with the wine. Egyptian winemakers had invented a simple fermentation lock,[137] a cone of mud formed on the top of the clay lid of a wine vessel, a cone which was pierced with a small hole to allow gas to escape. Something of the sort has also been found in the Agora excavations in Athens, in this case on amphorae.[138] I find no evidence for such a device in Rome, nor was there probably any need of it; given a fairly tight fit between dolium and operculum, CO_2 will have floated on the surface of the wine as a protective blanket and any excess will have dissipated from the gaps in the lid. We have Macrobius' explicit testimony that the purpose of the lids was to keep the air from the wine as far as possible. At the end of primary fermentation bulk wine, *vin ordinnaire*, has been allowed to remain on its lees, designed as it is for daily consumption and for sale to taverns. Wines to be aged have been racked to clean vessels after the primary ferment and perhaps again before being sealed or modified in one of the ways to be discussed later. The ancient vigneron knew perfectly well that wines allowed to remain on their lees (French *sur lies*) are more prone to infection. Today, though some varietals are sometimes aged *sur lies* to increase flavor extraction, it is understood that lees provide an ideal growth medium, primarily in the form of amino acids from autolyzing dead yeast cells, for any number of spoilage organisms.[139] In either case, after all apparent evidence of fermentation has subsided and no more bubbles rise to the surface, the wine may be racked and sealed.

The huge vats are covered with the same terracotta covers, but this time they are sealed (*oblinere*) with the same clay or plaster attested for sealing wine stored in amphorae.[140] After the wine is sealed there will be far less work for the cellarman. Columella explains that after the sealing of the vessels until the spring equinox it will suffice for him to examine the wine every thirty-six days, though wines aged at higher temperatures will require more frequent monitoring. Each

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[137] Leonard Lesko, *King Tut's Wine Cellar* (Berkeley: B. C. Scribe Publications, 1977): 20; T. G. H. James, "The Earliest History of Wine in Egypt," in McGovern, Fleming and Katz (1995): 197–213. But cf. Philip Mayerson, "Jar Stoppers and the Sealing of Winejars," *Zeischrift für Papyrologie und Epigraphik* 136 (2001): 219–20, who interprets holes at the necks of wine vessels as pouring holes for 'uncorked' vessels, not as vents for gases.

[138] Koehler (1995): 329.

[139] Vine, et al. (1997): 213.

[140] Persius 4.5.29; Columella, *DRR* 12.39.2.

time the jars' seals are broken, he advises, the mouths of these vessels are to be scoured with pine cones.[141]

Clarification

Nothing is said by our ancient vignerons concerning filtration before bottling, as might be prescribed by their modern counterpart. Filtration (*lignatio*) was certainly known to the ancients and was designed to clarify (*defaecare*) the wine by trapping any lees left in suspension; they also knew that the resulting aeration of wine caused it to lose some of its harshness and imparted a certain suppleness.[142] For this purpose they used linen sacks, sometimes infused with scents such as myrtle. At the same time the ancients were aware that filtration strips wine of some of its bouquet.[143] But it was apparently only at the time of serving the wine that this sort of filtration was done.

Thus the ancients clarified wine in the cellar in two ways, by racking and by fining. Racking, as previously noted, is simply the process of removing a desired liquid from undesirable elements in it. In this case lees are allowed to precipitate from wine. Precipitation and development of a firm sediment can be considerably enhanced by storing wine in a cool place, ergo the siting of the ancient cellar as well as the embedding of the dolia. Modern racking is done by siphoning, and the ancients knew and used the siphon, though there is no evidence for its use in this context, nor would its use have been very practical with dolia largely embedded in the ground. Racking was done by simple ladling, as with oils, though this is equally inadequate with wine in that it aerates wine and promotes oxidation and the development of aerobic infections. But our ancient vigneron was between Scylla and Charybdis; as previously discussed, aging *sur lies* also promotes infections. Once the wine was racked the new container was 'topped up' to maximum capacity with water or wine in order to reduce ullage and inhibit these same infections, and then carefully resealed.[144]

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[141] Columella, *DRR* 12.30.
[142] Cf. Pliny, *NH* 14.28.2; 19.19.4; 23.24.
[143] Horace, *Sat.* 2.4.53–54.
[144] Boothroyd (1986): 63–66.

A properly prepared must will clarify spontaneously after fermentation, given enough time, but sometimes a defectively prepared one will not, in which case 'fining' agents can be used to precipitate particles still in suspension. Fining, French *collage*, operates mechanically or chemically. Today agents such as isinglass (a proteinaceous substance derived from the viscera of fish) and bentonite (a powdered clay) are used, as well as egg white and agar. The protein albumin in the organic materials coagulates haze particles in wine and precipitates them, but it also removes tannins and flavanoids and some haze particles are unaffected. Bentonite, a chemical agent made from clay which consists largely of montmorillonite, a hydrated silicate of magnesia from volcanic sand, is not as effective but cannot over-fine a wine.[145] The chemical action of fining agents was probably recognized by the ancients, though scarcely understood; the physical action was well known.[146] Among the astonishing variety of additives prescribed for ancient wines was a type of clay, an agent the Romans had learned from the Greeks.[147] This is nothing more than our bentonite. Albuminous substances used by the ancients included egg white, blood, and milk. Additionally, colloids also precipitate at low temperatures, another way in which the Roman *cellarium* functioned passively in the wine making process.

Infections

As our ancient cellarman checked his wine for clarity, he will also have kept a close watch for the first signs of infection.[148] The ancients were well aware of the mechanics of contagion, if not its causation, and knew simple preventative measures for it. Thus Pliny's injunction that storage dolia be arranged with sufficient space between them not only to facilitate movement of cellarmen but also to prevent contagion.[149] Less sensible are 'tests' he and others prescribe to determine if wine is likely to remain sound and therefore merits

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[145] Austin (1968); Jackisch (1985): 83–86.

[146] Cf. Billiard (1913): 508–09, citing Horace *Sat.* 2.2.58; Frontinus in *Geopon.* 7.27.

[147] Pliny, *NH* 14.24; *Geopon.* 7.12.

[148] For a complete modern analysis, Amerine et al. (1980): 557–81.

[149] Pliny, *NH* 14.27.2; Cf. Florentinus in *Geopon.* 6.2.

aging.[150] The two most frequently mentioned maladies of wine are acetification and 'flower'.

Acetification (*in acetum vertere, acescere, coacescere*)[151] is an unmitigated disaster for the wine maker. Since acetic bacteria such as *Acetobacter aceti, A. pasteurinus, and A. peroxydans* and the *Gluconobacter* species are aerobic, wines are especially susceptible in storage containers poorly topped up or sealed. It is acetic bacteria, of course, which produce vinegars; but typical spoilage organisms of this sort produce ethyl acetate and give a smell like nail polish remover which makes the product unacceptable as vinegar, much less as wine.[152] Acetification is dead easy to diagnose because of the distinctive odors it produces, but despite some bizarre and totally ineffective prescriptions of the ancients[153] acetic infections were (and continue to be) almost impossible to cure. The best 'remedy' is and was proper preventative measures.[154] Since acetic spoilage bacteria are aerobic, the simplest preventative will have been simply ensuring minimal ullage in fermentation and cellaring vessels and careful sealing to exclude air. And like wine yeasts, acetic bacteria require nutrients and are inhibited by high alcohol levels. As previously mentioned, wine lees are a rich source of nutrients, so that frequent rackings and fermentation to a high alcohol level are also effective preventatives.[155]

'Flower' or flor (*flos vini*)[156] is a closely related secondary ferment caused by the organism *Mycoderma vini* which converts ethyl alcohol to CO_2 and byproducts. This is also an aerobic ferment which forms a film on the surface of the wine. At first it forms small islets whose 'floral' shape give it its name; then islets coalesce and oxidize ethanol to CO_2 and water, forming byproducts which include acetic acid. If the mycoderma has completely covered the surface of the wine the resulting off-flavors and odors are impossible to remove, but if it is detected when the first few islets have formed it can be strained or skimmed. The ancients were well aware of this.[157] Pliny considers a white flor a good sign, a red flor a sign the wine will not last.

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[150] Pliny, *NH* 14.26.1; Cato, *Agr.* 108.

[151] Pliny, *NH* 14.26.1; Varro, *RR* 1.65.

[152] Jackisch (1985): 81.

[153] E.g., Pliny, *NH* 14.26; Tarentinus in *Geopon.* 7.16.

[154] Billiard (1913): 531–33; Jackisch (1985): 81.

[155] Austin (1968): 157.

[156] Cato, *Agr.* 11; Columella, *DRR* 12.30; Pliny, *NH* 14.27.3.

[157] Cato, *Agr.* 11; Columella, *DRR* 12.30.

Tchernia explains the distinction; the white flor is nothing more than a 'veil' of Saccharomyces, the sign of a healthy yeast fermentation. In fact, the absence of any flor on a modern fermenting wine is taken as a sign that it has already or soon will acetify. But a gray vinegar flor becomes rosy as it thickens and begins to turn the wine to vinegar.[158] Again, since the ferment is aerobic, the best cure is prevention.[159]

There are other infections of wine. *Lactobacillus trichodes* is a spoilage bacterium that forms mannitols from fructose as well as CO_2, ethanol, acetic acid, and lactic acid. It is especially prevalent in wines of insufficient acidity. Because the bacterium causes increased viscosity of the wine due to polysaccharides formed as a protective covering, wines spoiled by it become so thick that one can dip a finger into it and lift up a 'rope'; thus the name 'ropiness' is applied to it.[160] The condition is described by several of the geoponics,[161] though only Columella offers a preventative in the form of salt added to the wine.[162] The ancients were at pains to add salt below the taste threshold, and salinity at this concentration will have had no appreciable effect on the bacterium, which is famously tolerant of salinity (lactobacilli are regularly used to ferment cheeses, sausages, and fish sauce, as we will see, at the same time salinity in them inhibits spoilage organisms). In addition, some lactic bacteria degrade alcohol to acetoin and diacetyl which introduce a disagreeable buttery taste. *Bacterium gayoni* and *B. intermedium* are spoilage microbes whose metabolytes produce an aroma described as 'mousy'. Additionally, species of lactobacilli such as *L. plantarum* and *Bacillus tartarophthorum* catabolyze the tartrates of wine to produce lactic and acetic acids producing a bitter and/or sour flavor. Pasteur coined the term *tourne* to describe these defects.[163]

Wild yeasts are also a threat at this stage. *Candida vini* and *C. valida* are film yeasts that attack low-alcohol wines and oxidize ethanol to carbon dioxide aerobically and can significantly reduce alcohol levels if unchecked. Especially susceptible are wines made from spoiled grapes. The infection manifests itself as wine which is turbid, jaun-

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[158] Tchernia in Tchernia and Brun (1999): 128–32.
[159] Cf. Billiard (1913): 33–34.
[160] Jackisch (1985): 82.
[161] E.g., Cato, *Agr.* 148; Pliny, *NH* 14.26.
[162] Columella, *DRR* 12.33.
[163] Austin (1968): 154–55.

diced, acidic, and bitter. The most serious threat, however, is lowered ethanol levels, making the wine susceptible to opportunistic infections. Identifying any of these with specific maladies mentioned by the ancients is impossible, though it is clear that in general secondary ferments were a problem, particularly after wine had been racked and thus aerated. Vitruvius says that wine in cellars exposed to excessive southern heat becomes "*confusum et imbecillum*," turbid and weak. And Pliny says that "in certain cellars local wine is subject to secondary fermentation, an accident which strips it of taste; the wine is then called *vapa*."[164] According to the ancients, the wine turns at the time of the rising of the Dog Star or again near the winter solstice, or by the action of violent winds or thunderclaps, and transport by navigation sometimes has the same calamitous result.[165] The relationship of secondary ferments with season is incidental, since these are times when wine is typically racked, and that with violent weather imagined, though it is perfectly true that violent jostling of wine, as in navigation, can bring about secondary ferments in unfiltered wines by disturbing yeast sediments.[166]

There is also a malady mentioned by Pliny[167] and called by him 'cabbage' (*brassica*) which spoils the taste. Pliny recommends that the taste be restored by soaking beet leaves in the wine, a desperate cure. Jones in his Loeb translation opines that perhaps 'cabbage' is a popular term for stale wine beginning to have the taste of cabbage water. In fact, the most likely culprit here is the spore-forming yeast *Dekkera*, still found in some California wineries and imparting an off-odor and taste described today as 'horsey'. Alternately, wines infected by lactic bacteria such as the *Lactobacilli* already described as well as others of this species and *Leuconostoc spp.* and *Pediococcus spp.*, separately or in combination, produce lactic and acetic acids and mannitol which have a distinctly unpleasant smell.[168] The aromas produced are today sometimes described as 'krauty'.[169]

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[164] Vitruvius, *de Arch.* 6.6; Pliny, *NH* 14.25.4; Cf. Cato, *Agr.* 148. *Vapa* is also called *vapidum vinum, vinum mutatum* (Horace, *Sat.* 2.2.58. The term *vapa*, incidentally, is the source of the common ethnic slur by way of Southern Italian slang.

[165] Pliny, *NH* 14.22.2; Paxannus in *Geopon.* 7.10; Fronto Africanus in *Geopon.* 7.12–14.

[166] Cf. Billiard (1913): 534; Jackisch (1985): 80.

[167] Pliny, *NH* 19.135.

[168] Jackisch (1985): 81.

[169] Amerine and V. L. Singleton, *Wine: An Introduction* (Berkeley: U. of CA Press, 1977): 63.

By far the most alarming ancient infection to the modern sensibility is Columella's reference to small animals such as snakes and rodents which fall into the wine, presumably during primary fermentation when the wine is unsealed. But hardly less alarming is Columella's remedy in this instance: the body of the animal is to be removed, burned, and its ashes stirred back into the wine![170]

Other 'maladies' of wine described by the ancients are not so much infections as defects of style or deficiencies of organoleptic qualities, but as such they warrant a mention. Inferior aroma (*odor deterior*) results most often from bad fermentation conditions or defective vessels. Cato has an unusual cure for the latter: heat a piece of roof tile in a fire, then coat it with pitch and attach it to a string before lowering it carefully into an empty dolium which is then sealed for two days, after which the tile is removed, the defective wine poured into the dolium and left for fifteen days and then sealed.[171] *Goût de terroir* (*regionis, agri vitium*)[172] is a condition of wine caused by poor soil conditions and/or mode of cultivation, resulting in wine of inferior taste and bouquet. It can be attenuated but not eliminated. Columella prescribes for it the lees of a good vintage, a dubious solution. Finally, wines which are stored beyond their peak lose their bouquet and and may even become rancid (*caries*) or bitter (*amaritudo*).[173] These defects, particularly the latter, were thought to be peculiar to big, hearty reds such as the ancient Surrentine, typically aged for considerable spans, though, curiously, the ancients apparently did not think of either as capitol defects since they were indicative of great age. Obviously wine snobbery has a long history. Such wines were treated by smoking, a procedure which, Biliiard objects, simply masked the defects.[174]

Modification

At various points during the vinification process wines may be modified by the addition of a bewildering variety of substances both to make it more palatable as well as to improve its stability. Even the

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[170] Columella, *DRR* 12.31.
[171] Cato, *Agr.* 113.
[172] Cf. Columella, *DRR* 12.19.30.
[173] Pliny, *NH* 23.22.2–3; 14.6.3.
[174] Cf. Billiard (1913): 535–36.

most proactive of modern vintners, however, might well be amazed at the degree to which the ancients modified their wine. Billiard has his French sensibilities thoroughly insulted: "Quel gosier ou quel stoîcisme!" But even Billiard distinguishes between amelioration, designed to facilitate preservation, and 'adulteration", by which he apparently means any other treatment not currently accepted by French winemakers of his own day. Even this purist is compelled to acknowledge that the ancients' motives were as often as not their concern to remedy wines made defective by the exigencies of ancient fermentations, since they clearly recognized that 'unadulterated' wines were the most healthful.[175]

A consideration of the myriad forms of modification practiced by the ancients for purely organoleptic reasons would far exceed the limits of this study, but some consideration is in order for those modifications aimed at least in part at making wine more stable. Just such a modification is the application of salt, decried by Billiard as "detestable"[176] but practiced by the Romans, following Greek precedent, as a way both to disguise defects of wine and to render wine more stable,[177] and, incidentally, still practiced in France itself even to this day, where it is thought to preserve the wine, aid in clarification, and enhance taste.[178] Columella, for example, specifically prescribes it for *mucor*, the ropiness described above; the fact that its effectiveness is dubious in concentrations typically prescribed does not in any way detract from the ancients' motives. In the same vein, Palladius says that it aids clarification, and Frontinus ascribes to it the ability to inhibit secondary fermentations.[179] Salt was added in dry form or as brine, the latter in the form of sea water which had been subjected to elaborate measure to ensure its purity, or in the form of a sort of artificial sea water.[180]

Of undoubted effectiveness in rendering wine more stable were modifications designed to correct deficient acidity. Again, acidity is an organoleptic quality expected in wines—wine with severe acid

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[175] Billiard (1913): 489–91, citing Pliny, *NH* 23.22.3. For modern experiments with modification using Columella's recommendations, cf. Tchernia in Tchernia and Brun (1999): 113–7.

[176] Billiard (1913): 500–02.

[177] Cato, *Agr.* 23.2–3; 24; 112; Columella, *DRR* 12.2–3; 12.25.

[178] Tchernia (1986): 105; Tchernia in Tchenia and Brun (1999): 114–5.

[179] Palladius 11.14; Frontinus in *Geopon.* 7.12.

[180] Cf. Billiard (1913): 501–02.

deficiency has a medicinal taste, while one moderately underacidified has a dull, insipid taste and poor bouquet—but a sufficient level of acidity is also second in importance only to ethanol level in maintaining the long-term health of wines. Furthermore, yeast flourishes best in an acidic environment. Desirable acids in wine are citric, tartaric, and malic, as well as lactic acid in a wine style subjected to a secondary malo-lactic fermentation.[181] In this regard a regular, almost prescribed, modification to ancient wines was that of plastering (*gypsatio*), which has a triple action: mechanical, physical, and chemical. It acts as a 'fining' agent by precipitating mucilaginous materials; it enlivens color and limpidity; and it increases in a remarkable way the acidity of wine. Specifically, calcium sulfate (plaster of Paris) is added to a must, calcium tartrate precipitates, and sulfuric acid replaces tartaric acid and overall pH is significantly reduced. But not only are there serious health issues associated with sulfuric acid, but the action of calcium sulphate is unpredictable since it has low solubility and may not react, resulting in too much bitterness; thus the practice of plastering is discontinued in modern wine making in most areas because more reliable acid blends are cheap and readily available.[182]

Obviously the ancients hadn't the luxury of this option, and we suspect that wines in this climate were habitually acid-deficient. Thus plastering of wines is attested in the Mediterranean from the fourth century BCE and was common in Rome throughout the historical period. Palladius and Democritus[183] think it especially good for vintages diluted by rain and add that it gives to wine a premature age and remarkable clarity. Frontinus[184] is struck by its ability to increase acidity. All perfectly valid points. Quantities were carefully modulated by the ancients, no doubt because of the unpredictability already mentioned as well as the fact that plastered wines had a well deserved reputation as unhealthful.[185] Columella recommends that plaster be added in the same proportion as salt,[186] that is, one ounce per amphora, but adds that the proportions should be adjusted accord-

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[181] Boothroyd (1986): 37–8.

[182] Jackisch (1985): 104; Tchernia in Tchernia and Brun (1999): 116–7.

[183] Palladius 11.14; Democritus in *Geopon.* 7.4.

[184] Frontinus in *Geopon.* 7.12.

[185] Cf. Pliny, *NH* 23.24.2.

[186] Columella, *DRR* 12.21.4; 12.20.

ing to the provenience of the wine. Palladius recommends 1–2%, Democritus 1% plaster in conjunction with cooked musts.

Used by the ancients to decrease acidity were marble dust and chalk (calcium carbonate).[187] Pliny again thinks this practice is noxious.[188] Billiard has actually interpreted the practice as designed to improve acidity: "Marble and chalk, although slightly alkaline, actually promote acidity by forming malate and tartrate of potassium and insoluble calcium tartrate which precipitates and leaves tartaric acid."[189] Nothing of the sort. In modern wine making, calcium carbonate is regularly used to reduce acidity; calcium carbonate removes tartrate anions, leaving carbonic acid, which then dissipates in the form of CO_2 and water, leaving no residual acidity.[190]

Also used extensively by ancient winemakers were various spices,[191] though here again we must distinguish those spices used for their organoleptic qualities from those used explicitly for their preservative effects. In the latter case, so-called *vina ficticia*, spices were obviously used strictly as preservatives, since authors go to some lengths to recommend amounts beneath the taste threshold.[192] And of course spices do possess antiseptic powers.[193] The most valued was pitch (*pix*) or resin (*resina*), added directly to the must (this is the same pitch, of course, that was also the main agent for waterproofing wine vessels). The provenience of the practice is unknown, but it was widespread in Italy and indeed throughout the Mediterranean world. Numerous varieties were used: terebinth (turpentine), lentisk, cypress, pine, cedar, umbrella pine, Scotch pine, spruce, larch, mugho pine. Some were indigenous to Italy while others came from the Orient as well as Asia Minor, the Levant, Greece, and Spain. The best was thought to be that of the silver fir (*Abies excelsa*).[194] Pitch was typically

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[187] Cato, *Agr.* 23; Columella, *DRR* 12.20; Pliny, *NH* 14.24; Frontinus in *Geopon.* 7.12.

[188] Pliny, *NH* 23.24.2.

[189] Billiard (1913): 502–3.

[190] Jackisch (1985): 107.

[191] Cf. Billiard (1913): 504–06.

[192] E.g., Columella, *DRR* 12.23. At 12.22 Columella describes an elaborate method for producing pitch for the treatment, having first leached lye through it to remove the resinous odor. Unfortunately, it is these very aromatic volatiles which have the antiseptic powers he is looking for.

[193] Cf. Guido Majno, *The Healing Hand: Man and Wound in the Ancient World* (Cambridge, MA: Harvard U. Press, 1975): 215–27.

[194] Pliny, *NH* 14.25; 16.16–23.

introduced into the must in the course of fermentation, in raw form, cooked, liquid, powdered, or dissolved in *defrutum*.[195] Medical writers thought resinated wines unhealthful, causing headaches and vertigo as well as the malady called *crapula*, the word thus designating both the resin and the 'crapulous' hangover it was thought to promote.[196]

Besides resinous additives, other aromatics used for their presumed (and in many cases actual) preservative purposes were iris, fenugreek, leaf of spikenard, costus, date, angular rush, sweet rush, myrrh, sweet reed, cinnamon, balsam, saffron, aloe, mastic, pepper, gall nuts, roasted cedar cones, and many others.[197] Each could be employed individually or, more commonly, in combination, often mixed with *defrutum* when the wine was chaptalized. Billiard is justifiably astonished by Pliny's injunction[198] to preserve (*condiunt*; the sense is unambiguous) wine with vinegar! On the assumption that Pliny has used the verb in the sense of 'seasoning,' Billiard cites many examples of *posca* (vinegar) as a commercial beverage and so opines that the idea of drinking vinegar by choice was not perhaps so astonishing after all. A 'good' acetic fermentation will have inhibited others which would make the wine undrinkable, and certainly the ancients knew only too well the preservative powers of vinegar.[199]

Perhaps the most drastic, but in many ways the most logical, way to ameliorate deficiencies in a wine, both technical and aesthetic, is and was simply to blend it with another (French *assemblage*).[200] The ancients were perhaps not so sophisticated at this practice as modern *negociants*, but they had come a long way down that path. Pliny, for example, mentions a wine from Marseilles so 'fat' that it was undrinkable and which was therefore used exclusively to blend (*condire*) with other, flaccid wines;[201] the same author recommends that a well

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[195] Cato, *Agr.* 23; Columella, I 12.20; Pliny, *NH* 14.25.3.

[196] Pliny, *NH* 23.24.2.

[197] Cf. Pliny, *NH* 12.41 & 14.25; Columella, *DRR* 12.20.3–6; Palladius 11.14. Cf. Tchernia in Tchernia and Brun (1999): 115–6 (fenugreek).

[198] Pliny, *NH.* 14.24.

[199] Billiard (1913): 506–07. I was equally astounded while researching this part of the study to discover an American product called "Jogging in a Jug" which is nothing more than cider vinegar marketed as a health aid. Naturally I felt compelled in the interest of science to try it. I cannot attest to its powers to substitute for jogging as a restorative, but I was certainly rendered *incapable* of jogging for some time.

[200] Billiard (1913): 509–12.

[201] Pliny, *NH* 14.8.8.

aged wine with pronounced bouquet be blended with a young wine to 'age' the latter.[202] Elsewhere big, heady Falernian is mixed with a sweet 'Chian' style;[203] wine of Erythaea is blended with Hecataean, and a small quantity of Falernian or Formian mixed with a cheap red "to confer on the latter the appearance of nobility."[204] In general, any flabby new wine is refreshed with a transfusion of another, more vigorous wine.[205] The key to blending is to recognize particular strengths and weaknesses of individual *crú*, and the development of a technical vocabulary toward this end is a crude indicator of the degree of sophistication achieved in doing so. Billiard has devised a glossary of Latin oenological terms which indicates that the Romans could speak with some precision about qualities of sweetness, acidity, astringency, smoothness, 'fatness' and 'flabbiness', aroma, and bouquet; on the other hand, they never seem to have used the sort of descriptive language used today to describe the subtleties of these last two qualities, produced in wine by esters and other volatiles (e.g., 'grass', 'flint', 'black currant', etc.). Finally, as to color, the ancients recognized white (*vinum album*), dark (*vinum nigrum*), rosé (*vinum medium*), blood red (*vinum sanguineum*), and tawny (*vinum fulvum* or *vinum croceo colore*),[206] and Pliny cites a practice for adding artificial colorant to wine, "so many poisons are employed to force wine to suit our tastes—and we are surprised that it is not wholesome!"[207]

Aging

After our ancient wine maker has made the best wine he can under the circumstances, he has an important decision to make: whether to age his wine or no, and if so, for how long. The purpose of aging or cellaring is to allow wine to mature by completing the merging of elements in the wine, by developing good bouquet through reaction upon ethanol of acids in the wine to produce esters, and by precipitating excess tannins to eliminate harsh astringency. Aging

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[202] Pliny, *NH* 14.9.1.

[203] Horace, *Sat.* 1.10.24.

[204] Horace, *C.* 1.20.11. We needn't be so cynical about the negociant's motives as the poet.

[205] Pliny, *NH* 23.22.3.

[206] Cf. Aulus Gellius, *NA* 13.30; Pliny, *NH* 14.11.1.

[207] Pliny, *NH* 14.130.

must occur with minimal exposure to air to prevent oxidation, in this case manifested as conversion of ethanol to acetaldehyde, and with minimal exposure to sunlight to prevent loss of color in red wines. Ideal cellaring temperature is 50–60°F (10–15°C).[208]

Almost any stable wine benefits from cellaring, but even bulk storage of wine is an expensive proposition—cellar space, after all, is not unlimited and use of it for aging represents 'capital' that cannot be used for manufacture of new wines. The economic question then becomes one of diminishing returns: does the potential increase in marketability of the aged product justify the increased cost of producing it? The ancient wine maker will have faced the same question complicated by considerations of biological stability; better to sell immediately to the *negociant* even the best of vintages and even at a lower price than wait and be left with well aged vinegar or perhaps something worse. To that end the ancients developed tests of wines' stability, all of the attested ones, so far as I can determine, equally useless. For example, Cato[209] suggests that a small quantity of barley groats be put in a new (i.e., uncontaminated) dish and over this a sextarius of wine poured, the mixture to be next heated three times, the groats strained out and the wine set out in the open until the next morning. At that point if the wine tastes like the original it will keep, but if it has developed a slight sourness it will not. Obviously the barley groats are boiled in the wine to extract a small amount of additional fermentable in the form of dextrose, so the 'test' is not pure fantasy, but boiling the wine three times is likely to kill any spoilage organisms in the original wine, so that 'souring' (which in this case is almost surely acetification) has doubtless been caused by ambient *Acetobacter* or *Gluconobacter* when the wine is exposed to air. The most practical advice comes from Varro,[210] who says that in general all wines should be aged for at least a year before consumption, but that wines from grape varieties prone to sour quickly (presumably, low alcohol wines) must be consumed within the year. On the other hand, he adds, powerful reds such as Falernian are more profitable the longer they are kept. Whether a powerful red aged for over a hundred years, as is attested, will have been particularly drinkable at that point is not a question we can answer. "De gustibus non est disputandum."

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[208] Boothroyd (1986): 81–83.

[209] Cato, *Agr.* 108.

[210] Varro, *RR* 1.65.

Another difference in ancient and modern cellaring practice is the time of bottling. Bottling (*defundere, in amphoras defundere*)[211] corresponded in many ways with modern practice, but whereas today wine is typically aged in bulk, either in stainless steel tanks or in oak casks or both, the ancients often proceeded to this step in the vintage year and then aged in bottle. And whereas today wine goes from stainless steel or oak to glass, the ancients bottled in the same pitched terra cotta, simply in smaller increments. The amphora [Fig. 28] (also *cadus*, apparently interchangeably) was the standard Italian form, the best said to come from Capua, but most probably manufactured right on the estate where the product to be contained therein was created.[212] Often, when destined ultimately for long-distance travel, they were encased in wickerwork of Esparto grass, broom, osiers, or heavy straw in order to absorb shocks. These prototype *fiasci* were called *urnae/amphorae spartae*.[213] In either case, the amphora was filled with wine, stoppered with some organic material such as cork, fennel stalk, or a wooden bung, and the stopper coated with pitch and then smeared with clay or plaster to form a hermetic seal.[214] Then the proprietor affixed his seal to identify the vintage and to discourage theft. If the wine was cellared in bulk, that is, in dolia, it was covered with terra cotta *opercula* and sealed in the same fashion. Koehler[215] thinks that amphoras of wine were stored upright but also on their sides in racks, and for the same reason as corked bottles today: the wine keeps the stopper of the bottle moist so that it doesn't dry out, shrink and crack, thus admitting spoilage organisms. Such a practice may have precedent as early as 3500 BCE at Godin Tepe in central western Iran, where a red residue was found on one interior side of presumed wine jars. Additionally, an appliqued rope motif running across the shoulder of the vessel and along two sides indicate where real ropes are to be applied has been interpreted as chocks to keep the vessel stable on the rack.[216]

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[211] Juvenal, *Sat.* 5.30; *Digest* 33.6.15.

[212] Cato, *Agr.* 135. Cf. M. H. Callender (1965): passim.

[213] Cato, *Agr.* 11.

[214] Columella, *DRR.* 12.32; 12.39; 12.41–42; Horace, *C.* 3.8.10; Persius 4.29. Cf. Philip Mayerson, "Jar Stoppers and the Sealing of Winejars," *Zeitschrift für Papyrologie und Epigraphik* 136 (2001): 217–20 (Egypt).

[215] Koehler (1995): 330.

[216] Virginia R. Badler, "Archaeological Evidence for Winemaking at Godin Tepe," in McGovern, Fleming and Katz (1995): 45–56, esp. p. 50 and Fig. 4.2.

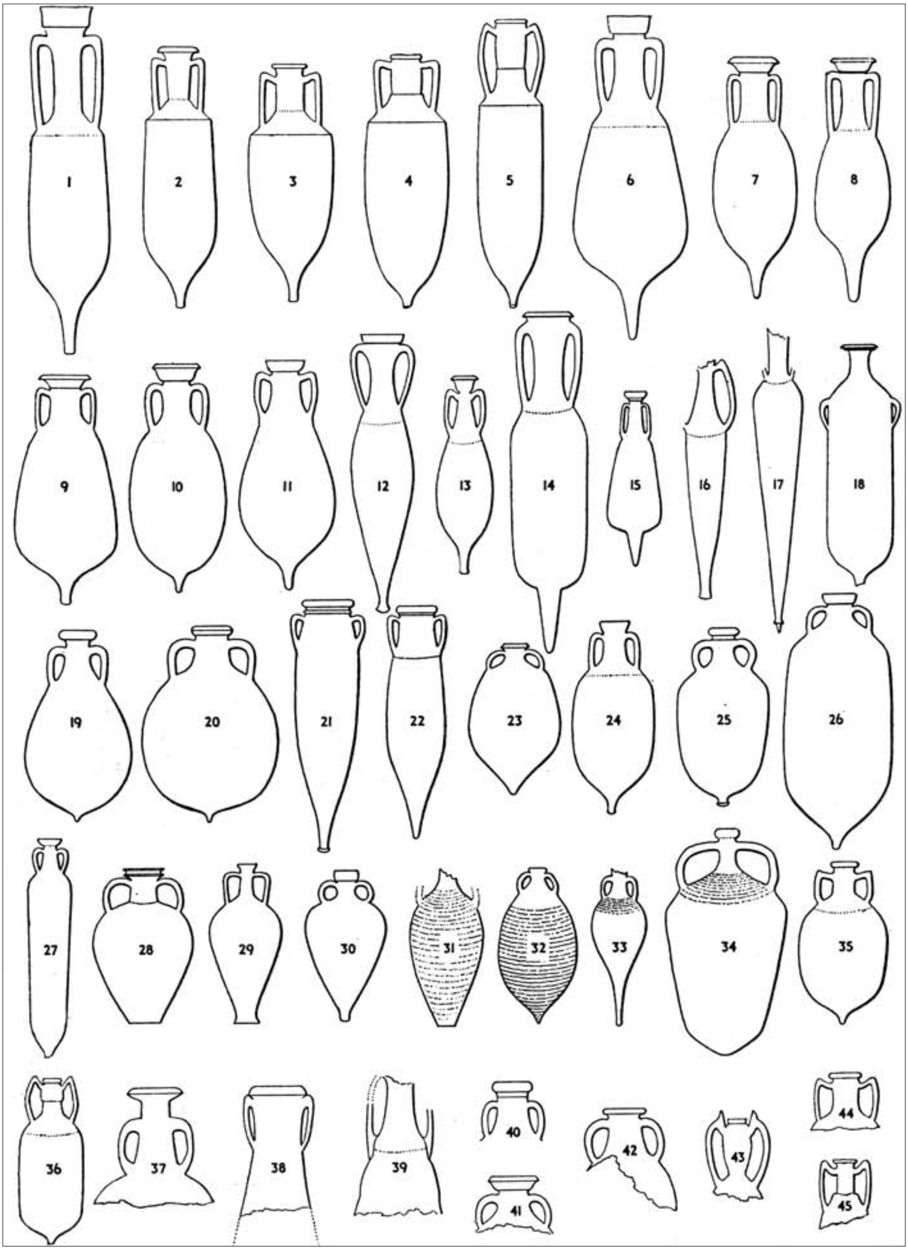

Fig. 28. Dressel's typology of Roman amphorae. (After Dressel, *Corpus Inscriptionum Latinarum* XV, pars II, Tab. II).

There is no evidence that those Roman winemakers who fermented in casks aged their wines in the same casks for the purpose of imparting woody flavors and aromas to the wine, as is true in modern aging in oak. But lack of evidence in this area is almost meaningless. The ancients did have two practices, deplorable to modern sensibilities, designed specifically to enhance the flavor of aging wine, in this case by accelerating the aging process: heating and smoking. A loft in the Greek household, the *apotheca*, became common in Rome under the same name or as the *cella superior*. Originally for all valuables, it gradually became the exclusive storage area for aged wines. Thus the poets speak of bringing *down* an aged bottle for celebrations. Cato doesn't mention the room, confirming Pliny's assertion that the Romans adopted it in 120 BCE.[217] In some cases, he adds, this 'cellar' came to represent a considerable fortune in aged wine.[218] Deliberately sited to receive the smoke of wood fires in the kitchen, the *cella superior* was as a consequence sometimes referred to as a *fumarium*.[219] Once again Pliny deplored the practice of 'aging' wines thus as insalubrious,[220] but wines thus produced were nonetheless valued by gourmands.[221] A room on the eastern axis of a villa rustica on the Via Gabina some 14km east of Rome has been interpreted by the excavators as a possible *fumarium*,[222] although this one on the ground floor. Depressions in the floor will have originally held storage dolia or amphorae. Along one side were rectangular masonry basins in which a quantity of ash was detected. East of the chamber was a raised basin with an *opus spicatum* floor which the excavators tentatively interpret as a treading floor. Thus they conjecture that the rectangular basins were 'smoking racks'.

The purpose of the practice, oddly, was to acidify the wine.[223] A fascinating experiment conducted by Billiard seems to support the efficacy of the treatment. Billiard had several terra cotta amphorae

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[217] Pliny, *NH* 14.16.1.

[218] Pliny, *NH* 14.17.1.

[219] Martial 10.36.1; Columella, *DRR* 1.6.

[220] Pliny, *NH* 23.22.2.

[221] Juvenal, *Sat.* 5.33–35.

[222] Walter M. Widrig, "Two Sites on the Ancient Via Gabina," in Kenneth Painter, ed., *Roman Villas in Italy: Recent Excavations and Research* (London: British Museum, 1980 [= *British Museum Occasional Paper No. 24*]): 127–8. However, 'smoking racks', if such they were, were for aging the wine, not for speeding fermentation. Cf. Tchernia in Tchernia and Brun (1999): 135–8.

[223] Pliny, *NH* 23.22.3; Columella, *DRR* 1.6.

made, conforming as closely as possible to the size, shape and porosity of ancient prototypes, and unglazed and pitched according to Columella's recipe mentioned above. They were then filled with wine, sealed in the ancient fashion, and some were then placed in niches to catch wood smoke, others stored in areas to receive heat but no smoke to serve as controls. The results were suggestive, though hardly conclusive: formic aldehyde, one of the main bacteriostatic elements of wood smoke, was not found in the test samples, even after three years' exposure to smoke. But the percentage of ethanol had decreased dramatically, as much as 50%, at the same time that acidity had increased significantly, to the point that it imparted a pronounced taste. No spoilage organisms were detected in the wine, suggesting that the increased acidity was the result of chemical reaction, not enzymatic activity (e.g., acetification). The ruby color of the red wine had almost completely disappeared, probably oxidized, and had been replaced by a tawny color. The taste, incidentally, Billiard found to be extremely disagreeable.[224]

Related to smoking, but distinct from it, was heating, a sort of crude Pasteurization, as it were. Pasteurization today involves heating the substrate in a sealed, anaerobic container for several minutes to 140–150°F (60–66°C) to kill all microbes, both harmful and beneficial. This heat when applied to wine also develops bouquet which develops naturally only after several years. Ancient practice was therefore not only to confer a false 'age' on the wine but also to conserve it. Heating took place in a loft distinct from the *fumarium* called the *tabulatum*;[225] the ancients knew that too much smoke taints wine, as Billiard discovered. Galen[226] describes in some detail both the action and the place it is effected. This loft was situated to take advantage of active heat from braziers, baths, etc., as well as passive solar heat (i.e., upper, southern exposures). Billiard speculates that in the the summer months the temperature might easily reach 140°F if not more.[227]

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[224] Billiard (1913): 524–26 and n. 6. Tchernia (in Tchernia and Brun [1999]: 142–5) hypothesizes that a change in stoppering from pitched bungs to more permeable materials such as plaster of pozzolana may have led to slow but perceptible differential evaporation os water, which will have left a more alcoholic wine with a pronounced pungency which the ancients valued as an indication of great age.

[225] Columella, *DRR* 1.6.

[226] *de Antidot.* 1.3.

[227] Billiard (1913): 526–28. Cf. Amerine and Singleton (1977): 16.

Other Wines

A specialized type of wine was raisin wine (*passum*), equivalent in some way to highly concentrated German *auslese* wines. Ancient vintagers seem to have harvested very late, by modern standards, to concentrate grape sugars. To further concentrate the sugars, grapes harvested especially late might additionally be raisined for several days before being processed. Several grape varietals were known to conform better to the practice than others.[228] The method of processing is described by several of the geoponics,[229] but Columella's prescription is typical. Citing the Punic geoponic Mago, Columella describes two methods. In the first instance grapes are gathered when dead ripe and dried on hurdles in the sun, covered at night to protect them from dew. When dry the berries are plucked from the pedicles, thrown in a vessel, and covered with best-quality must. On the sixth day thereafter, when the raisins have absorbed the must, they are put in press bags and pressed. Only then are the raisin skins trodden, mixed with fresh must, and then pressed a second time. The resulting must is conducted to fermentation vats and allowed to ferment 20–30 days. It is then strained into clean vessels, covered and sealed in the usual way. The second method requires the use of 'bee-grapes', otherwise unexplained. One wonders if these might in fact be grapes that are botrytized, that is, infected with *Botrytis cinera*, a mold known as 'noble rot' which in dry weather sucks water from the fruit, concentrates sugars, reduces acids, and leads to wines of exquisite quality such as French Sauternes and German beerenauslese wines. Admittedly, this is a bit of a stretch; Pliny explains that 'bee-grapes' are those of which bees are especially fond,[230] presumably because of the highly concentrated sugars. But Pliny is an incorrigible etymologizer, and earlier documents call the grapes *appianus*, not *apiarius*. In any case Columella says such grapes should be hung from poles in the sun until raisined, then removed, plucked from pedicles, and trodden in a peculiar fashion: a layer of raisins is covered with old wine and trodden, then another

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[228] Vergil, *Georg.* 2.93; Pliny, *NH* 14.11.

[229] Columella, *DRR* 12.39; Dioscorides, *de Mat. Med.* 5.9; Pliny, *NH* 23.22; Palladius 11.19; Didymus in *Geopon.* 7.18.

[230] Pliny, *NH* 14.24.

is poured over these, covered again with old wine and trodden in the same way, and then yet a third layer treated in the same way. After five days of maceration and primary fermentation the mixture is trodden again and processed in the usual fashion.

Such wines were quite sweet, perhaps suggestive of modern *vin santo*. High sugar concentrations themselves inhibit yeast fermentation, and ethanol levels will have reached concentrations sufficient to stop fermentation completely when residual sugars were still quite high. This reminds us that the Romans were fond of sweet wines. But in the absence of sterilizing agents such as are used today to kill yeasts before all sugars are spent, the ancients were generally forced to allow fermentation to take its course and then sweeten their wines at the point of consumption.

An excellent example of the genius of ancient peoples in finding uses for almost every byproduct is the fact that not even the press refuse from the vintage was without its uses. Cato, for example,[231] says that this refuse (grape skins, seeds, and stems, modern *rape* or *marc*, Latin *vinacea*) is sifted, trodden, placed in pitched vessels, carefully sealed, and kept for winter livestock fodder. Marc was also used to make a thin wine (French *piguette*, Latin *lora*; the alcoholic beverage also called marc is actually distilled *piguette*, but the ancients did not regularly distill and may not have known of the process). This wine was given to the use of the household slaves under the generic term *vinum operarium*.[232] Marc was macerated in prescribed proportions of water to make, incredibly, two grades of this otherwise low-grade product, one from a 1:10 marc to water ratio, the second from a 1:3 ratio. Cato also describes a product (one hesitates to call it wine) made in a similar way from lees and thus called *vinum faecatum*, which are placed in olive frails, pressed, and presumably fermented in the usual way. All will have had extremely low alcohol concentrations and are said to have lasted only a year (*annotina*), two at most if treated with the addition of the foam of *sapa* and *defrutum* production and good wine lees.[233]

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[231] Cato, *Agr.* 25.

[232] Cato, *Agr.* 57; Varro, *RR* 1.54; Pliny, *NH* 14.12.1.

[233] Cato, *Agr.* 147; 153; Columella, *DRR* 12.40.

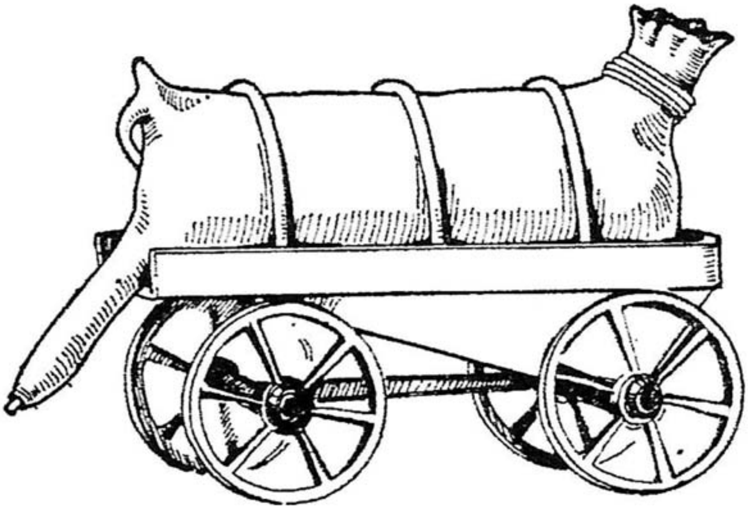

Fig. 29. The original *culleus*, the skin of an ox used as a container for bulk liquids. Here it is mounted on a wagon for transport. The *culleus* ultimately became a standard liquid measure. (From White (1975): Fig. 38: Courtesy of Cambridge University Press).

Tapping

The final stage of the wine making process was the spring tapping of bulk wine not previously bottled as described above, and preparation for shipment.[234] At the beginning of spring when aging has progressed and the winter chill of the cellar has 'cold-stabilized' the wine, the ancient vintager samples his product to evaluate its merits and decide on further aging or sale to the *negociant*. In fact, a religious festival, the *Vinalia* of April 15, marks this important event. Tapping (*diffusio*) also separates the wine from any residual lees.[235] The ancients, thinks Billiard, were especially anxious to rack the spring wine from lees before it was exposed to summer winds, obviously because the heat associated with these southerlies encouraged secondary spoilage fermentations. Wine was thus racked from dolia to amphorae and sealed in the way described above. At this point wine might also be transferred in bulk to the *negociant*, and Cato

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[234] Cf. Billiard (1913): 487–89.

[235] Foroaster in *Geopon.* 7.6.

describes an ingenious method for transferring fixed measures to the *negociant's* huge wineskins. A vat (*lacus*) is made with four handles at its top so that it can be lifted. There is also a hole at the bottom of one side into which a stoppered pipe is fitted, and the *culleus* level marked on an inside wall. The vat is placed on a platform, filled to the *culleus* level with wine, then unplugged and piped into the negociant's bulk vessel [Fig. 29]. In such ways does wine make its way to and from all parts of Italy and the Roman world, and especially to the city of Rome itself, where it is drunk in huge quantities.

CHAPTER FOUR

LEGUMES, VEGETABLES AND FRUITS

Thus far the Mediterranean Triad of grains, olives, and grapes, the staples of the ancient Roman diet, supplying the basic fuels—fats and carbohydrates. But man does not live by bread alone—nor oil nor wines either, at least not for long, or very satisfactorily. Fats and carbohydrates are critical elements in the human diet, but complete proteins, vitamins, minerals, and trace elements must be supplied otherwise and are every bit as vital to maintenance of long-term health as are the basic staples.

Many of these elements are supplied by legumes, vegetables and fruits. The Romans were heirs to a long and distinguished history of horticulture and were avid horticulturists themselves. A modern Westerner transported to archaic Rome would be struck by the variety of fruits and vegetables *not* available to the Roman peasant; but by the end of the classical period, most of the products of the garden and orchard to be seen on the modern Western table had been introduced at Rome, had been cultivated by the Romans, and had been bequeathed by them to much of western Europe, at least as exotics. The exception was New World introductions such as tomatoes, potatoes, certain squashes and beans. It was particularly in the first two centuries of the common era that most of the fruits and many of the vegetables common in the West today were introduced to Rome, where cultivation quickly followed.

Obviously, given such a variety of products, our approach in this portion of the study will need to be more generic. Thus we will examine the categories of legumes, vegetables, and fruits from the standpoint of standard food processes utilized for their preservation in antiquity. Fortunately, the processes *are* so standard that the approach does very little violence to the evidence. To reiterate somewhat, plant products can be stabilized within the limits of ancient technology by dehydration, including reverse osmosis, by acidification, and by metabolic processes. The corresponding food processes are drying (desiccation), curing, pickling, and various forms of fermentation. Obviously, there is nothing mutually exclusive about any of these processes, and it is quite common for several or even all the processes to be utilized on the same product.

Legumes

That is not the case with legumes,[1] which were desiccated almost exclusively by the ancients, as would be expected. As noted before, the ancients classed the legumes as cereals, as well they might. Physically, legumes, like cereal grains, are seeds which nature has designed for long-term storage of germ nutrients by way of desiccation. And nutritionally legumes, again like cereals, are important sources of carbohydrates and proteins. Thus legumes have been processed by humans since the beginnings of agriculture with cereals, and, following nature's lead, in much the same way.

Legumes, at least in the sense in which we use the term here, are flowering plants whose fruit grows in pods containing two to ten seeds. Legumes are differentiated as high-oil/high-protein (e.g., lupine) and moderate-protein/low-oil (e.g., peas, lentils, and beans of the *Phaseolus* group). The latter, which have protein content of 17–30% and oil content of 1% or less, are more important as foodstuffs. Starches are also often present. Legumes harbor symbiotic bacteria, *Rhizobium leguminosarum*, in characteristic nodules along the roots, which fix nitrogen in the soil, and are thus an excellent rotation crop for the cereals which rapidly deplete nitrogen. Furthermore, their vines and pods make excellent fodder for livestock. They are high in the protein lysine and are therefore an ideal adjunct nutritionally to cereals which are low in this essential amino acid. But they have certain nutritional disadvantages. For one thing, legumes are not as digestible as cereals, and flatulence is caused in part by certain indigestible sugars in them. For another, there is moderate toxicity in some, including the standard broad or fava bean of Roman antiquity. This toxicity may manifest itself as a genetically determined sensitivity (favism) to the hemaglutenins in this bean. The condition is found not uncommonly in Mediterranean countries—in modern Italy, especially in Sardinia—and may be fatal in children.

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[1] Kimberly B. Flint-Hamilton, "Legumes in Ancient Greece and Rome: Food, Medicine or Poison?" *Hesperia* 68.3 (1999): 371–85.

Additionally, the chickpea causes lathyrism, a disease caused by eating plants of the genus *Lathyrus*, the vetch family, and characterized by irreversible muscular weakness and paraplegia.[2]

Legumes known from classical Rome[3] are chickpeas, lentils, peas, lupins, fava beans, two types of vetch (used as fodder), fenugreek, mustard, sesame, and the as-yet unidentified *ocinum*. Because of their physical and chemical similarities to cereals, legumes were processed in much the same way. Pliny[4] advises that the fava is harvested and processed in early summer, as is typical of legumes. Like cereals legumes have husks, in this case pods, which must be removed, as well as a tough outer bran which may need to be removed as well. Columella[5] describes a rather peculiar method of threshing favas: loose sheaves of the beans are piled at one end of the threshing floor and then are pushed by three of four men with their feet (in clogs, as for olives) along the length of the floor to the other end where the stalks, now stripped of beans, are piled separately and the process repeated. Fine chaff still adhering to the beans is "winnowed" without the need for wind by simply tossing them some distance in the air with winnowing forks. Because the chaff is so much heavier than the beans, it falls well short and is easily separated. Lentils and vetches are threshed somewhat differently. Pliny, citing Mago,[6] says that these legumes must be roasted, presumably in their pods, then soaked in water and dried (tempering again), then mixed with bran or fragments of baked brick and a half-modius of sand and lightly pounded. Obviously the clay and sand provide grit to facilitate threshing and will have been sifted out afterwards. Sesame is steeped and dried, then thoroughly brayed, then dropped in a vessel of water so that chaff floats to the surface and can be removed. Then the seeds are spread out on a linen sheet and dried quickly to prevent fermentation, this latter recognizable by a livid color.

Once threshed and dried, the two threats to the stability of legumes, as of cereals, are molds and vermin, especially weevils and rodents. The ancients forestalled both threats by sealing their legumes in

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[2] Mullen and Tobin (1980): 140–150.

[3] Spurr (1986): 103–117. Spurr makes a convincing case that the fava bean had become the most widespread legume in Italy by the Roman period.

[4] *NH* 18.257.

[5] Columella, *DRR* 2.9.12–13.

[6] Pliny, *NH* 18.98.

amphorae. Apparently the process could be quite effective; Varro[7] is our authority for the fact that beans and other legumes stored in carefully sealed oil vessels could keep for quite a long time. He reports that fava beans stored in this manner in a certain cave of Ambracia stayed good from the age of King Pyrrhus of Epirus until the pirate campaigns of Pompey the Great, a span of about 220 years!

In the same passage, Pliny reports that chickpeas stored in bulk do not breed pests (*bestiolae*), a claim with some degree of credibility, since the dried chickpea has an incredibly tough bran. He says that otherwise there are those who pile heaps of legumes on pitchers underlain with ashes and smeared with pitch and containing vinegar, in the belief that this prevents pests from breeding. The ashes and terra cotta will have kept the seeds dry enough, and the aromatic pitch will have had some deterrent effect on the pests, but the practice sounds dubious in general. Others, Pliny says, put legumes in fish-pickle amphorae which they seal with gypsum—a perfectly sound practice. Still others sprinkle lentils with a mixture of vinegar and asafetida (*silphium*) and dress them with oil when dried. Again, this sounds like perfectly sound practice; vinegar will have inhibited molds, and asafetida, adored by the Romans as a condiment, as we will see, has a pungent odor which will have discouraged vermin.[8] So far, Pliny is doing quite well, or perhaps we should say his sources are. Unfortunately Pliny doesn't quit while he's ahead, insisting that the quickest and easiest preventative of pests is simply to harvest at the new moon.

The use of vinegar sprinkled directly on the lentils, as reported by Pliny, might be described as a sort of pickle, and the same process is also reported by his predecessors, Cato and Columella.[9] To preserve lentils, Cato recommends that they be moistened with a pickle of vinegar and asafetida (*laserpicium* in this case) and dried in the sun. Columella says that lentils are first dried in the sun, then sprinkled and rubbed with bruised root of *silphium* mixed with vinegar, then dried again. They are then cooled and stored in bulk in bins if the

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[7] Cited by Pliny, NH 18–73.307–08.

[8] The Medieval apothecary name for asafoetida was Stercus Diaboli, 'Devil's dung', a name richly deserved in my opinion, though the pungent, sulphuric odor disperses in cooking and the herb leaves a delicious, subtle flavor.

[9] Cato, *Agr.* 116; Columella, *DRR* 2.10.16.

quantity is large, perhaps mixed with ashes, or in discarded olive or salt-fish amphorae if the amount allows. Sealed immediately with gypsum in such vessels, he says, lentils will stay good indefinitely.

Vegetables

Thus legumes are typically threshed and dried and stored carefully either in bulk or in sealed vessels, having sometimes been subjected to a type of dry pickle. For other plant products such as fruits and vegetables the process used depended largely on the point of origin on the plant; the processing for all root vegetables, for example, or stalks, or leaves, or fruits, is largely determined by the physical characteristic of the product itself. Root vegetables, for instance, are designed by nature for long-term storage of nutrients, since they, like seeds, are the 'pantry' for the future germinating plant. The difference is that here the new growth germinates from the root itself. In fact, it is perhaps not strictly proper to speak of 'processing' such root vegetables at all, since they have the invaluable attribute of remaining fairly stable in a cool, dry storage area and can be kept in this way for months.[10] In fact, in loose, dry soil they may simply be left intact during the winter and 'harvested' at will. Root vegetables known to the Romans included turnips, rutabaga (navew), onion, garlic, leek, chive, shallot, carrot, parsley (the Romans used both leaf and root), horseradish, parsnip, radish, squill, taro, gladiolus, and asphodel, and probably purse tassel, rampion, salsify, madder and elecampane as well. So important were such root crops in the survival of the poor that it is probably fair to say that they were the third most important subsistence crop in ancient Rome, next to cereals and legumes.

It should come as no surprise that the geoponics have little to say about dry storage of most of the aforementioned root vegetables; storage of such subsistence crops is common knowledge in preindustrial societies and therefore not worthy of discussion. And we might add in passing that for fruits and vegetables in general it is clear from even a cursory examination of the testimonia that the

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[10] Cf. Don Brothwell and Patricia Brothwell, *Food in Antiquity: A Survey of the Diet of Early Peoples* (Baltimore: Johns Hopkins Press, 1969): 109–16; André (1961): 15–22.

geoponics were largely concerned to describe the processing of items newly introduced in their own times, whereas later writers simply follow their leads with an occasional addition. In any case, dry storage is described by our authors for garlic, onion, turnip, and rutabaga, and may be inferred for most, if not all, the other root crops as well. But authors also describe various ways in which dry storage might be improved. For example, roots can be partially dehydrated and then reconstituted at the time of consumption. Thus Pliny says[11] that turnips will last almost until the next harvest if spread out to dry before storage. To prevent germination, garlic and onions may be soaked in warm brine and then hung over a fire to dry. Both may be stored in chaff to maintain low moisture content.[12]

Root crops were stored as pickles and conserves as well, particularly, no doubt, for export to urban markets. Some such processing of root vegetables must have been necessary in this case, since long-distance transport of fresh produce was simply impossible in the Mediterranean due to the climate, costs, risks, and slowness of transport. André[13] argues that processing was even more necessary in the countryside, where subsistence diets in the wintertime were probably the norm. Root vegetables were preserved in brine, in vinegar, in honey, in some combination of these, and/or in oil. Brine appears in three strengths: *aqua salsa* (salted water), *muria* (brine) and *muria dura* (hard brine). Some idea of the relative concentration of each can be deduced from Columella's formula for hard brine.[14] A wide-mouthed dolium is placed in the sunniest available spot filled with fresh rainwater or, if this is unavailable, with spring water of a sweet flavor. White salt (the Romans used several varieties of salt, as we shall see) was placed in a rush or broom basket and lowered into the dolium. The supply of salt was replenished as long as it continued to dissolve. A way to test the concentration was to place on

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[11] Pliny, *NH* 18–127.

[12] Pliny, *NH* 19.34.115–16; 19.32.106. In some parts of the world carrots and parsnips are still stored whole in sand or in straw layers earthed over to form mounds or in pits in these layers in sand. Carrots so stored last 10–12 months if carefully layered. Any root vegetable will benefit from a dusting of ash or lime before storage. Taro is best left in the ground and can last as long as 2–3 years in soils where there is no serious root-rot problem. Cf. Bill Mollison, *Ferment in Human Nutrition* (Tyalgum, Australia: Tagari Publications, 1993): 81–84.

[13] André (1961): 46–49.

[14] Columella, *DRR* 12.6.1–2.

the surface of the brine a piece of fresh cheese; if it floated, the brine was ready.[15] Columella advises that the brine be immediately distributed to pitched amphorae if the dolium is otherwise needed, and kept covered in the sun to prevent mustiness and impart a pleasant odor.

Columella's formula for pickling a variety of onions may be taken as typical for other root vegetables:[16] the bulbs are dried in the sun, cooled, packed in amphorae with thyme and marjoram spread underneath them, and covered with a pickle of three parts vinegar to one part brine. Marjoram is packed on top to keep the bulbs submerged, and as the desiccated onions absorb brine, more is added as needed. For pickling turnips and rutabagas Columella recommends a slightly different procedure.[17] Best turnips or rutabagas are chosen, pared of their outer skin, incised with an 'X' "in the usual way" (probably on the butt or root end), being careful not to cut completely through the bulb. Then the incisions are sprinkled with salt and the bulbs allowed to exude moisture for three days. Then they are washed "in their own juices" or in hard brine, placed in baskets with a 'follower', a board cut to fit on top, and weighted for twenty-four hours, to force even more exudation, then packed in pitched dolia or glass vessels, into which a mixture of mustard and vinegar is poured. Elsewhere Pliny[18] laments that leeks had become so fashionable that Nero once decreed he would eat nothing else but leeks preserved in oil on certain days of each month, as a restorative for his voice. How exactly Nero's voice coach prepared this preserve Pliny unfortunately does not explain. Presumably the leeks were pickled first to preserve them and then covered with oil to provide an anaerobic environment.

Leaf vegetables are a universal element of diet but never a staple, first because they lack storage nutrients such as starches, proteins, or fats, and second because they are characterized by highly unstable

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[15] Aglaia Kremezi in her book on Greek cuisine [*The Foods of Greece* (New York, 1993):22] describes an analogous empirical method for making hard brine: "To test if the brine [for pickling olives] was right, a whole egg was thrown in, and if a part about the size of a small coin called a *dekara*, roughly the size of a quarter, floated above the surface, the brine contained the right amount of salt You can use a less salty brine, but then you must keep the olives in the refrigerator."

[16] Columella, *DRR* 12.10.

[17] Columella, *DRR* 12.56; cf. Palladius, *DRR* 13.5.

[18] Pliny, *NH* 19.105–07.

protoplasmic proteins rather than so-called storage proteins. They are also subject to rapid wilting and oxidation because of their relatively large surface area. The one exception to the norm is cabbage, a staple in certain areas where it is subjected to a lactic fermentation to produce sauerkraut.[19] But we have no evidence that the Romans ever utilized this process, despite their extreme fondness for cabbage. That is not to say that the Romans never processed greens, of which they recognized as edible a plethora: beets (grown for their leaves, not the root), red and white chard, cabbage, kale, broccoli, mustard, dock, nettle leaves, mallow, chervil, orach, lettuce, endive, chicory (arugula), rape, purslane, watercress, and wild sparrage.[20] Apicius prescribes a pickle for endive of brine, a little oil, and chopped onion.[21] Pliny[22] assures us that lettuce became so popular after the physician Musa's famous cure of Augustus using it that a way was subsequently found of preserving it "even into months when out of season," by pickling it in honey and vinegar. Pliny also describes a brine pickle: the lettuce leaves are salted in a basin to begin exudation, then dried, then packed in vessels layered with shoots (of what he does not say), to which a pickle of two parts vinegar and one part brine is added, the whole then pressed down with a fennel stopper to completely submerge the leaves. Pliny prescribes the same method for chicory, tops of rue, tops of thyme, savory, marjoram, and wild radish shoots.

The modern reader may be intrigued by this last item. The Romans, as are many of their modern Italian descendants, were very fond of stalks of plants, particularly young shoots of plants which became inedibly fibrous when larger. Besides wild radish shoots the Romans ate asparagus, though they used the term in the generic sense of 'sprouting vegetable' and included in it modern wild and cultivated asparagus as well as cabbage shoots, butcher's broom, whitevine, charlock, fennel stalks, gourd shoots, strawberry shoots, rue stalks, house leeks, and wild hop shoots.[23] Additionally, the Romans ate grape vine shoots, cardoons, celery, fennel-giant, rest-

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[19] Mullen and Tobin (1961): 170–71.
[20] Cf. Brothwells (1969): 17–27.
[21] Apicius 3.18.
[22] Pliny, *NH* 19.38.128.
[23] Brothwells (1969): 117–27.

harrow, and artichoke stalks. Of these we have attestation that cardoons were preserved in honey diluted with vinegar and flavored with laserwort and cumin (lest there be even a day without cardoons, Pliny sneers),[24] that fennel-giant was preserved in brine and honey,[25] that rest-harrow shoot was pickled in brine,[26] and that grape vine shoots, otherwise boiled and eaten fresh, were pickled in vinegar and brine.[27] Doubtless many others were preserved in similar fashion.

Many of these vegetables probably underwent a lactic fermentation, though the fact is obviously beyond recovery. Today in traditional Indian pickling, for comparison, spontaneous fermentation in high-moisture vegetables under brine is proved experimentally for cucumbers, cabbage, turnips and olives. Agents are the standard lactic acid bacteria (LAB), initially Leuconostoc species and *Lactobacllius brevis*, followed by *L. plantarum*, Pediococcus, Enterobacter and Klebsiella species. As pH drops, yeasts begin to dominate.[28]

Fruits

The Romans also ate a tremendous variety of fruit, and the literary evidence is extensive here because Roman agronomists were arguably the first people in history to put the orchard on a systematic basis; they were certainly the first to selectively cultivate exotic species and varieties and to actively seek out new species for this purpose. During the classical period many of the most common fruits on the modern Western table were introduced to the West by way of Rome: peaches, sweet cherries, quinces, pomegranates, citrons, oranges, lemons, and several varieties of nuts, to name but a few. We have every reason to believe that fruits also played a prominent role in the Roman diet as well.

The Romans carefully selected varieties for their potential for whole storage, but they also pickled, conserved, and dehydrated their fruits,

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[24] Pliny, *NH* 19.63.

[25] Pliny, *NH* 20.96.260.

[26] Pliny, *NH* 27.29. Assuming Pliny refers to the shoots, for the food use of which there is attestation elsewhere. The root is used as a medicament.

[27] Pliny, *NH* 14.23.119.

[28] R. Sankaran, "Fermented Foods of the Indian Subcontinent," in Wood (1998): 779.

the last named process being the most evident, especially for the pomes. As we have seen, drying is probably the oldest form of food preservation. Primitive man learned empirically that certain foods such as cereal seeds and legumes when dried while still attached to their stalks were stable for long periods, and he developed analogous drying techniques for preservation of other plant products, meats and fish. Gradually he learned to extend the technique to high-moisture fruits. Fruits which mature with high sugar content and low moisture, e.g., figs and dates, are especially likely candidates for desiccation; the high sugar content retards spoilage until the water activity makes the fruit quite stable. But gradually man learned to control factors influencing the migration of moisture from the interior to the exterior of foodstuffs, such as hot wind, and of the final water activity level necessary to achieve stability. For example, a naturally occurring barrier to moisture transfer occurs on the epidermeis of many fruits in the form of a waxy 'bloom'. But this can be eliminated in the case of many berries and pomes by dipping the fruit in a dilute alkali solution and/or in very hot water. The ancients had clearly discovered both techniques and often used them together. Furthermore, systematic, large-scale dehydration of most fruits can only be achieved in climates with relatively high temperatures and low humidities where rainfall is extremely rare during the fall harvest; even today the central California valleys and the Mediterranean are the two areas with the most nearly ideal conditions.[29] On the negative side, sun drying causes extensive loss of carotene and Vitamin C, the loss of carotene being on the order of 80%. Losses in most fleshy vegetables are comparable.[30]

As noted above, from the first century CE, the Romans had access to a variety of fruits. Among the most common berries available were mulberries (after Varro's time), blackberries, myrtleberries (used as an aromatic), cornelberries, serviceberries, grapes, and olives. Fleshy fruits included apples (at least thirty-six varieties by Pliny's time), figs, pears (five varieties in the time of Cato; by Columella's time they were too numerous to catalog), quinces (introduced before 220 BCE), pomegranates, a variety of plums, cherries, apricots (from c. 50 CE),

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[29] M.A. Joslyn, "Food Processing by Drying and Dehydration," in Heid and Joslyn (1967): 345–55; Troller and Christian (1978): 115–16.

[30] Desrosiers (1970): 142.

peaches (from the first century CE), jujube, carob (from the time of Columella), citrons (an exotic whose date of introduction is uncertain), bitter oranges and lemons (also from the first century CE), dates (as imports only), cucumbers, gourds, and melons. Among the nuts available were acorns (used both as a nut and as a cereal), hazelnuts, chestnuts, beechnuts, almonds, pistachios (but only as an expensive import), walnuts, and pinenuts.[31]

Among the berries, grapes were the most common table fruit. Grapes were stored whole by the Romans, were dehydrated (i.e., raisined), and were conserved. For all three processes, the fruit had to be in perfect condition since, as we have seen, any broken fruit will quickly initiate a spontaneous fermentation. Cato and Varro[32] advise the *vilicus* to see that the harvesters select the most perfect grape clusters for preservation as table fruit. Columella[33] recommends that *uvae bumasticae* (hard-skinned or, alternately, purple grapes in clusters) be cut and their pedicles immediately dipped in pitch, obviously to retard moisture loss and enzymatic action. When Columella says "immediately" he means it; the vessels of pitch are to be carried into the vineyard to be close at hand. Elsewhere Columella reports[34] that 'the ancients' selected Sircutulan, Venuculan, larger Aminean, and Gallic grape varietals, obviously varietals with thick skins, as well as others with large, hard berries which were loosely clustered. The grapes were gathered before they were dead ripe when the weather was warm and dry (and the moon was waxing, of course!). In his own day, Columella adds, Numisian grapes were preferred for whole storage, doubtless for the same reasons.

Grapes thus selected had to be refrigerated under very dry conditions to prevent molds. Additionally, whole fruits such as this were often sealed in vessels. If the fruit was perfectly dry and sound, sealing in tight vessels in cold, dry storage will have been quite successful, since such fruit continues to respire CO_2 and a concentration of 20% or more will inhibit spoilage. CO_2 storage of fruit in sealed containers is still used today but is very expensive.[35] Cato[36]

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[31] Brothwells (1969): 30–47; André (1961): 42–43.

[32] Cato, *Agr.* 25; Varro, *RR* 1.54.2.

[33] Columella, *DRR* 12.44.

[34] Columella, *DRR* 12.45.

[35] Jennifer Stead, "Necessities and Luxuries: Food Preservation from the Elizabethan to the Georgian Era," in Wilson (1991): 90.

[36] Cato, *Agr.* 7.2.

recommends grapes be placed in pots (doubtless sealed, though Cato omits the detail) which are in turn placed in dolia of wine-press refuse (*vinaceis*) to maintain constant temperature and moisture content. Varro[37] specifies small pots for the purpose (*secretam corbulam*), or dolia filled with *vinacea*, or pitched amphorae, carefully sealed and submerged in a pond or placed in the larder. Columella[38] says that the clusters treated as described above are placed on hurdles so that they don't touch, taken indoors, carefully sorted, and three or four clusters packed in vessels which are carefully stoppered and sealed with pitch. Then *vinacea* is strewn on the bottom of a dolium and a layer of pots arranged over this, upside down, with enough room between so that more *vinacea* can be packed between them. Several more layers of pots are created in this way and then *vinacea* packed up to the brim of the dolium which is then covered and sealed with a mixture of ashes and gypsum. Quite ingenious, really; the *vinacea* will have provided insulation and moisture control and the dolium, buried, I think we must assume, will have kept this carefully insulated 'refrigerator' at a fairly constant 55°F.

A second arrangement is also carefully described[39] which Columella attests will preserve whole grapes as much as a year. Carefully selected grapes are treated with pitch as above and are placed in a basin (*labella*) of completely dry chaff, sifted and free of dust. The basin is covered with an identical basin, inverted over it, and sealed with a mixture of clay and chaff. The pans are then carefully arranged in the driest loft and covered over with dry chaff. Columella tells us his own uncle had sealed grape clusters in trays in this way and had submerged them in a cold cistern or in spring water to refrigerate.

A third arrangement described by Columella combines elements of both; this time *defrutum* is poured in the bottom of a pitched dolium, a rack constructed over it, and the pans treated as above placed on the rack, constructed in tiers as above. Then the lid of the dolium is pitched and treated generously with *defrutum* and covered and sealed with ashes (mixed with gypsum?). Alternately, grape clusters are hung from the racks in the dolium so as not to touch each other or the *defrutum*, or a layer of barley bran or dry sawdust

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[37] Varro, *RR* 1.54.2.

[38] Columella, *DRR* 12.45.

[39] Columella, *DRR* 12.44.

of poplar or fir, or flower of gypsum is strewn on the bottom of the dolium, a layer of grape clusters arranged upon this, covered with barley-bran 'insulation', and the layering repeated. Perhaps most ingenious is a technique in which tiny pitched vessels are constructed to enclose individual clusters attached to the vine, their lids constructed in two parts to be placed around the pedicle and then carefully sealed.

Desiccation of grapes is quite challenging; grapes have a high sugar content, as we have seen, but they also have a high moisture content, unlike dates and figs, and are therefore highly susceptible to metabolic action. Grapes may be partially raisined on the vine to prevent this, but the best antidote is simply rapid dehydration. Columella[40] describes an ingenious method for achieving just that. Whitest grapes of the highest sugar content, carefully selected for large, loose clusters and picked during fine weather, are spread briefly on boards, but loosely, to avoid bruising. Meanwhile a solution of boiling lye water is prepared and clusters dipped into the solution until discolored but not cooked in order to remove the wax of the skin. These clusters are then meticulously arranged on hurdles so that they don't touch and are allowed to dry. When moderately dry they are stable because of their high sugar content and are then stored in sealed vessels in a dry place. An interesting variation is reported by Cato,[41] who says that Duracinian (literally, "hard-berried) and large Aminean varietals are hung on hurdles to raisin and are then smoked in the blacksmith shop. The practice seems to have persisted, witness Horace's[42] reference to "properly hardening the Alban grape in smoke." One wonders how smoked raisins might taste. Grapes were also conserved in concentrated grape concentrates such as *sapa, defrutum*, and *lora*,[43] though the practice was such a commonplace that our authors make little reference to specifics. Apicius[44] also gives an odd recipe for preserving grapes in water. Perfect grapes are immersed in rainwater which has been boiled down by a third, sealed with plaster in pitched vessels and kept in a cool, shady place.

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[40] Columella, *DRR* 12.16.1–3.

[41] Cato, *Agr.* 7.2.

[42] Horace, *Sat.* 2.4.72: Rectius Albanam fumo duraveris uvam.

[43] Cato, *Agr.* 7.2.

[44] Apicius 1.12.8.

When the grapes are removed for use the water itself can be used as a medicament.

There is good reason to believe that, historically, pickling of table olives may have preceded oil production in the domestication of the tree, because of the low ratio of oil to vegetal water for feral olives (1:20 or less), making the capitol-intense production of oil unprofitable.[45] During our period, preserving olives as table fruit involves a completely different set of problems from other fruits, naturally, since they are high in fat content and have virtually no sugar. Specifically, as we have seen, the challenge is to maintain the highly unstable fats in a stable condition while removing the vegetal water, *amurca*, which otherwise rapidly spoils the fruit. One solution is simply to process the fruit in the same way as for oil up to the stage of pressing in order to make olive relish. For green olive relish, Cato recommends[46] that olives be picked right before they begin to darken, then pulped in the usual way and then soaked in fresh water. This part of the processing relies again on differential osmosis; because the aqueous amurca is denser than the oil it diffuses into the water, which Cato recommends be changed frequently until the olives are "well soaked", at which point the water is pressed out lightly and the olive pulp mixed with vinegar, olive oil, and a half-pound of salt per modius of olives, along with fennel and mastic. Mastic, a resin extracted from the mastic tree, *Pistaccia lentiscus*, a small tree or shrub indigenous to the Mediterranean, has powerful bactericidal properties and an aroma somewhat like balsam. Cato's 'tapenade' is packed in small jars. A second recipe from Cato, to be used "after the vintage", i.e., quickly, uses equal parts must and vinegar, mixed with the olive pulp. A Greek-style relish, he says, is made with olive oil, vinegar, coriander, cumin, fennel, rue, and mint. Greeks still love olive paste flavored with fennel, incidentally.

Columella describes a similar process for black olive relish.[47] Black olives are gathered very ripe, spread to dry for one day, sorted, cleaned, put in a new frail and weighted overnight to exude moisture. The next day they are pulped with the stones of the mill carefully adjusted so as not to crush the kernels, mixed with toasted, hand-

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[45] Forbes and Foxhall (1978): 38.

[46] Cato, *Agr.* 117–19.

[47] Columella, *DRR* 12.51.

rubbed salt, caraway, cumin, fennel seed, and Egyptian anise seed. The relish is packed in vessels and covered with olive oil which is topped up as needed. Pliny's relish[48] for twenty-five pounds of olives uses a solution of six pounds of quicklime, water as needed, and twelve pounds of oak ashes, to form a lye in which the pulped olives are soaked for eight to ten hours, after which the pulp is drained, thoroughly rinsed, and immersed in very clear, soft water for eight days, the water to be changed frequently. Then an infusion is made with hot water, fennel, and hard brine. When this has cooled, the olives are added. We might speculate as to how common the lye soak prescribed by Pliny was, or had become by his own time, a standard part of processing all waxy fruit. It is rarely mentioned, but matters of common knowledge are typically glossed over by the practicing farmers Cato, Varro, and Columella, whereas the academic Pliny seems compulsively compelled to mention even such details—all praise be to him!

Olives were also cured and pickled as today. In the first category, Cato says that Orchites are good for the purpose, partially dehydrated, dry-salted for five days, then rinsed of the salt and sun-dried for an additional two days.[49] Columella[50] records an ingenious variation on this treatment. Black olives are mixed with mastic seed, fennel seed and toasted rock salt, packed in amphorae which are then stoppered with a fennel stalk and daily rolled along the ground. Every three or four days the amurca is poured off. After forty days the salt is rinsed off and the cured olives put back into the jars for storage.

For pickling, certain varieties of olives were favored, including one, *condiatnea*, whose very name means "pickling olive."[51] Additionally, there are various rules of thumb for choosing pickling olives. The ever-parsimonious Cato recommends that deciduous olives be preserved as relish for the farm hands and that ripe olives that appear likely to yield the least oil be pickled for the same consumers.[52] Otherwise the Orchite and Posea are best preserved green in brine or conserved in unsalted *sapa*.[53]

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[48] Pliny, *NH* 15.1.
[49] Cato, *Agr.* 7.3.
[50] Columella, *DRR* 12.50.
[51] Cato, *Agr.* 1.24.1.
[52] Cato, *Agr.* 58.
[53] Cato, *Agr.* 7.3.

Columella, as usual, gives the most explicit directions for the procedure. Green olives, picked in September or October, are first 'cracked'[54] probably by being struck with a flat stone in exactly the same way it is done today by Greek and Italian families.[55] Once again the trick is to breach the waxy bloom of the berry without crushing the kernel, whose bitterness will spoil the flavor of the fruit. A lye solution can be used for the purpose, of course, but there are simpler expedients; for hard, green olives, a carefully modulated whack with a smooth stone will crack the skin but not the kernel. For ripe, black olives the same blow will smash the berry and disperse too much of the precious oil, so a slit is made in the skin to allow the pickle to infuse. After Columella's green olives are cracked they are soaked in hot water for a short time to soften them and leech out amurca. Then excess moisture is squeezed out, the olives mixed gently with the same fennel, mastic and salt mixture prescribed by Cato, and the flavored berries put in jars (*fidelia*) and topped up with "freshest possible must." Fennel stoppers are used to keep the berries submerged. After three days, Columella says, the olives may be used, a remarkably quick cure.

When 'white' Orchites or Shuttle olives or Royals are cracked they are soaked in cold hard brine to preserve their color, Columella does not say for how long, though certainly for several days. When enough have been prepared in this way to fill an amphora, a bunch of dry fennel stalk is placed on the bottom of the vessel. Meanwhile seeds of green fennel and mastic are cleaned and mixed in a small pot, the olives drained and cleaned and excess moisture squeezed out and then mixed with the pickling herbs. The amphora is filled to the brim and the pickle of two parts fresh must to one part hard brine poured in. A fennel stopper keeps the olives submerged. This pickle, Columella assures us, will keep olives perfectly sound for a whole year.

Some variations: the olives may be cut with a sharp reed instead of cracked, a more laborious procedure which has the advantage of better maintaining color. Fresh must may be substituted by *sapa* or *passum* or 'beeswax-water' (*mella*, see below, Ch. 6) if available; or

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[54] Columella, *DRR* 12.49.1: contunde. Note Forster's "squeezed," which won't do at all.

[55] Cf. Kremezi (1993): 21. The Greek name for cracked green olives is *tsakistes*.

the pickle may be hard brine alone; or salt and vinegar for forty days, after which this pickle is poured off and replaced with one of two or three parts *defrutum* to one part vinegar. The list goes on, and the variations seem endless. Premium green olives may also be dry cured and then preserved in best oil, as today. Or green olives may be pickled in brine, then pressed for the green oil long after the olive vintage is over.[56] Pickling herbs may include chives, rue, parsley, mint, pepper, and mastic shoots.

Black olives for pickling were harvested "in the cold of winter," presumably November and December, when they had turned dark but were not yet overripe.[57] They were hand picked to prevent bruising, carefully culled, mixed or layered with dry salt, sometimes mixed with mastic, and placed in baskets which were topped off with more salt. In this fashion they were suspended and the amurca allowed to drip out for thirty to forty days. Then they were wiped clean with a sponge, put in a storage vessel and covered with *sapa* or *defrutum* to the neck of the vessel, into which the usual fennel plug was put to keep the 'swimmers' submerged. The taste of this 'pickle' will have been quite strange to modern tastes, a combination of sweet and salty. Alternately, the pickle might be various proportions of a sugar such as *defrutum*, honey, or *mella* and vinegar to produce a 'sweet and sour' pickle. Other pickling spices might include mastic seed, fennel seed, fennel sprigs, parsley, rue, and bay sprigs.

Black olives whose skin was still too impervious to take the pickle were easily recognized because, placed in the storage vessel after the salt cure, they became 'swimmers', *colymbades*, whence the modern Greek category. Green Pauseans, which like most green olives were 'swimmers', were sometimes kept in this state and presumably will have been quite bitter,[58] but black 'swimmers' were cut in two or three places, probably with the reed prescribed elsewhere, and soaked in pure vinegar for three days before being pickled in *defrutum* or other pickles.

Were pickled olives fermented as well? We have no direct evidence for the fact, but comparative evidence suggests that they were. Today fermented olives represent the majority of those processed in

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[56] Apicius 1.14.

[57] Columella, *DRR* 12.50.

[58] Columella, *DRR* 12.49.8.

the Mediterranean. These olives are treated with lye for 5–12 hours, washed to remove the alkali, then brined to stabilize them and encourage a lactic fermentation, at the end of which pH typically falls to a range of 3.8–4.4. Salt may be added in stages to encourage the colonization of successively more halophilic strains. Today in the initial stages of fermentation, typical organisms are Pseudomonas, Flavobacteria, Aeromonas, *Enterobacter cloacae*, Citrobacters, *Hebsiella aerogenes*, and *Escerichia coli* (not the pathogenic strain.). These are overgrown after about two days by species of the genera Pediococcus, Leuconostoc and Lactococcus. These in turn are overgown by Lactobacilli and yeasts.[59] We note that all these strains are opportunistic colonizers. Since there is nothing in the ancient recipes which would preclude the same sorts of colonization, I think we may assume that they were operant there as well.

Other berries such as mulberries, blackberries, cornel berries, and serviceberries or sorbs were most often pickled and conserved, as we might expect.[60] The one exception was the sorb, for which desiccation is also attested,[61] though the absence of attestation for desiccation of the other berries obviously does not mean it didn't happen. The procedures for pickling and conserving are much the same as for the grape.

Fleshy fruits were stored whole, dehydrated, pickled, and conserved, though dehydration—simple, cheap, and effective as it is—will surely have been the most common process. Wealthy villa farmers had more options than the peasantry; the Roman villa came equipped with special rooms for storage of whole fruits and conserves. Varro[62] describes the fruit-house, *oporotheca*, as dry and cool, with a northern exposure and windows open to the wind but with shutters to keep the fruit from shriveling when the wind is too sustained. To make it still cooler, walls, floors and ceilings are plastered with marble

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[59] Linda J. Harris, "The Microbiology of Vegetable Fermentation," in Brian J. B. Wood, ed., *Microbiology of Fermented Foods* (London: Blackie Academic and Professional, 1998): 59–67. For comparison, most traditional Indian pickles are not fermented, but fermentation in high-moisture vegetables under brine is proved experimentally for cucumbers, cabbage, turnips and olives. Agents are the standard LAB, but as pH drops yeasts begin to dominate: Sankaran (1998): 779.

[60] Cato, *Agr.* 7.3; 14.3.3; Apicius 1.12; Varro, *RR* 1.59; Columella, *DRR* 12.4–5; 12.16.4.

[61] Cato, *Agr.* 143.3.

[62] Varro, *RR* 1.59.

cement. Columella's description of the conserve room, *apotheca salgamis*, is similar:[63] a cool, dry, shaded locale to prevent fermentation and mold, with vessels of terra cotta, pitched or unpitched as the type of fruit demands, or of glass, numerous rather than large (one bad apple. . . .), wide-mouthed and cylindrical rather than pot-bellied, so that as food is removed, the remainder will settle to the bottom and remain submerged.

Firm-fleshed, waxy-skinned fruits such as apples, quinces and pears are fairly stable in such a cool, dry environment as the *oporotheca*. Additionally, whole fruits of this sort were frequently placed on or buried in an insulator such as chaff, straw, sawdust of cedar, poplar, or holmoak, in sand, gypsum, or even in wool.[64] In the absence of a suitable *oporotheca*, trenches were dug in a cold, dry outdoor area, lined with one of these substances, the fruit embedded in it, the whole covered with an impervious 'lid' such as clay or plaster, and the whole mounded with more insulation. Alternately, the fruit could be placed in pots, embedded in desiccants or not, and buried in the earth to provide natural refrigeration and a CO_2 blanket. Fruits for which whole storage of some sort is attested are apples, citrons, gourds, cucumbers, pears, pomegranates, quinces, and sorbs.[65] Surely the most elaborate variation on whole storage is reported by Columella of pomegranates:[66] some people pluck the fruit with their pedicles (an excellent technique in general), tie them to the tree, and cover the entire tree with nets to protect from birds, or fit over the suspended fruit small terra cotta pots (presumably with the two-part lid described above) and daub the whole pot with a mixture of clay and chaff. Columella worries that the weight of such pots will damage the living tree and advises as an alternative that the little pots be placed in very deep trenches or in dolia, with the pedicles grafted into the branches of an elder bush placed whole in the trench or dolium. A cover is placed over the trench or dolium, daubed with the clay-chaff mixture, and earth mounded over this. It is also Columella[67] who reports that chests of beechwood or limewood "such

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[63] Columella, *DRR* 12.4.4–5.

[64] Columella, *DRR* 12.46.6; Varro, *RR* 1.59; Florentinus in *Geopon.* 10.7.

[65] Varro, *RR* 1.59; Columella, *DRR* 12.14; Pliny, *NH* 19.24.74; Apicius 1.12; Palladius, *DRR* 9.10; Florentinus in *Geopon.* 10.7.

[66] Columella, *DRR* 12.46.

[67] Columella, *DRR* 12.47.

as those used to store official robes" (presumably stackable) are placed in a very cold, dry loft with a very thin sheet of paper spread on the bottom, and apples arranged in them, a different variety in each chest so that they don't taint each other's varietal character. The apples should be stored with pedicles down and the "floweret" (*flosculi*, i.e., the dimple opposite the pedicle, sometimes called the umbilicus) up. The chests are covered and sealed with the clay/chaff mixture to provide an airtight barrier.

Citrus fruits, introduced to wealthy Romans in the first centuries of the common era, could be handled quite differently. Citrus fruit is so acidic, of course, that its juice is itself a preservative, but the pithy rind is highly susceptible to molds and mildews. But Palladius[68] correctly adduces that citrons can keep, left on the tree, for nearly a whole year, and he might have added the same for oranges and lemons.

Fleshy fruits were also pickled and conserved in a variety of ways. We have attestation for these processes for figs, apples, cherries, citron, cornelberries, gourds, cucumbers, peaches, pears, plums, quinces, and sorbs,[69] and doubtless these represent a small portion of the total. Pickles and conserves attested are the usual: brine of various strengths, vinegar, *sapa*, *defrutum*, honey, and *passum*, all in various proportions. The modern Westerner may be a bit startled by the notion of pickled citrus fruits, but the practice is still common in parts of the Mediterranean and elsewhere. For purposes of comparison, the seventeenth-century ethnographer Rumphius reported that on the Malay Peninsula, limes pickled in brine and stored in well sealed jars were maintained for years.[70] In the realm of pure conserves, Columella advises[71] that all kinds of fruits may be preserved in honey, but each must be kept separately since they spoil each other (a dubious idea; perhaps he means that they impart their flavors to each other). The method, he says, not only preserves the

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[68] Palladius, *DRR* 9.10.

[69] Apicius 1.12; Columella, *DRR* 12.14; Palladius *DRR* 9.10; Pliny *NH* 19.24.74; Cato, *Agr*. 7.3 and 143.3; Varro *RR* 1.59; Columella *DRR* 12.10.4 and 12.15 and 12.10.3; Cato *Agr* 143.3 and Varro *RR* 1.59; Cato, *Agr* 7.3, and 43.3 and Varro *RR* 1.59, respectively.

[70] S. Tolkowsky, *Hesperides: A History of the Culture and Use of Citrus Fruits* (London, 1938): 37.

[71] Columella, *DRR* 12.10.4.

fruit but also produces a honey flavored by the fruit, called *melomeli*, which is reputed good for those suffering from fever. The disadvantage is that the honey also imparts its flavor to the fruit (apples, in this case) and they lose their varietal character.[72]

As noted earlier, drying of fleshy fruits has been the preferred method since prehistoric times, and Columella is well advised[73] in claiming that dried fruit when abundant provide a major portion of the diet of country folk during winter. Fruits for which dehydration is attested in our period are apples and pears (many varieties, though some were regarded as more suitable), figs, plums, pomegranates, quinces, and sorbs.[74] Again, there can be little doubt that other fruits were treated in the same way. As with olives, the waxy bloom represents an impediment to migration of moisture content, and the same expedients are attested here as well. Fruits are picked underripe,[75] and may be cut in several places with a small reed or bone knife (the ancients knew that bronze implements would taint the flavor of fruit) and/or were plunged in boiling seawater momentarily[76] before drying. There is no specific attestation for a lye dip, but this method will doubtless have been used as well. Columella's description of the actual drying of figs is probably fairly typical:[77] the fruit is spread out on reed hurdles in a very sunny spot. These frames are constructed so that plenty of air can circulate underneath. At dusk, 'shepherds' hurdles' of straw, rushes or ferns are set up as lean-to's to protect the fruit overnight from dews and rain. When the fruit is sufficiently dry it is stored in well pitched jars called *orcae*, a layer of dry fennel underneath, the fruit tamped down to a nearly solid mass and a layer of fennel added at the top before the vessel is sealed and stored. Columella[78] records a curious variant in which partially sun-dried figs are trodden "with washed feet, in the manner of flour (*in modum farinae*), then mixed with toasted sesame seed, Egyptian anise, fennel seed, and cumin, until completely blended.

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[72] Columella, *DRR* 12.47.

[73] Columella, *DRR* 12.14.

[74] Cato, *Agr*. 143.3; Varro, *RR* 1.59; Columella, *DRR* 12.10.3; 12.14–15; 12.46; Pliny, *NH* 15.8.34.

[75] Columella, *DRR* 12.14.1.

[76] Columella, *DRR* 12.46.5.

[77] Columella, *DRR* 12.15.

[78] Columella, *DRR* 12.15.3–5.

Then the "dough" is shaped into balls of moderate size in the manner of *tracta*, a kind of pasta, wrapped in fig leaves tied with rushes or some other natural string and placed on hurdles to dry, after which the fig loaves are placed in pitched or unpitched vessels, heated to drive out moisture, sealed and stored in a dry loft. The mass becomes so hard in storage that it can only be removed by breaking the vessel. Others shape the fig loaves into stars, flowers, or bread loaves (our Pompeiian segmented loaf?) before storing them, a delightful artisinal touch.

Again, the drying procedure attested for figs is doubtless representative for other fruits as well. But one fruit deserves special note. Mushrooms are ideal for drying and, though almost completely devoid of carbohydrates, their food value should not be underestimated. Mushrooms might be thought of as pre-metabolized food, since they are saprophytic and are almost unique in their ability to metabolize plant polymers, lignin, hemicellulose and cellulose, all completely indigestible to humans, to a digestible form. When reconstituted, dried mushrooms retain almost all their original nutritional value.[79] The Romans knew and appreciated *Amanita caesarea*, which they, however, confusingly called *boletus*; the true king bolete (*Boletus edulis*, porcino, cepe) which the Romans called *suillus*; the field mushroom *Agaricus campestris*, perhaps the shaggy ink cap *Lactarius deliciosus*, and both white and black truffle. As today, truffles were a great delicacy to the Romans; they were dried by stringing them on rushes and were stored whole embedded in sawdust in pots and then carefully sealed.[80]

Nuts are another fruit that is highly nutritious, easily gathered and easily preserved in the shell with a minimum of processing. They are palatable sources of proteins, fats, minerals, and vitamins and because of their high fat content are sometimes processed for oil even in areas that grow olives.[81] The exception is chestnuts, whose singularly low fat content allows them to be processed by boiling, drying, and storing at room temperatures without fear of oxidative rancidity.[82] We have no attestation for oil processing of nuts in Rome,

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[79] Brothwells (1969): 91–93; André (1961): 43–46; R. J. Scrase and T. J. Elliott, "Biology and Technology of Mushroom Culture," in Wood (1998): 541.

[80] Pliny, *NH* 22.98; cf. Apicius 1.12.10.

[81] Brothwells (1969): 148.

[82] Jasper Guy Woodroof, *Tree Nuts: Production, Processing, Products* (Westport, CT: AVI, 1979): 55.

nor of any other special processing with the exception of Cato's[83] injunction to the vilicus' wife to keep fresh hazelnuts in jars buried in the earth, and Varro's[84] notice that walnuts are sometimes stored in sand. Judging from Apicius' recipes, however, nuts must have been stored in some way in great abundance.[85]

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[83] Cato, *Agr.* 143.3.

[84] Varro, *DRR* 1.59.

[85] For the use of acorns in subsistence diets, Sarah Mason, "Acornutopia? Determining the Role of Acorns in Past Human Subsistence" in Wilkins, Harvey and Dobson (1995): 12–24. Mollinson [(1993): 112–14] says that pine nuts were found stored in jars of honey, still in good condition, in Pompeii in 1873, but I find no attestation of this remarkable fact.

CHAPTER FIVE

ANIMAL PRODUCTS

The chapters in this survey are arranged according to the probable importance of the food product in the diet of the ancient Roman, a rather anticlimactic scheme but one which I hope has the virtue of representing, to the extent that we can do so given the exigencies of the source material, the reality of ancient food processing. One of the most obvious differences in comparison to the modern Western and especially western European and North American diet is the relative insignificance of animal products—meat, milk products, eggs, fish—in the ancient diet. We have reason to believe that many if not most ancient Romans rarely ate meat, for example, and perhaps never ate fresh (uncured) meat. Indeed, it is thought that among the urban poor meat from animal sacrifice, distributed to the poor by the state as a public benefaction, was one of their main sources of fresh meat.[1]

Milk Products

That is not to underestimate the critical importance in the ancient diet of animal proteins when they were available. As we have seen, proteins are the basic building blocks of human physiology, and in many ways animal proteins are unsurpassed in their efficacy as molecular construction materials. That is certainly true of milk, the only common foodstuff which nature has designed specifically as mammalian food. "Though milk is surpassed by many other foods in its content of any one specific nutrient, it is almost unique as a balanced

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[1] On the relative importance of meat in the Roman diet, including some tentative conclusions concerning the relative importance of cow, sheep and pig meat, using zooarchaeological and literary evidence, cf. Michael Mackinnon, *Production and Consumption of Animals in Roman Italy: Interpreting the Zooarchaeological and Textual Evidence* [= *JRA Supplementary Series* No. 54] (Portsmouth, RI: Journal of Roman Archaeology L.L.C., 2004): 102–04.

source of most of man's dietary needs. Only the whole carcass of an animal, including the bones and liver, could contribute as much as milk, taken as a single food." Milk, of course, is still best as part of a mixed diet, but by itself a half-liter of cow's milk provides about 25% of the calories, 40% of the protein, 70% of the calcium and riboflavin, and 33% of the Vitamin A and thiamine generally regarded as requisite for a five-year-old child. The constituents of milk vary with species and even within species and by season and microclimate, but in general they are composed of water (about 85%), fat, casein (milk protein), lactose (milk sugar), albumin (whey protein), and ash. Again, the most critical components in milk are its proteins and, significantly, when milk is combined with a cereal diet which provides complementary Vitamin B_6 and carotene and the pro-Vitamin A, the essential amino acids in milk and cereals complement each other perfectly.[2]

Extremely high food value, extremely low biological stability. In nature, of course, milk passes directly from mother to offspring, under which conditions the problem of spoilage doesn't arise. But when used as a foodstuff, milk is extremely perishable since its liquid state, composition, and neutral pH render it particularly prone to spoilage and pathogenic microbes, either naturally present in the milk or introduced in handling. Milk may naturally contain human pathogens such as tuberculosis and brucellosis, and many others are easily introduced. Add to considerations of biological stability the fact that raw milk sugar (lactose) is indigestible by large numbers of people, and that processing metabolizes most lactose in milk to a digestible form. It is certainly understandable, therefore, that the processing of milk for long-term storage is a virtual *tour de force*, incorporating as many as five fermentations as well as chemical and physical dehydration, salt curing and brining, refrigeration, and, on occasion, smoking as well. And all these in a craft at least 4,000 years old, and perhaps far more.[3]

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[2] S. K. Kon, *Milk and Milk Products in Human Nutrition*. (Rome: FAO, 1959): 12–15.

[3] Cf., e.g., Peter I. Bogucki, "The Antiquity of Dairying in Temperate Europe," *Expedition* 28.2 (1986): 51–8: evidence for dairying, especially for cheesemaking, from the early Neolithic of temperate Europe (c. 5400 BCE).

Soured Milk Products

Specifically, these processes include the churning of milk into butter or otherwise rendering the fat; the making of cheese and cheese-like products; the souring of milk by such organisms as Streptococci and Lactobacilli to create an acidic environment and a yogurt-like product; and the concentration (dehydration) of milk to a solid or semi-solid state by boiling it over an open fire. In hot climates where spoilage can occur rapidly, some such form of heat treatment is imperative. Additionally, several of the lactic acid bacteria (LAB) of fermented milk products are known to produce a number of biocins effective against spoilage and pathogenic strains.[4] All these treatments have a greater or lesser effect on food value, but in general the greater part of nutrition, especially of milk proteins, is preserved.[5]

In some traditional societies butter is churned directly from whole, fresh milk, though it is now most often churned from either sweet or ripened (soured) cream skimmed from the whole milk. Ripened butter is prized for its flavor but quickly becomes rancid, whereas sweet-cream butter is less susceptible to rancidity. Butter making is also a seasonal activity in traditional societies, since it is during the spring calving, kidding and lambing season that female livestock who are not stall-fed have a superfluity of milk. Some 84% of butter is fat, valuable for its high caloric value and Vitamin A.[6]

Butter (*butyrum*), however, was rarely used in ancient Rome except as a cosmetic. Many reasons may be assigned for this. Certainly the relatively plentiful supply of fats from olive oil is significant. There is also the fact that cows' milk makes the best butter, and dairy cows were a very expensive commodity in ancient Italy except in the Po Valley and northward, due to the shortage of suitable pasturage elsewhere. The Mediterranean climate further south was doubtless also a factor. It is not so surprising, then, that only Pliny[7] deals with the processing of butter. Milk is placed in a tall vessel which has a hole just under the mouth to admit air. A little vinegar (reading *aceto* for the obviously corrupt *aqua*) is added to sour the milk, and the vessel is periodically shaken and the fatty element, the butter, coagulates

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[4] H. Oberman and Z. Libudzisz, "Fermented Milks," in Wood (1998): 314.

[5] Kon (1959): 18.

[6] Kon (1959): 44–46.

[7] *NH* 28.35–36.

and floats on the top. The stronger the taste, the more prized is the butter.

Pliny's reference to "strong taste" indicates that his butter is fermented. Milk naturally sours, i.e. ferments, when kept at ambient temperatures for any length of time, a characteristic used by man since the dawn of history to produce soured milk products whose acidity partially stabilizes them. This fermentation is effected by the microorganisms cited above as well as others, metabolizing milk sugar, lactose, to form lactic acid. In addition, certain yeasts may convert lactose to alcohol, which of course is also bacteriostatic. Lactic acid inhibits the colonization of, and later destroys, many pathogens, particularly typhoid and paratyphoid organisms and noxious coliforms. However tuberculosis and brucellosis bacteria may survive for weeks, even in high-acid products, so unpasteurized soured-milk products always carry some risk.[8]

Fermented-milk products are generally classified as soured-milk products (yogurt, koumiss, kefir, labna, etc.) and cheese, though the distinction is rather arbitrary. In general, sour-milk products are those naturally fermented and coagulated (acid denatures the proteins of milk) whereas cheeses are also or alternately renneted and their curds and whey physically separated. Pliny[9] mentions production of sour-milk products by "barbarian tribes," a statement which suggests that such products were foreign to Rome, but this inference is belied by Columella's explicit directions for making three distinct products of the sort, and by the fact that Apicius includes a recipe for one of them in his famous cookbook. The three products are *oxygala* (literally, 'sour milk'), *melca*, and *schiston*. Columella's directions for making *oxygala* are instructive:[10] drill a hole near the base of a new pot (*olla*) and stopper it with a small stick. Fill the pot with fresh sheeps' milk; add a *bouquet garnis* of green seasonings, marjoram, mint, onion, and cilantro, suspended by a string in the milk. After five days, unplug the pot, drain the whey, restopper, wait three more days, drain again and throw away the bouquet garnis but add crushed thyme and marjoram and thinly sliced leek to taste. After two more days, drain the whey again, restopper and add ground salt to taste.

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[8] Kon (1959): 38–42.

[9] Pliny, *NH* 28.33–36.

[10] Columella, *DRR* 12.8.1–3.

The product is now stable and the vessel may be sealed until ready for use. A variation: for the *bouquet garnis*, use pickled pepperwort leaves or fresh dittander and instead of the herb mix prescribed use green savory and coriander seeds, dill, thyme, parsley and salt. This product must have had the consistency of a soft cheese, since the whey was drawn off three times before salting and potting.

Melca[11] was made by pouring milk into jars containing boiling vinegar, then cultured overnight in a warm place. *Schiston* or *schiston lac* (literally, 'separated milk'), a product, we are told, invented by the physicians of Pliny's day,[12] is made by boiling milk, especially goat's milk, in a new vessel while stirring with a fig branch. Then a small quantity of must is added. The fig branch contains latex, a plant 'rennet', as we shall see, and the must apparently is added to introduce a yeast ferment as well. If this interpretation is correct, *schiston* is technically a cheese. But again, the product is used for primarily as a medicament.

Cheese[13]

Earliest evidence of cheesemaking comes from Mesopotamia and dates from c. 7,000–6,000 BCE. Woolley concluded that cheese had been made at Ur, and an earlier Sumerian frieze from El-Ubaid depicts the rudiments of cheesemaking. Remnants of cheese itself were found in the tomb of Hories-Aha and date from c. 3,000 BCE. Manufacture of goat cheese appears to have been common in Egypt, and cheese is frequently mentioned in the Old Testament. Homer speaks of cheese, most famously the ewes' milk cheeses of the Cyclops Polyphemus, and Herodotus refers to Scythian mares' milk cheese, as well as Phrygian mares' and asses' milk cheeses.[14] Thus Rome was heir to a long history of cheesemaking, and the fact that the earliest inhabitants of the city were shepherds suggests that cheesemaking was intimately bound up with the earliest history of the culture.

It seems obvious from the paucity of references to soured-milk

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[11] Apicius 7.294 and 303.

[12] Pliny, *NH* 28.33.

[13] The two best discussions are Joan M. Frayn, *Subsistence Farming in Roman Italy* (London: Centaur Press, 1979): 39–43 and Curtis (2001): 400–02.

[14] Scott (1986): 1–2.

products in the Roman testimonia that such products were not common foodstuffs. That is hardly the case with cheese (*caseus*), however. Cheese was doubtless the most important milk product in the rural diet of the Romans of our period, and probably the exclusive one for most people in the city, isolated as it was by its size and difficulty of transport from sources of fresh milk. Frayn conjectures that the use of milk for cheese was more important for the subsistence farmer than either meat or wool production.[15] Cheeses were also items of national and international trade, witness Pliny:[16] Of provincial cheeses at Rome the palm goes to those of Nîmes in particular, especially from the villages of Lozère and Gévaudan, but only when young and fresh. The Dalmatian Alps provide Docleate and the Tarentaise Alps Vatusian. Apennine cheeses include Cobanum from Liguria, a pecorino, Luni cheese from the borderlands of Tuscany and Liguria, and Sarsinate from Umbria. Luni cheese is pressed into 1,000 pound wheels.[17] Closer to home, Vestinian cheese from the Caedician Plain is excellent. Gallic chevre tastes medicinal, but the fresher smoked goat cheeses to be had locally are good, especially that made in Rome itself. Of transmarine cheeses, Bithynian cheese is quite famous." Imagine: fresh cheeses from Provence in Rome; half-ton wheels of Ligurian pecorino; smoked chevre made in the city!

Unlike yogurt and other sour-milk products, cheese is a solid or semi-solid substance formed from the curd of milk, separated from the whey by a coagulant and/or by heat. Cheese undergoes the same fermentations as sour-milk products; agents include species of the genera Streptococcus, Leuconostoc, Pediococcus, and Lactobacillus, all from the family of Lactobacteriaeceae, producing a lactic acid

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[15] Frayn (1979): 40–1.

[16] *NH* 11.97.

[17] Scott [(1986): 3] refers to Diocletian's Price Edict as fixing the maximum prices of 'Lunar' cheese, with its trademark, the 'Horns of the Moon', and cites this as the forerunner of Parmeggiano. I fail to see how he (or his source) infers such a thing from Diocletian's bald reference (6.96) to *casei sicci* ('dry cheese'). In any case it may be unwise to make inferences from this late document (Diocletian ruled 284–305 CE) concerning Luna cheese of the first century. The figure of 1,000 pounds is not a manuscript error, to judge by Martial's (13.30) reference: Caseus Etruscae signatus imagine Lunae/praestabit pueris prandia mille tuis, 'A cheese marked with the image of Etruscan Luna/will provide a thousand lunches for your children,' apparently punning *mille prandia* with *mille pondi*. These must have been giants; for comparison, a modern Parmeggiano is about 17" (39 cm) in diameter and weighs about 75 lbs. (34 kg.).

fermentation with traces of other products such as acetic acid and carbon dioxide. Low-acid producers are *Streptococcus lactis* and *S. cremoris*, used today in commercial starters for cheese and yogurt. Other modern agents, in order of lactic-acid formation, are *Lactobacillus casei, L. lactis, L. helveticus*, and *L. bulgaricus.* Traditional societies use certain containers such as unglazed, porous terra-cotta bowls and skin bags to colonize 'pure' starter cultures, or simply use a portion of whey containing the culture from a previous batch. If the culture fails, one simply goes to a neighbor and borrows a pail of whey or buttermilk.[18] As milk sours and/or as it is heated, successive colonization takes place. The typical scenario goes thus: milk is initially soured by the Streptococci present in the milk itself, which thrive at pH levels around 6.5; then Lactobacilli such as *L. bulgaricus* overgrow them as pH approaches 5.5. Likewise, Streptococci thrive at temperatures of 86–90°F (30–32°C), Lactobacilli at 95–113°F (35–45°C). Milk removed from its source cools to temperatures favoring streptococci, and gradual heating encourages overgrowth by successive lactic bacteria. As milk temperature approaches 145°F (63°C), most microbial life is killed.[19]

The natural coagulum obtained by the acidification of milk is injected with a chemical coagulant to further solidify the milk solids and render the aqueous component, the whey, to reduce water activity and increase acid concentration. The coagulant *par excellence* has always been rennet, a substance containing the enzyme rennin, found in the stomachs of suckling mammals. But other coagulants may be used as well. Additionally, cheese may be made from enriched, whole, partly skimmed, or skimmed milk, can be made into cheese-like products such as cream cheese and whey cheese (e.g., ricotta). Cheese may be eaten quickly as unripened 'farmer's cheese' or may be aged and ripened by internal bacterial fermentation and/or by surface microbes or injected molds such as Penicillia. Cheese may also be heated and physically manipulated to further denature the milk proteins and render 'string cheeses' such as pasta filata and cheddar.[20]

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[18] Carl S. Pederson, "Processing by Fermentation," in Heid and Joslyn (1967): 482–88; 497–504.

[19] J. G. Davis, *Cheese* (New York: American Elsevier Pub. Co., Inc., 1965): 166.

[20] Kon (1959): 46–47; E. Renner, "Nutritional Aspects of Cheese," in P. F. Fox, *Cheese: Chemistry, Physics and Microbiology, vol. 1: General Aspects* (London: Chapman and Hall, 1993): 557–79.

Cheese retains much of the nutritive value of milk, though nutritive changes are not insignificant. By far the most important element of loss of nutritive value is the draining of whey; about half the total solids of whole milk, including almost all the fat and approximately three quarters of the proteins, especially casein, remain in the curd. Most unfermented lactose is lost to the whey; two-thirds of calcium, most Vitamin A, one-quarter of riboflavin, and one-sixth of thiamine remain in the curd. In hard, pressed cheeses, very little additional calcium is lost during the ripening process, but in cheeses where whey drains slowly considerable calcium leaches out. Vitamin C is lost during ripening, though very little is available to begin with; other vitamins are stable, and the actions of molds and bacteria during ripening actually synthesize several of the B-vitamins. Because whey contains valuable milk nutrients, it is often reprocessed under heat to extract more cheese and/or is used as food for livestock, especially pigs, or is drunk.[21]

The basic traditional cheesemaking process is relatively simple, though variations are literally numberless. Fresh milk is heated, then injected with or exposed to culturing agents such as the Streptococci and Lactobacilli referred to above. This culture is allowed to ferment for a period of time, often overnight, at which point the morning milk may be added to the now-vigorous ferment. At some point a coagulant such as rennet is added to further solidify milk solids and render whey. The coagulum is then cut into small pieces, curds, which float in the whey. The liquid whey is then often heated separately to further render whey and solids (denaturation) and the curd further cut and drained. At this stage the cheesemaker has large- and small-curd cottage cheese. Several hours later the curd is salted and may be placed in forms, often wrapped in cheesecloth. Then the curd may be pressed to render a hard cheese. When the desired water activity is obtained, the cheese may be waxed or dry-salted on the exterior or brine-soaked to form a horny, relatively impervious rind, and then is stored for greater or lesser time periods to ripen. The ripening may take place in storage areas where ambient molds such as Penicillia facilitate the ripening process, or these molds, which are aerobic, may be injected into holes pierced in the cheese. A

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[21] Kon (1959): 48–50; Scott (1986): 37–43; P. F. Fox, "Cheese: An Overview" in Fox (1993): 1–36.

ripened cheese is a living thing and continues to undergo metabolic processes, but can easily remain healthful and palatable for a year or more.[22]

Cheese can and has been made from practically any milk, as the Romans were aware; Varro[23] cites Cossinius' assertion that of all liquids taken as sustenance, milk is the most nourishing, particularly ewe's and goat's milk. Mare's milk, he continues, has the most purgative effect, followed by ass's milk, cow's milk and goat's milk. Apparently, then, all these milks were used by the Romans in some fashion, though references to purgative effects suggests some were used as medicaments. Cossinius adds that the most nutritious milk product is fresh milk from non-parturient animals, both perfectly accurate. Cow's milk cheese Cossinius regards as most nourishing but also most constipating; then ewe's milk, and the least nourishing and constipating (was Cossinius a medical writer?) is goat's milk. Likewise, soft, fresh cheeses are most nutritious and least constipative and the opposite is true of dry, ripened cheeses. Thus it is apparent that the Romans used a variety of milks to make a variety of cheese styles.

It is impossible even to speculate how prevalent cheeses of each style and type may have been, though it is clear that ewe's milk and goat's milk cheeses were far more common than cow's milk cheeses, for reasons already adduced. To judge simply by references in the literature, ewe's milk cheese (pecorino) was by far the most common. Varro[24] has Scrofa remark that there are two especially significant sources of revenue which fall outside his standard categories (the participants in Varro's imaginary dialogue have been creating a taxonomy of agriculture), namely, sheep shearing and, "even more important," milk and cheese, considered by the Greek geoponics as a separate category per se, *tyropoiia*. Given the huge economic importance of wool commerce in villa farming from Varro's time on, this is quite a striking statement. Further, Columella[25] advises that in remote areas the sheep bailiff must reserve almost all spring lambs for pasturing but in suburban areas they must be sent to the butcher

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[22] Kon (1959): 47–48.

[23] Varro, *RR* 2.11.1; cf. Pliny, *NH* 28.33.

[24] Varro, *RR* 2.1.28.

[25] Columella, *DRR* 7.3.13–14.

because the low transport cost makes their sale profitable and because the profit from the ewes' milk and cheese will be no less. Zooarchaeological evidence, though scanty and difficult to interpret because of the similarities of ovine and caprine skeletons, supports the idea that dairy sheep were far more common than dairy goats.[26] Such evidence also confirms the infrequency of dairy cows, the exception being northern Italy.[27] Another comment of Columella's[28] suggests that economic impact reflects importance in basic sustenance; sheep, he says, satisfy the hunger of country folk by the abundance of their milk and cheeses, not to speak of certain nomadic barbarians for whom they are so much the staple that they are called *galactopotai*, 'milk drinkers'.

The comments of the geoponics might lead to the conclusion that the creamery was another component of the villa farm, but that, unfortunately for us, was not the case. The reason lies in the system of transhumance[29] still practiced in the Mediterranean in which flocks must be taken to the uplands in the early summer for adequate pasturage, returning by drove roads in the fall. The summer absence corresponds to the peak of milk production; cheese production was therefore a cottage industry practiced by the shepherds, goatherds and cowherds themselves. Cato, in fact,[30] speaks of a contract for leasing sheep to a shepherd, payment to be in kind, presumably in the fall, in the form of a pound and a half of cheese per ewe, half 'dry', i.e., pressed cheese suitable for aging. We should probably imagine our 'creamery', therefore, as the same sort of mountain hut still found in Alpine regions where the herdsman is also the cheesemaker, returning from the high pastures in the fall with his 'cash crop' in the form of beautiful wheels of semi-dry cheese.

In any case it is obvious that cheesemaking was a craft industry in ancient Rome, and that from this artisanal activity nonetheless derived a variety of cheese styles, both hard and soft. Columella, for example,[31] says that cheese of a thin consistency, i.e., low in butterfat,

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[26] MacKinnon (2004): 102–04.
[27] MacKinnon (2004): 95.
[28] Columella, *DRR* 7.2.1.
[29] Cf. Gerhard H. Waldherr, "Transhumanz im Mediterran—Ein Überblick," in Herz and Waldherr, ed. (2001): 331–57.
[30] Cato, *Agr.* 150.
[31] Columella, *DRR* 7.8.1.

must be sold quickly as soft cheese, since it becomes too sharp quickly. Perfectly true, by the way; low-fat milks sour much more quickly than high-fat. If the milk is rich and thick, Varro continues, it will be profitable to make a hard, ripened cheese. By imperial times there were at least thirteen styles identifiable, and gourmet cheeses were being imported from as far away as Britain and the Pyrenees.[32]

Unfortunately, because of the contract nature of cheesemaking, few of these styles are described by the agronomists, nor is the cheesemaking process itself, with the single exception of Columella's directions for a prototype soft and hard cheese. Fortunately Columella's prescription is a model of clarity, and comparison with artisanal cheesemaking of today makes it clear the process is essentially the same.[33]

Columella first insists that the milk to be used be as fresh as possible, for if it is left to stand or is mixed with water it sours quickly. Our cheesemaker has many options in choice of milk. He can use exclusively ewe's or goat's milk or cow's milk or some combination thereof, as taste or necessity dictates. But in general ewe's and goat's milk produce more acidic cheeses than cow's milk and are higher in fat. Secondly, dairy cattle are typically milked twice a day at dawn and dusk; many traditional cheesemen heat the evening's milking and allow it to sour overnight before adding the sweet morning milk the next day. Columella's comment suggests that a sweeter product is preferable, and so only a single milking is mentioned. Since we assume that only ewe's and/or goat's milk are used, his cautionary note on overacidulation is well taken.

On the other hand, Columella mentions nothing about culturing the milk. This could mean that he expects the milk to be naturally colonized by ambient microflora, but it could just as well mean that culturing of milk was so much the norm that it does not bear mentioning. Cheese can be made from uncultured milk by simply heating and adding the coagulant to create a sweet, bland, high-lactose product. Or it may be passively or actively cultured with the agents mentioned before, each of which yields a different concentration of lactic acid. In any case, if Columella's milk is actively cultured, it

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[32] Bruno Battistotti, *Cheese: A Guide to the World of Cheese and Cheesemaking* (New York: Facts on File, 1984): 12.

[33] Columella, *DRR* 7.8.1–7.

will almost certainly have been cultured in the traditional way. Today a starter is typically made from one or more pure strains, but until 1880 most cheesemakers relied on natural souring of milk or used soured whey from a previous batch as starter culture or used naturally soured milk from a favorite, healthy milker for the purpose.[34]

Columella says that a pail of fresh milk to be heated should always be made "somewhat warm," (*non sine tepore aliquo*), but should not be brought in contact with the flames, as some think proper, but rather the pan should be positioned at the proper distance from the flames. Again, this is perfectly sound advice, so far as it goes. To reiterate, fermentative strains are most active around 'blood' temperature but are destroyed above 145–155°F (63–68°C). Today milk is gradually brought to a temperature of 68°–104°F (20°–40°C), depending on the type of bacterial colony and curd desired, before the rennet is added. For comparison, traditional cheesemakers in Alpine areas and in rural Greece heat the milk in a large basin positioned on a stone or masonry hearth, and the cheeseman must stir the milk constantly to maintain a homogeneous temperature and prevent scorching. When the right temperature is achieved, embers are quickly removed so that the culture will not spoil, and the rennet is then added.[35]

Rennet, as mentioned, is a substance derived from the stomachs of suckling mammals, for example, the fifth stomach of ruminants such as cows, which contains the enzyme rennin (now often called chymosin to distinguish it from the proteolytic enzyme renin) and smaller quantities of pepsin. Both, like the enzymes produced by culture microflora, have the ability to metabolize lactose to lactic acid and to denature, i.e., coagulate milk proteins. Proteins are also easily denatured when heated (e.g., boiling an egg), and this denaturation also causes casein to coagulate. The upshot is that the combination of heat and rennin is very effective in causing milk to curdle so that whey separation can begin. A pure acid curd is crumbly and porous, whereas a rennet curd is firmer, denser, more elastic, and impermeable; when both mechanisms are used a 'combination curd' is produced, sharing some of the characteristics of both. This combi-

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[34] Erik Høier, et al., "The Production, Application, and Action of Lactic Cheese Starter Cultures," in Barry A. Law, *The Technology of Cheesemaking* (Sheffield: Academic Press, 1999): 99–100.

[35] Cf., e.g., Kremezi (1993): 29; Giuliano Bugialli, *The Foods of Italy* (New York: Stewart, Tabori and Chang, 1984): 249.

nation curd is produced by adding a minimal amount of rennet at a relatively low temperature so that lactic microflora can develop curd simultaneously.[36]

Traditionally, rennet was prepared by cheesemakers using the dried stomach linings of suckling ruminants soaked in brine or in whey at the point of use. Best rennet is derived from calves which are at least two weeks old and exclusively milk fed, hungry for at least ten hours before butchery. Traditionally the fourth stomach (abomasum) was severed from the third with a part of the latter attached, since none of the upper, valuable end of the rennet stomach is wasted because enzyme production is strongest at this end where the milk enters. There were two traditional methods of drying. In one the stomach contents were squeezed out, one end of the stomach tied off, the stomach inflated and the other end tied off, and the stomach hung in a cool, dry place to dry. In the second method the stomach was split open, cleaned, splayed, dry salted, and left on an inclined board to drain. In either case, the stomach was then cut into strips of the appropriate size.[37] In the absence of calves, Columella recommends rennet from a lamb or kid, though it was sometimes obtained from the stomachs of hares as well[38] Palladius recommends rennet from the congealed milk from stomach of lambs or kids or the stomach linings of suckling mammals.[39]

Additionally, milk can be curdled by various botanical agents with the proper enzymes, such as flower of wild thistle, safflower seeds, fig tree sap or green pine nuts (which also flavor the curd), or any

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[36] M. Johnson and B. A. Law, "The Origins, Development and Basic Operations of Cheesemaking Technology," in Law (1999): 14–16; Marianne Harboe and Peter Budtz, "The Production, Action and Application of Rennet and Coagulants," in Law (1999): 33–65; Bent Foltman, "General and Molecular Aspects of Rennets," in Fox (1993): 37–68.

[37] J. L. Sammis, *Cheese Making* (Madison, WI: The Cheese Maker Book Co., 1946): 64.

[38] Varro, *RR* 2.11.5; cf. Scott (1986): 170–85.

[39] Palladius, 6.9. Frayn ([1979]: 41) takes Palladius' phrase "pellicula quae solet pullorum ventribus adhaerere" to mean the stomach linings of chickens, but this is quite impossible; only the stomach linings of suckling mammals produce rennin, the enzyme which metabolizes mammalian milk. Palladius uses the term *pullus* in its radical sense of "young animals" (cf. L. *puer/puella*, 'boy'/'girl'). Frayn also states that Roman farmers used the 'beestings', the colostrum or first milk given by a mammal after parturition, again citing Palladius' *coagulum*. This, too, is unlikely; the term simply means rennet or the congealed milk produced by it in the stomach of the suckling animal.

chemical acids such as vinegar. Fig sap, latex, is especially effective.[40] The most important consideration, says Columella, is to use the least possible quantity of reagent, in the case of rennet no more than the weight of a silver denarius per pail of milk. Varro's rule of thumb is an olive-size quantity of rennet per two congii (1.5 gal./7 L) of milk. Then the mixture is allowed to sit while the rennet acts and bacterial fermentation continues to increase acidity.

Once the curd has set, continues Columella, separation of whey should proceed as quickly as possible. Columella is here speaking of his soft, low-acid cheese. But for hard, high-acid cheeses destined for aging, the curd will have been allowed to 'ripen' until the proper acidity was achieved by bacterial fermentation. The acidity of ripened milk can be judged by taste, of course, but taste can be highly subjective. An age-old test of ripeness, still used, is the hot iron test, in which an iron bar is heated in a flame until scorching hot, touched to a sample of coagulum, then drawn away. The length of the fine, silky thread pulled as the bar is withdrawn is a reliable empirical indicator of acidity.[41]

Today whey separation (the technical term is syneresis) is begun when curd has a gelatinous consistency and is expedited by slicing curd with curd combs to produce curds of a characteristic size—about the size of rice grains for dense, dry, grainy cheeses, perhaps as large as a walnut for soft, creamy cheeses,[42] and by 'scalding' the curd to various temperatures. Columella says nothing about curd cutting, unfortunately, though the process is self-evident. As an aside, the implement used in modern Italy is called a *spino*, derived from the Latin *spina*, "thorn". One wonders if a thorny branch of a tree or bush may have been used at some point to effect the process.

For soft cheeses, large curds are placed directly in wicker forms or molds or baskets to drain. This explains Columella's injunction

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[40] Cf. Pliny, *NH* 16.72. J. G. Davis [(1965): 272] reports that in 1908 Gerber made a successful coagulant from the latex of various fig species and christened the plant enzyme active therein ficin. Optimum temperature for its use is 122–149°F (50–65°C) and optimum pH is 4.6, the terminal levels of many cheeses. Ficin is used today for vegetarian 'cheeses' such as those made from peanut 'milk'. Experiments have also been conducted with extracts from flowers of the prickly artichoke (*Cynara carduncului*, the cardoon) with mixed results. Extract of dried flowers of thistle have also been used successfully.

[41] Sammis (1946): 63.

[42] Battistotti (1984): 30; Scott (1986): 193–95; P. Walstra, "The Syneresis of Curd," in Fox (1993): 141–91.

that thickened curd be transferred immediately to wicker vessels, *fiscellae*, to baskets, *calathi*, or molds, *formae*, as well as his observation that country folk immediately begin to press the cheese.[43] The baskets Columella mentions are typically made of broom, rushes or palm leaves.[44] What distinction he has in mind for 'forms' I cannot determine, but one suspects he means those made of wood, since elsewhere he refers to boxwood molds. Curds destined for hard cheeses are today heated a second time to 115°–132°F (46°–56°C) to expel even more whey, a fact which might explain Columella's "some people who prefer to put the flames to it"; it seems that Columella is aiming at a soft, mild, moist cheese of limited duration while 'country people' put aside dictates of fashion to produce a dense, pungent, long-lived cheese. How ironic that Parmeggiano-Reggiano, the prototype for such cheeses, is now among the aristocrats of cheeses.

Salting may actually occur at various times and in various ways. Some salt may be added to raw milk, and salting may also occur following drainage of whey either before or after the curd goes into forms. Salting hastens syneresis and has the secondary effect of retarding or stopping bacterial metabolism and therefore acid production. Again, curd salted before molding exudes more whey and will ultimately produce a denser cheese. Today the method of salting also varies; dry salt may be sprinkled onto draining curds and/or onto the surfaces of formed cheeses, or these latter may be immersed in a brine. This last method seems to be a recent development, though one increasingly popular.[45] The method—placing a cheese in a liquid to drive out liquid—is counterintuitive, but it would not be the first time the ancients discovered a counterintuitive technology which was nonetheless effective, and we know from Columella's description of the salting of farmer's cheese that a brine dip was an option. For what it is worth, Columella's country cheese is dry-salted after it has been unmolded, and Varro[46] says that mineral salt is preferred to

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[43] Cf. Ovid, *Fasti* 4.770, part of the prayer for the Parilia: "dentque viam liquido vimina rara sero" ("May the porous wicker form grant passage to the liquid whey.")

[44] Frayn (1979): 137.

[45] Battistotti, p. 30; Scott (1986): 199–201; Johnson and Law in Law (1999): 20–21; T. P. Guinee, "Salt in Cheese: Physical, Chemical and Biological Aspects," in Fox (1993): 257–302.

[46] Varro, *RR* 2.11.5.

sea salt, doubtless because of the bitter residual magnesium and calcium salts in sea salt, to be discussed in the next chapter.

It is interesting to hear Columella speak of wicker baskets and *fiscellae*. Today in parts of rural Greece these same little wickerwork forms are still used, the curd ladled into them as they sit in a pot for collecting the precious whey, then unmolded about forty-five minutes later and consumed fresh as farmer's cheese, or dry-salted and allowed to cure and ripen further in storage.[47] Some of the greatest artisanal cheeses in the world, in fact, are still made in these simple forms, which leave their unmistakable mark on the cheese's rind. Cheeses may also have been drained in terra cotta strainers, though we have no definitive evidence; such strainers are found as early as the Neolithic in archaeological contexts which suggest cheesemaking,[48] and we have numerous examples of terra cotta strainers from both Greece and Rome. But, of course, strainers can be used for any number of culinary processes.

To create a denser cheese, the curd is placed in a more substantial form and is weighted or pressed to extract even more whey. Traditionally pressed cheeses are first wrapped in cheesecloth; again, no mention from Columella, though his silence may not be significant. Columella's prototype hard cheese is placed in a form and weights are placed on top of it (*pondera superponunt*); doubtless a wooden or wicker 'follower' was placed on the top of the mold and simple stone weights placed on top of this to provide the pressure. But simple mechanical cheese presses have also been around since the beginning of cheesemaking, and it is not unlikely that these were used by the Romans as well. If so, Columella's weights will have been added to a simple lever mechanism to increase pressure, more weight being added gradually as the cheese became denser. It is important that increasing pressure be applied gradually, since high initial pressure compresses the surface layer of the curd and can actually lock moisture into pockets in the curd body. Care must also be taken that the temperature of the curd at pressing be below the liquid fat temperature (about 75°F/26°C) lest the fat component liquefy and be lost in the whey.[49] Columella's description seems to suggest some

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[47] Kremezi (1993): 28–29.

[48] Bogucki (1986): 54.

[49] Scott (1986): 201; Johnson and Law in Law (1999): 21–22.

sort of hybrid process in which the pressed cheese is unmolded, dry salted, placed on clean boards under weights to exude more whey (by means of reverse osmosis and pressure), then put back into press molds and "more violently compressed" before being unmolded a second time, then treated with toasted salt again and again compressed under weights on the boards. This goes on for some nine days, after which the cheeses are rinsed, placed, so as not to touch, in rows on wickerwork trays made for the purpose, and stored in a cool, shady larder. When the rind has sufficiently formed and density is correct the wheels are stacked upon each other in a cool, relatively humid larder so that they maintain correct moisture levels. Hard ewe's-milk cheeses so made are so stable, says Columella, that they may be shipped overseas. Farmer's cheese, to be eaten fresh, is much simpler. It is simply unmolded from the wicker forms, dipped into dry salt or brine, then dried in the sun briefly, and consumed within a few days.

As noted before, whey is a highly nutritious byproduct of cheesemaking, and as we have seen, the Roman food processor is at pains to maximize the yield from his raw material. Whey is ideal food for livestock, particularly swine, to whose meat it imparts a wonderful sweetness. It is no coincidence that the part of Italy which produces one of the world's greatest cheeses, Parmeggiano-Reggiano, is also the area that produces one of its greatest cured hams. But whey solids can also yield another cheese, and whey proteins are nutritionally superior to casein which is somewhat deficient in sulfur amino acids. Whey from the making of a high-fat cheese is today often reheated and allowed to sour and separate and the fine, soft curds which results collected as ricotta, literally 'recooked' cheese. Unfortunately we have no attestation here, but it is not unlikely that the process was utilized by the ancient Roman subsistence farmer by whom every shred of human nutrition had to be wrung from his foodstuffs.

Another variation on the process is the making of drawn cheeses such as mozzarella and provolone,[50] the so-called 'pasta filata,' layered cheeses of modern Italy. In this process curd is allowed to drain

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[50] Cf. Bugialli (1984): 252–7; Scott (1986): 235–39; Paul S. Kindstadt, Michelle Rowney and Peter Roupas, "Technology, Biochemistry, and Functionality of Pasta Filata/Pizza Cheese," in Law (1999): 193–221.

naturally for three hours, after which it is cut into strips, placed back in the cauldron and immersed with boiling water. The casein is quickly denatured, the strips float to the top of the water and are lifted and stretched with long paddles. The cheeseman next grabs a strip, tears off a piece, and quickly kneads it into various shapes such as balls, pears, braids, and sausages. This is precisely the technique identified by Columella as "hand-pressed cheese (*caseus manu pressus*):[51] when the curd is slightly congealed and still warm it is cut into strips (*rescinditur*) and boiling water (*fervente aqua*) is poured over it and then is either shaped by hand or pressed in boxwood molds.

Another variation on the process was the making of various flavored cheeses. We have already seen that curd was sometimes coagulated with fig sap or pine nuts, in part because these agents imparted a pleasant flavor. Columella[52] says that some actually drop the pine nuts into the milk pail before milking, while others crush them and mix them with the fresh milk. And milk coagulated with "shoots from a fig tree" (the green bark has been incised to allow the sap to exude) also has a pleasant flavor.[53] Other people crush and sieve thyme and mix it with coagulating milk, and Columella adds that the same may be done with "whatever flavor you like." Finally, he mentions that hard cheeses may be smoked with apple wood and wheat stubble (*culmi*; one wonders if this should be emended to *ulmi*, elm) to impart a delicious flavor and pleasant color.[54]

Unfortunately, none of the ancient authors gives us any details of the ripening process, nor does it leave traces in the archaeological record, so we are forced back upon comparative evidence exclusively. Factors which influence ripening are the constituents of milk, the type of microflora present in the curd, the method of cheesemaking, moisture content, salinity and size of the ripening cheese, as well as temperature and humidity of the curing room.[55] This accounts in part for the endless variations in character of cheese

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[51] Columella, *DRR* 7.8.7.

[52] Columella, *DRR* 7.8.6.

[53] Columella, *DRR* 7.8.2.

[54] Columella, *DRR* 7.8.7.

[55] Battistotti (1984): 30–31; Scott (1986): 261–75; P. J. Fox, J. Law, P. L. H. McSweeney and J. Wallace, "Biochemistry of Cheese Ripening," in Fox (1993): 389–438; Johnson and Law in Law (1999): 22–23; Wilhelm Bockelmannn, "Secondary Cheese Cultures," in Law (1999): 132–62.

varietals as well as the changing flavor of individual cheeses as they progress through their life cycles. During ripening, casein is catabolized to simpler proteins which are more digestible and confer a different flavor and aroma on the cheese. Allowed to continue too long, the process yields the pungent odor of ammonia characteristic of overripe cheese. Ideal ripening temperature is 40°F (4.5°C) for soft cheeses and 64°F (18°C) for hard cheeses; humidity of 90% and above is ideal for soft cheeses, 75–85% for hard cheeses. Most modern creameries have controlled airing rooms, whereas our ancient cheeseman could achieve the parameters for soft cheeses only underground or in caves. This fact also helps to explain the predilection for hard cheeses among country folk alluded to by Columella.

As we have seen, ripening cheeses are given a rind or crust by dry-salting or brining the cheese and then drying, a rind which varies in appearance and texture according to the style of cheese. Without intervention, the rind will inevitably develop a flourishing colony of bacteria and/or molds, particularly the latter, which are aerobic and therefore limited to the cheese's exterior. Cheeses which are mold-ripened, especially by molds of the Penicillium family, have a characteristic white rind and the smell of fresh mushrooms; those ripened by bacteria have an orange-red surface color and a pungent, musky smell but a delightfully sweet taste on the palate. The rind also controls the exudation of moisture and gases from the interior of the cheese, and the cheeseman must constantly monitor the rind for signs of cracking and treat sick rinds by brushing with oil or by further brining, or by waxing the surface. Again, none of these processes is addressed by our ancient sources, though Columella does mention one method of preserving hard, year-old ewe's milk cheese in which large chunks are cut and placed in a pitched vessel and covered with best must with enough excess to compensate for the absorption of must by the cheeses. If the cheeses do not remain completely covered they will spoil. The vessel is sealed with plaster and twenty days later this prototype port-wine cheese is removed and seasoned to taste or eaten as is.

Meat

Meat is the flesh, especially the muscle tissue, of mammals, fowl and fish, when used as food. Conventionally meat includes eggs, since they share most of the nutritive profile of meats. Meat is valued nutritionally as a source of proteins, surpassed only by milk and eggs in this regard. Amounts of Vitamins A, D, E, and K are negligible in meat, and calcium levels are very low; on the other hand, meat is high in uric acid precursors, iron, and B vitamins. Meat, unfortunately, is also highly unstable, subject to enzymatic autolysis as well as bacterial putrefacients and pathogens. This explains why meat cuts are always relatively costly, a fact which limits its consumption in most societies, and this was certainly so in the city of Rome, where the cost of cartage was astronomical by modern standards. Because of meat's inherent instability and the slowness of ancient transport, in fact, the importation of butchered meat into the city was impracticable on any large scale; the fresh meat which did make its way to Rome must invariably have come 'on the hoof'. On the other hand, the meat of quadrupeds was the only commercial commodity besides slaves which was self-propelled.

But the practice of butchery of fresh meat is not our concern, wherever it may have taken place. Early on primitive man found that several of the techniques which we have already explored in other contexts could be effective, under carefully controlled conditions, in stabilizing meats. Specifically, the flesh of animals can be dried, dry cured, brined, pickled, fermented, and/or smoked; refrigeration is only partially effective here, and at temperatures which the Romans could achieve was virtually useless.

Fowl

In the realm of fowl, the Romans knew chickens, pigeons, geese, ducks, teals, cranes, peafowl, thrushes, and turtledoves.[56] Obviously many of these birds could be transported and sold live, but one wonders if some may not have been cured or pickled as well. Herodotus[57] reports salted quails as a favorite food of the Egyptians, and small birds, unidentified as to species, were pickled by Egyptians of all periods, judging by depictions of this activity in tombs.[58] Because of

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[56] Varro, *RR* 3.2–3.

[57] Herodotus, *Histories* 2.77.

[58] William J. Darby, Paul Ghalioungui and Louis Grivetti, *Food: The Gift of Osiris* (New York: Academic Press, 1977): 310.

the migratory patterns of many birds in the Mediterranean, especially of waterfowl, the eating of fresh fowl there is a feast or famine scenario, so that some form of processing is certainly economically mandated. Unfortunately our Roman sources fail us completely here.

Eggs are valued in almost all cultures for their culinary and nutritive properties. Eggs are an extraordinarily good source of proteins as well as fats, carbohydrates, trace minerals, and vitamins. Their digestibility when cooked is high. Though organoleptic qualities change when eggs are stored, there is little nutritional change for up to four months at room temperature.[59] The Romans commonly stored raw eggs in dry storage. Columella, for example,[60] says that eggs may be conveniently stored buried in chaff in winter, in bran in summer, having first been covered with pounded salt for six hours. The effect of the dry salting will have been to kill many of the spoilage organisms, particularly molds, on the surface of the shell. Others, Columella adds, bury eggs in piles of fresh beans or in bean flour (*faba fresa*) or in unmilled salt, or pickle them in brine. But, he warns, any form of salting causes the egg to shrink (dehydrate) inside the shell and thus discourages buyers. Columella's advice on dry storage is sound, though his advice on brining whole uncooked eggs is rather dubious; eggshell, essentially a thin layer of calcium carbonate, is gas permeable; the most effective way to make the shell totally impermeable is to coat it with olive oil or wax. Thus treated and stored in a desiccant such as those Columella prescribes, eggs will keep for about a year.[61]

Mammals

Meat proper, that is, mammalian flesh, is generally preserved according to climatic conditions and the meat's fat content. Under the right climatic conditions, meat may be dried to achieve stability, but those conditions were not operable in our case. By far the most frequently

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[59] Muller and Tobin (1980): 210–12.

[60] Columella, *DRR* 8.6.1–2; cf. Varro, *RR* 3.9.12.

[61] Mollinson (1993): 184; Peter Brears, "Pots for Potting: English Pottery and its Role in Food Preservation," in Wilson (1991): 67. For comparison, until the 19th c. in England, eggs were cleaned and coated with gum arabic or butter or oil and packed in bran or sawdust; thereafter they began to be pickled in a lime-water solution.

preserved meat product—indeed, the most important meat period—for the Romans was pork. Pigs are in many ways an ideal subsistence farm animal: the hog yields a greater percentage of edible meat from the carcass than any other mammal; it is also the most efficient farm animal at converting grain to meat; it reproduces faster and in greater numbers than any other domestic animal and grows to slaughter size very rapidly. Additionally, production of swine requires a minimal investment in animals and equipment, and range swine are largely self-sufficient. Likewise, pork is an ideal meat for processing: cured pork is easily processed on the farm with simple technologies and is ideal for shipping long distances and for long-term storage at its destination. Furthermore, pork is a most nutritious meat and the hog yields numerous useful byproducts, including lard, the most valuable and versatile fat produced by any domestic livestock.[62] Little wonder, then, that pigs were such an important farm animal in most parts of the Empire. Analysis of bone assemblages from a large number of archaeological sites reveals that pigs were the dominant food animals in all parts of Italy except southern Italy, at least during the classical period, and that the "high pork pattern" of west central Italy, the heart of the Empire, emerged in the late Republic. This high pork pattern seems to have had a socio-economic aspect as well, to judge by individual villa sites where pork seems to have been the luxury meat associated with higher-status parts of the villa such as the villa urbana.[63]

Our literary sources give us explicit directions for the curing and pickling of pork, indicative of the important role pork processing played in Roman agribusiness. Unfortunately they say little about the butchering of hogs destined for processing, and this is a critical part of the processing itself, for reasons we will discuss momentarily. Fortunately, the traditional butchering process changed very little before the first quarter of the twentieth century and is still unchanged

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[62] Maurice David Helser, *Farm Meats* (New York: MacMillan, 1923): 9–10; Frank Frost, "Sausage and Meat Preservation in Antiquity," *Greek, Roman and Byzantine Studies* 40 (1999): 241–52.

[63] Anthony King, "Diet in the Roman World: A Regional Inter-site Comparison of the Mammal Bones," *Journal of Roman Archaeology* 12 (1999): 168–202. For a piggery on an industrial scale, see Carandini II (1985); 182–88. Cf Michael Mackinnon ("High on the Hog: Linking Zooarchaeological, Literary and Artistic Data for Pig Breeds in Roman Italy," *American Journal of Archaeology* 105 [2001]: 649–73) for evidence of at least two distinct breeds of pigs in Roman Italy.

in many parts of the world. Thus, comparative practices are reliable here.

In temperate and subtropical climates, hogs are slaughtered in late fall and early winter to take advantage of their increased bulk from summer mast and of natural refrigeration. Thus Palladius'[64] remark that hams and lard are cured during the cold winter months. Zooarchaeological evidence confirms that pigs were most often slaughtered in the fall of their second year (c. 15–18 months) when they had attained their maximum weight. An eighteen-month-old hog will more than double in weight during the three months of autumn mast feeding, and evidence suggests that sows were bred seasonally to ensure that offspring would reach full maturity at this time.[65]

Hogs for slaughter must be healthy, unfed for twenty-four hours (this facilitates bleeding); they must not be traumatized or excited at slaughter since the former bruises the meat and bruised meats "sour" during curing, and the latter causes a complex series of metabolic and endocrinal reactions which also sour the meat. Lack of stress and trauma are particularly important in hogs destined for making of fermented meats such as sausage. The only intrinsic quality which makes one species' meat more suitable for fermentation than another's is a relatively high glycogen content. This is so because enzymes present in muscle convert glycogen to lactic acid *post mortem*, thus reducing the pH of the meat and inhibiting spoilage. Some breeds of pigs have genetic complements which expedite this conversion either more rapidly or to a lower final pH. But severe exercise or any stressful circumstance proximate to slaughter depletes *in vivo* supply of glycogen and thus raises ultimate pH higher than the normal 5.5, causing unpleasant dark color, sticky consistency and diminished flavor.[66] Thus Columella's[67] advice that the hog should be prevented from drinking on the day of slaughter so as to be "fresher and drier." His etiology is incorrect, but the advice sound.

The animal is first stunned and then 'stuck' to sever the carotid arteries and jugular veins, either before or after killing, and then hung up by the hindquarters to release blood as quickly as possible; blood is highly perishable and will quickly taint a whole carcass if

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[64] Palladius 13.6; cf. Columella, *DRR* 12.55.

[65] MacKinnon (2004): 157.

[66] R. A. Lawrie, *Meat Science* (Oxford, Pergamon Press, 1995): 1–12.

[67] Columella, *DRR* 12.55.

not removed.[68] One wonders if this may not be the origin of Roman sacrificial practice; sacrificial animals should go 'willingly' to the place of sacrifice and were therefore kept off their feed before slaughter. The Romans will have observed empirically that meat from recently fed, recalcitrant animals tainted quickly, and they will not have enjoyed the taste any more than the gods presumably were imagined to, with whom they shared the meat of sacrifice. Likewise there was a religious functionary quite apart from the officiating priest, one named the *popa*, who stunned the animal with a type of sledge hammer before another functionary called the *cultrarius* slit the animal's throat and drained the blood prior to slaughter.[69]

After the carcass has been thoroughly bled the hide is scalded and scraped of hair; the carcass is then hung up, gutted, and, after the fat is removed, split into halves. Next the head is removed and the jowl meat removed from it to be cured into jowl bacon or pickled pork.[70] Shoulders are trimmed as close to the shape of hams as possible and cured as such. The two most important cuts are the rumps, used as hams, and the bellies, cured as bacon. Hams are trimmed so as to expose as little meat beneath the skin as possible, since the cure hardens exposed meat, thus impeding the further diffusion of salt. Excessively large hams, on the other hand, are trimmed of some skin and fat to facilitate absorption of salt and achievement of stability before the interior meat sours.[71]

In rural America at the beginning of this century, as described by Helser in his excellent account of traditional practices, oak barrels or stoneware crocks were used for the curing of pork. Glazed stoneware had the advantage that, if a batch of meat soured, it could be thoroughly cleaned and used again, whereas wooden barrels cannot be rid of spoilage organisms without the use of powerful chemical agents not available to the farmer. In either case the vessels were scalded before use. Romans used exclusively terra cotta vessels for the purpose, to judge by the testimonia. Cato[72] advises that hams and "small

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[68] On Roman slaughter practices, see MacKinnon (2004): 173–5 and especially 178–84, a synthesis of zooarchaeological and textual evidence, along with some comparative practices from antiquity.

[69] On the connection of altar and abbatoir, see Joan Frayn, "The Roman Meat Trade," in Wilkins, Harvey and Dobson (1995): 112–13.

[70] Cf. Columella, *DRR* 12.55.

[71] Helser (1923): 36–44; cf. Frost (1999): 244–46.

[72] Cato, *Agr.* 162.

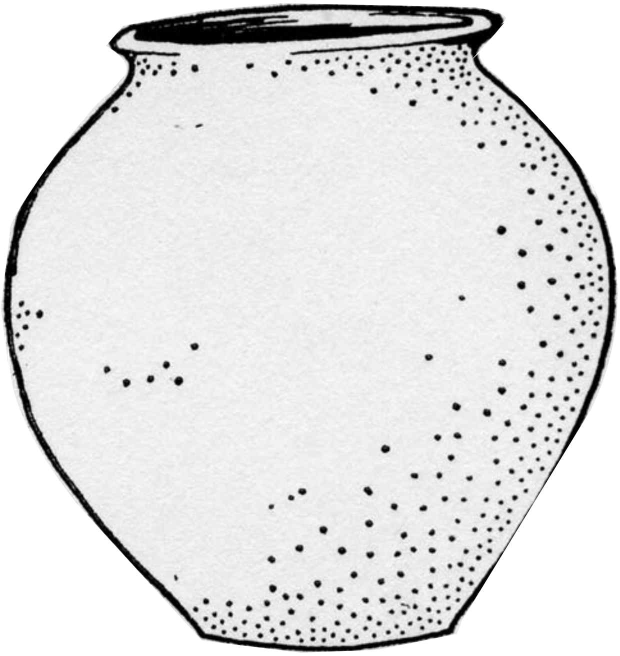

Fig. 30. The *seria*, a storage jar of medium size. (From White (1975): Fig. 51. Courtesy of Cambridge University Press).

pieces such as are put up at Puteoli" (obviously there was a thriving export market for pork products even at this early time) should be put up in *dolia* or *seriae* [Fig. 30], presumably waterproofed with gum arabic and thoroughly cleaned.

Pork and other meats may be dry-cured, brined, or pickled. Curing agents are fairly standard. Salts and sugars not only dehydrate the meat itself but are themselves bacteriostatic, as we have seen, because of their hypertonic effect on microorganisms. Furthermore, certain microorganisms are halophilic (salt tolerant) and these act in three important ways. First they often overgrow pathogens; secondly, they are often metabolizers of glycogen to lactic acid and thus lower final pH; third, they are often capable of reducing nitrates to nitrites to produce nitric oxide.[73] Traditional curing agents are common salt (sodium chloride) and various sugars; today, of course, sucrose is used in the West almost exclusively, but was unavailable in classical

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[73] Lawrie (1995): 16.

Rome. Sugars also partially counteract the hardening effect of salt on the meat. Anyone familiar with a good country ham or a prosciutto will remember its beautiful red color; in part this is characteristic of cured pork, but it is primarily the result of chemical action of curing salts which contain 3–4% potassium nitrate (saltpeter) or sodium nitrate. The red color is effected by formation of nitrous acid as the nitrates act on hemoglobin in the meat to produce a bright red derivative, hemorrhoidin. But the most important role of nitrate is the control of deadly *Clostridium botulinum*, itself a halophile, and this inhibitory effect thus secondarily allows salt concentrations to be reduced to levels more acceptable organoleptically.[74] Had the ancients discovered empirically the efficacy of this technology? Lawrie[75] wonders if sodium nitrate may not have been introduced fortuitously by the ancients along with sodium chloride. One wonders if something like this lies behind the ancient preference for 'red salt' or 'Egyptian salt' in meat curing.[76]

Meat to be cured must be thoroughly cooled but not frozen. A cool, well ventilated cellar is an ideal environment, and our Roman villa had just such a room called the *carnarium*. Brine curing is somewhat more dependable if ambient temperature never rises above 40°F (4.5°C); otherwise the dry cure is better. In this case dry rub is pushed up along the shank bone of hams and shoulders into the joint where the cut was trimmed from the side.[77] Then the salt is applied in bulk. Cato recommends for each ham a half modius of 'Roman salt' (presumably mineral salt from the Roman saltworks on the Tiber) ground in a mill. Though Cato does not specify, large-grain salt is preferred for dry-curing because fine-grain salt leaches out liquids faster than the salt can seep into the meat and thus seals the surface with a horny rind, preventing good penetration.[78] As a guess, this may be the import of Columella's recommendation of salt ground in a 'hanging mill' (*suspensa mola*); presumably he means a mill equipped with a rynd or some other tentering mechanism such that it can be adjusted for a coarse grind. A layer of salt is spread on the bottom of the curing vessel, then hams are placed upon it,

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[74] Troller and Christian (1978): 108.
[75] Lawrie (1995): 163–64.
[76] Cf. Helser (1923): 52.
[77] Helser (1923): 57.
[78] Stead in Wilson (1991): 66.

skin side down, and covered with more salt. Additional hams are layered in the same way such that they never touch, and the vessel is topped up with more salt. Columella recommends this same method in warmer weather and says that smaller cuts thus cured will keep indefinitely if, like salt fish cured in this manner, they are allowed to keep in the brine which results as the meat's moisture is exuded. Interestingly, Helser recommends that meat be rotated from bottom to top and vice versa when it is repacked, since a natural brine collects at the bottom of the vessel,[79] and this accords perfectly with Cato's advice[80] that hams be rotated in the same fashion after five days.

For dry curing in cold weather Columella recommends a slightly different method. Hams are boned, so far as possible, and toasted salt ground from the 'hanging mill' is stuffed into the bone cavity and run up along the remaining bone shaft. The hams are arranged on boards, encased in salt, and heavy weights (presumably placed on another board on top of the salt as a follower) are imposed to express liquid for three days. On the third day the weights are removed, the pork rubbed thoroughly with salt, and the weights reimposed. The same process is repeated daily, for nine days if the weather stays fair, for eleven or twelve if it is rainy or humid. The same method may also be used for flitches of bacon.[81] For purposes of comparison, Helser recommends that larger cuts be repacked at 21 days and flitches and smaller cuts removed at this time.[82] Since Columella's time recommendations are apparently for the flitches and smaller cuts, not the hams he has been discussing, his total recommended duration of 12–15 days is not completely out of line, especially as the compression of the meat actually facilitates infiltration of salt. Cato, however, recommends a total curing time for hams of only 12 days, a figure that sounds dangerously low.

Helser's traditional method has the meats hung in the smokehouse for 24 hours to 'sweat' before it is smoked; Cato would have his hams cleaned of salt and hung "in the breeze" for two days for the same purpose, then thoroughly cleaned, and smoked for two days. On the third day they are thoroughly wiped with a sponge, rubbed

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[79] Helser (1923): 58.
[80] Cato, *Agr.* 162.
[81] Columella, *DRR* 12.55.
[82] Helser (1923): 57–58.

down with a mixture of olive oil and vinegar, and hung in the larder (*carnarium*) "where neither moths nor worms will touch them." Columella would have us take the pork cuts to a body of fresh water and cleanse them of salt and then hang them immediately in the larder where a moderate amount of smoke can reach them.

Doubtless in the larder the hams and other cuts will have undergone a ripening process.[83] Traditional country ham and salami production rely on 'house flora' in the buildings, rooms, caves, and equipment used. They consist of a wide variety of yeasts and molds, among the more common of which are Penicillium, Aspergillus and Eurotium species. The Penicillia dominate sausages because of their higher water activity while the lower water activity on the surface of dry-cure hams and their longer aging process favor development of the latter species. For what it is worth, yeasts isolated experimentally from modern traditional country hams (Spanish hams in this case) were primarily strains of Debaromyces and Candida, though concentrations were minimal compared to bacteria and their role in ripening likely to be minimal as well. Penicillium molds, on the other hand, definitely improve the flavor of hams; Stead[84] describes eighteenth-century English practice in which hams were hung in a damp place for one or two months to develop a vigorous mold, which made them "cut fine and short," according to a contemporary. Stead thinks it likely the molds are the blue-green penicillium molds.

Hams and flitches were the two cuts of meat most commonly dry-cured by the Romans, and they must have been fairly common foodstuffs on the farm.[85] Indeed, Varro[86] has Scrofa remark that their

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[83] Cf. P. E. Cook, "Fungal Ripened Meats and Meat Products," in Geoffrey Campbell-Platt and P. E. Cook, edd. *Fermented Meats* (London: Blackie Academic and Professional, 1995): 110–29.

[84] Stead in Wilson (1991): 76, citing Hannah Glasse, *The Art of Cookery Made Plain and Easy* (London, 1747): 130.

[85] For comparison, Stead in Wlson [(1991): 73–4] cites Willliam Ellis' *Country Housewife's Companion* (London, 1750), which avers that bacon is "a serviceable, palatable, profitable, and clean meat, for a ready Use in a Country House; Ready, I say, because it requires not to be kept in a Cellar, or at any Distance from a Kitchen or Chamber, but may be had at all Times of the Year for being cut to boil, fry, broil or bake." Ellis reported that bacon was popular among rich and poor alike and was practically the only meat eaten among families in northern England. Pigs intended for bacon were fattened to huge proportions and were bred for fat because the fat took salt so well but did not taste as salty in the cure, whereas lean meat took up salt too readily and tasted so salty it had to be soaked or boiled to be palatable.

[86] Varro, *DRR* 2.4.3.

ancestors had branded as extravagant and lazy any man who would hang a flitch of bacon in his larder bought from a butcher rather than produced on the family farm. Elsewhere he reports that the Gauls of his own day made the best and largest flitches and that Comacine and Cuvarine Gauls (both tribes probably lived in Gallia Narbonensis) exported annually to Rome both hams (*pernae*) and shoulders (*petasiones*). About the remarkable size of Gallic flitches he cites Cato as saying that in Italy the Insubrian Gauls cure three to four thousand flitches annually, and that there in spring sows are accustomed to grow so fat that they cannot sustain their own weight and therefore must be moved in wagons. The Insubrians were a Gallic people who lived in what is today Emilia, in and around Parma; remarkably, there has apparently been a continuous tradition of excellence in cured pork here for more than two thousand years. Varro further reports a claim by the Spaniard Atilius, "a very credible man, learned in the lore of many subjects," that a piece of pork was sent from Lusitania in further Spain (Portugal) to the senator Lucius Volumnius; the flitch, with two ribs attached, weighed 23 pounds, and the meat was a foot and three fingers thick from skin to bone!

About brining of meat we hear very little from the ancient geoponics, probably because the higher winter temperatures of Roman Italy made the dry-cure more effective.[87] Additionally, as we have seen, meat dry-cured in closed vessels will incidentally create its own brine. The only extant reference to deliberate brining of pork, if it is so and not a reference to dry-cured pork in its own brine, is Varro's report[88] (by way of Scrofa) of a bronze image of the portentous sow which announced to Aeneas the site of the future Rome, the meat from which sow was still being exhibited by priests of Scrofa's (and presumably Varro's own) day, preserved in brine (*salsura*). The wise are skeptical, says Socrates; we are perhaps not too impertinent in questioning whether pork, even brined with the aid of the gods, could be preserved for over a millennium!

On the other hand, curing, either via dry-cure or brine, is a highly effective way to preserve pork. But from time to time pork sours, usually during the first four weeks of curing. Souring is detected by

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[87] For comparative practice, cf. Stead in Wilson (1991): 76–8.

[88] Varro, *RR* 2.4.18.

a distinct sour odor and typically begins at the 'stiffle' joint of hams and works toward the center of the meat, away from the brine. Hence the ancients' concern to pack cure along the bone and/or bone cavity especially carefully. Souring is caused by a number of organisms,[89] prominent among them the spoilage organism *Bacillus putrifaciens* and the pathogen *Staphylococcus aureus*, still a major cause of food poisoning in tainted meats. This latter is resistant to salt and nitrites, facultatively anaerobic, and heat resistant, and often develops during the lag time of LAB colonization. Fortunately it is a poor competitor and is quickly overgrown by other microflora. However, its enteterotoxins, five of which may be produced, persist but are rapidly catalyzed in the presence of reducing agents such as nitrite. Meat may also be tainted indigenously or after slaughter by infection. Disease caused by *Bacillus anthracis, Mycobacterium tuberculosis*, or *Brucella abortis* is obvious in the living animal and ideally leads to disposal of the carcass before butchery. But infection by various types of *Salmonella. Listeria monocytogenes, Campylobacter jejuni, Escherichia coli, Giardia lamblia*, and *Yersinia enterocolitica* are not detectable either in the living animal or immediately *post mortem*. The most immediate source of most such infection is the animal's blood, though meat is also contaminated by contact with feet, hides, or skin, fecal matter, or instruments of slaughter. Fortunately many of the pathogens are not viable at chill temperatures (c. 32°F/0°C) and others are overgrown by harmless psychrotrophic (cold-tolerant) organisms.[90]

Tainted meat must be discarded. But after a good cure the meat is remarkably stable when stored in a cool, ventilated area, except on its surface, where it is susceptible to insects (the "moths and worms" of Cato's comment) and to molds. Prevention of attack by vermin is the primary reason for smoking preserved meat, although the subtle, smoky flavor it imparts to the meat is so desirable that many modern, uncured meats such as so-called 'bacon' are artificially smoke-flavored simply to impart organoleptic properties. Real smoking acts as a preservative by forming a layer of creosote on the surface of the foodstuff, a coating which repels insects, inhibits further desiccation and bacterial colonization, and contributes to flavor.

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[89] L. Kröckel, "Bacterial Fermentation of Meats," in Campbell-Platt and Cook (1995): 77.

[90] Lawrie (1995): 13–16.

Creosote contains phenols and phenanthrene derivatives which inhibit bacterial infection and oxidative rancidity of the lipids in the fatty portions of hams and flitches. Active bactericides in creosote include formaldehyde, acids, carbonyls, alcohols, and polycyclic hydrocarbons. More specifically, the acids include formic, acetic, butyric, caprylic, vanillic, and syringic acids, alcohols are methyl, glyoxal, furfural, ethyl, and syringic acids, and aldehydes include acetaldehyde, diacetyl, acetone, and 3,4-benzopyrene. These are the main constituents, though more than two hundred separate components have been identified.[91] But if temperature is allowed to rise too high during the smoking process, deep-seated bacterial growth of the sort previously discussed ('bone taint') is encouraged. Thus the meat must be kept away from the source of heat which generates the smoke. Meat is therefore often hung in the rafters of a smokehouse, at least 6–8' (2–2.5m) from fires, or indirect smoke is introduced to the smokehouse by way of ducts at ground level. Hardwoods are usually used to smoke meats, since conifers' sooty smoke leaves a resinous flavor.[92] Exactly how smoking was effected in the ancient Roman *carnarium* is impossible to say; we have only Columella's terse remark[93] that cured meats are hung in the *carnarium* "where a moderate amount of smoke may reach them (*quo modicus fumus perveniat*), which will dry up any moisture." Again, good advice, wrong etiology.

About true pickling (as opposed to brining, but note that 'pickled pork' is typically brined pork) of meats we hear almost nothing from the ancients, curiously, perhaps because such products were not sold commercially by villa farmers. Apicius[94] tells us that sides of pork or beef or tenderloins of both are pickled in mustard, vinegar, salt, and honey, completely covered. He also says that fresh or cooked meats suspended in a vessel and covered with honey will keep in winter, but only a few days in summer. The use of honey as a cure will have been extravagant beyond the means of all but the wealthiest Romans, though we might have expected to see some form of grape concentrate and/or vinegar used as a cure; perhaps the taste it imparted to meat was thought unpleasant.

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[91] Helser (1923): 61–62; Lawrie (1995): 164–70.

[92] Helser (1923): 61.

[93] Columella, *DRR* 12.55.

[94] Apicius 1.7.

We are in similar straits when it comes to the making of cured sausages, though it is obvious from frequent incidental references in the literature that a wide variety of sausages, both fresh and cured, were quite common. The geoponics say nothing of the process, and our sole literary evidence is a recipe from Apicius for a hard-cured sausage called *lucanica*.[95] In addition, sausage making by its nature leaves no identifiable archaeological evidence. Thus it should be emphasized that the following discussion is largely inferential. The advantage of curing meat in a casing is that small portions of meat, scraps and organ meats can be cured in a cost-effective way; additionally, herbs and spices can be thoroughly mixed with comminuted meat to completely infuse their flavors and act as antioxidants, bacteriostatics and antibiotics.[96] Additionally sausages, unlike large cuts of meat such as hams, can be subjected to controlled lactic fermentations to produce lactic acid as a preservative and flavoring agent.[97] The origin of this technology is obscure, but it was already well known by the Babylonians and Chaldaeans and was certainly used by the Greeks long before the Romans.

The technology of traditional sausages is relatively simple and universal:[98] raw meat, usually pork and pork fat, is minced, mixed with sodium chloride and sometimes nitrates or nitrites, perhaps a small amount of a sugar, herbs and spices, and then stuffed into a casing, traditionally animal intestine. Apicius in his recipe recommends a mixture of minced pork, pepper, cumin, savory, rue, parsley, liquamen or garum (in place of salt), laurel berries, whole peppercorns and nuts, all to be stuffed carefully into the casing and then smoked. Though Apicius does not mention it, to direct fermentation, the traditional practice is 'back-slopping', i.e., using some mix from a previous successful fermentation as a starter culture. With traditional LAB fermentation, pH drops from c. 5.8 to c. 4.8 within one month. But in some traditional Italian sausages surface molds of the sort previously discussed later reverse that drop and produce a final pH

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[95] Apicius 1.61.

[96] For the effects in sausage, Lawrie (1995): 30; Campbell-Platt in Campbell-Platt and Cook (1995): 39. In general, cf. infra, Ch. 6.

[97] Cf. P. Zeuthen, "Historical Aspects of Meat Fermentation," in Campbell-Platt and Cook (1995): 53–68 (somewhat unreliable); Kröckel in Campbell-Platt and Cook (1995): 69–109.

[98] Geoffrey Campbell-Platt, "Fermented Meats—A World Perspective" in Campbell-Platt and Cook (1995) 44–51.

of 6.0–6.2. Surface molds such as *Penicillium nalgiovense* contribute to flavor, but other molds produce powerful mycotoxins. Smoking not only expedites dehydration but also inhibits this surface mold growth.[99] Preservation is achieved by a combination of microbial action, lowering of water activity via salting and dehydration, use of herbs and spices, and smoking. Lactic meat ferments can be effected by *Lactobacillus plantarum, L. brevis, Pediococcus cerevisiae, Micrococcus spp., and Leuconostoc mesenteroides*. The original inoculation of sausage meat was doubtless fortuitous; examination of sausage-making facilities in traditional areas reveals that ambient strains of these species will yield results of varying qualities. A sausage manufacturer lucky enough to have access to a particularly effective colony might well expect to establish a reputation.[100] During the fermentation nitrates (now universally present) are reduced to nitrites by various strains of Staphylococcus and Micrococcus and perhaps by *Lactobacillus plantarum*. This reduction must occur during the early stages of lactic fermentation, since bacterial reduction of nitrate to nitrite is insignificant below pH 5.4. Fortunately, less than 50 ppm of nitrite is sufficient to obtain the full cured color of sausage.[101]

In addition to their own bacteriostatic functions, salts and spice formulations can be used to control the rate and degree of fermentation of these strains; final acidity on the order of pH 5.5–4.0 is sufficient to suppress development of important pathogens, especially in semi-dry, salty sausage meats. In addition to lactic acid, certain fatty acids are also bacteriostatic, including the byproducts of lactic fermentation, acetic and propionic acids.[102]

Traditional hard-sausage processing mixes raw meat, especially pork, with fat, especially lard, in roughly a 2:1 ratio, to which mixture herbs and spices as well as salt are added. Sausage mixes are today invariably cultured in Western countries, whereas traditional producers in preindustrial societies rely on ambient strains to colonize the meat. To this end, wooden or porous earthenware vessels are often used. The mix is cased in the small intestine of various

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[99] Campbell-Platt in Campbell-Platt and Cook (1995): 39–40.

[100] Just this scenario developed in Pennsylvania Dutch country during attempts to reproduce elsewhere the characteristic flavors of Lebanon bologna. Several strains of Lactobacillus were discovered to be responsible for the ferment.

[101] Kröckel in Campbell-Platt and Cook (1995): 93.

[102] Carl S. Pederson, "Processing by Fermentation," in Heid and Joslyn (1967): 495–96; Mollinson (1993): 72–77.

animals, particularly pigs, and is then hung up to dehydrate and ferment at 72–82°F (22–28°C), then may be smoked and further desiccated over direct or indirect fire, and is stored at 50°–60°F (10°–15°C).

Fish

Italy is a peninsula whose waters abound with an incredible variety of fish and seafoods. Among those known to the Romans were pike, bream, pollack, perch, tench, cod, flounder, eel, haddock, mackerel, mullet, whiting, wolffish, wrasse, and tuna, as well as molluscs such as oysters, snails, and mussels; cephalopods such as sea urchins, squid and cuttlefish, and crustaceans such as shrimp, prawns, langoustine, and lobster. Modern Italians are passionate about seafood, as well they might be, since fresh or fresh-frozen seafood is available virtually year-round in all but the remotest areas. Though ancient Romans who lived along the coasts will have been fortunate enough to have access to at least the more common, and therefore cheaper, seafoods,[103] the vast majority of Romans were precluded by cost and slowness of transport from ever tasting such expensive delicacies. Nevertheless, it is probable that seafood was an important element in the diet of significant numbers of ancient Romans, albeit in the form of dried and/or salted fish and brined processed seafoods.

Again, the origin of the technology is timeless. Maritime and riverine cultures all over the world have effected techniques for preserving fish and shellfish. We know that the ancient Egyptians, for example, dried and salt-cured and pickled a variety of fish from the earliest dynasties.[104] Trade in salt-fish and salt-fish products in the Roman world began as early as the seventh century BCE and extended well into the Byzantine Age. Basic techniques seem to have been introduced from the East to the Western Mediterranean, especially by way of the Phoenico-Carthaginians and Greeks. The heyday of international trade in the Roman world, and probably of

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[103] But see for a cautionary note on the presumed importance of seafood in the Greco-Roman diets Nicholas Purcell, "Eating Fish: The Paradoxes of Seafood," in Wilkins, Harvey and Dobson (1995): 132–49. In a similar vein, John Wilkins, "Social Status and Fish in Greece and Rome," in Gerald Mars and Valerie Mars, edd., *Food, Culture and History, Vol. I* (London: The London Food Seminar, 1993): 191–203.

[104] Darby (1977): 369–79.

manufacture as well, was the second century BCE to the fourth CE, and evidence is especially plentiful for the first three centuries of the Roman Empire.[105]

Fish are a special challenge to the food processor. Nutritionally, in addition to the precious animal proteins, they are valuable sources of trace elements such as iodine and fluorine; oily fish are also rich in histadine; and the livers of tuna contain high levels of vitamins A and D. The problem is that freshly-caught fish begin immediately to undergo catabolic changes because autolytic enzymes, particularly in the liver and gut (pyloric caeca) quickly begin to break down muscle tissue and to hydrolyze (make water-soluble) proteins. This is *not* putrefaction, though the process provides an ideal environment for putrefacient microbes, unless they are otherwise arrested, and it radically changes the texture of the flesh. For these reasons many fish, especially large ones, are gutted and cleaned as they are caught. But in the presence of high salinity, on the order of 10–20% by weight, autolysis will continue but putrefacients and pathogens, especially *Clostridium botulinum*, are arrested; given enough time (several months to a year) fish flesh left in brine will be significantly hydrolyzed and remaining bone and solid tissue will precipitate. The liquid portion thus obtained is a clear, often caramel-colored, intensely salty sauce which is high in proteins and other fish nutrients. The solid 'lees' are a fish paste which is also highly nutritious. Both are so intensely salty that they can be eaten only as a condiment, but are excellent as a supplemental protein source as well as a primary source of such trace elements as fluorine, and some vitamins. On the Pacific Rim, where both products are still widely consumed, fish sauce and paste contribute significantly to diets, and there is evidence that consumption by Vietnamese people is largely responsible for the excellent state of their teeth—far better than that of typical Westerners—and the same has been suggested for the Herculaneans, based on skeletal remains found there.[106]

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[105] Robert I. Curtis, *Garum and Salsamenta: Production and Commerce in Materia Medica* (Leiden, E. J. Brill, 1991): 2–3. Curtis' excellent monograph is the definitive work, but cf. also Köhler, "Tárixos, ou recherches sur l'histoire et les antiquités des pêcheries de la Russie méridionale," in *Mémoires de l'Académie Impériale de Sciences de St. Petersburg*, 6th sér., tome 1 (1832, extract); R. Zahn, s.v. "Garum" in *RE* 7 (1912): cols 841–49; Claude Jardin, "Garum et sauces de poisson de l'antiquité," *RSL* 27 (1961): 70–96. For modern comparative practice, Mollinson (1993): 127–37.

[106] Mollinson (1993): 127–28. For Roman dental health, Curtis (1991): 24 and

We are talking, then, about three distinct products, the processing of which overlap: salt-cured fish (Latin *salsamenta*), fish sauce (*garum* and/or *liquamen*) and fish paste (*allec*). Strictly speaking, the last two are condiments and belong generically in the next chapter, but because the basic processing of all three depends upon the same biological and physical processes and are most often part of the same industrial process—indeed, the fish parts used to create *garum* are often byproducts of the manufacture of salt-fish, and *allec* is invariably a byproduct of *garum* manufacture—they will be treated here as a unit.

Salt-fish and salt-fish products were manufactured in the Roman world in installations called *cetariae* (pl. of *cetaria*, 'salt vat'), or salteries. There is literary evidence for such salteries in Italy as early as the second century BCE, and both literary and archaeological evidence identifies salteries at Emona (modern Ljubljana), Aquileia (Udine), Cosa (Ansedonia), Ostia, Rome, Antium (Anzio), Cumae (Cuma), Beneventum (Benevento), Puteoli (Pozzuoli), Pompeii, Velia, Vibo, Thurii, and Tarentum, as well as on Corsica, Sardinia, and especially Sicily. During our target period, however, there is very little evidence of large-scale commercial activity in Italian products except at Pompeii. Best current conjecture is that the commercial market at this time was so thoroughly dominated by Spanish imports that local production in Italy was largely destined for local markets. On the other hand, if Juvenal[107] is not grossly exaggerating (as is his wont, N.B.) in saying that Italian waters were overfished and exhausted in his own day, a decline of salt-fish industries in Italy and the consequent Spanish domination of commercial trade are to be expected.[108]

Salteries in the Western Mediterranean are mentioned in Greek literature as early as the fifth century BCE and must have existed there much longer, since at this point Spanish salteries were exporting to Greece. In the heyday of the industry salteries dotted the coastlines of the Mediterranean from the Straits of Gibraltar to the Propontis and on into the Black Sea and the Sea of Azov, and have

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Sarah Bisel, "The Skeletons of Herculaneum, Italy," in Barbara A. Purdy, ed., *Wet Site Archaeology* (Gainesville, FL: National Endowment for the Humanities, 1988 [= *U. of Florida International Conference on Wet Site Archaeology*]): 212 and Table 1.

[107] Juvenal, *Sat.* 5.92–98.

[108] Curtis (1991): 85–96.

also been located in Britain, along the Atlantic coast of Spain and Portugal, and even in the northern provinces, albeit on a much more modest scale. The greatest concentration of salteries was along the migratory routes of anadromous species, especially mackerel and tuna, as we would expect. In fact, the only absolute essentials for a saltery location are ready access to fish, salt, and fresh water. Many salteries were located at the confluence of a stream or river with the sea, along the migratory routes of fish, where local salterns produced ample salt. The fresh water is essential for cleaning fish and facilities and for mixing brine.

Physical plants can be as simple as a terra cotta or stone vat along a beach front, utilized by a small group of fishermen as a cottage industry, but many were industrial installations connected to a maritime villa, and there is attestation of imperial *ceteriae* as well. The prototype saltery detailed here is synthetic, based largely on villa salteries in Baetica (Spain), but there is enough conformity in such facilities to justify the exercise. Unfortunately, the physical remains of not a single saltery have been found in mainland Italy, not even at or near Pompeii where we know from other sources there was a thriving salt-fish industry.[109]

Our prototype saltery is a rectangular building located along the coastline of the Mediterranean at the confluence of a river. A salt-marsh saltern of the sort detailed in the next chapter provides a ready supply of salt. The central processing room is placed such that the pavement slopes seaward to facilitate cleaning; alternately, fermentation vats are arranged in two rows or semicircles on either side of a central corridor, in the middle of which is a declivity for collecting waste water and fish parts from the vats during cleaning. The shed is roofed to protect the vats from the elements, but the walls have large open windows to provide maximum ventilation. The heart of the installation is the series of vats, constructed of stone rubble or masonry and waterproofed on their interiors with *opus signinum* (waterproof mortar), placed at ground level or, more typically, buried in the ground to provide easy access. These vats are often square or rectangular except for a quarter-round ovolo at the

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[109] Curtis (1991): 46–147, to which my account of the synthetic installation is almost totally indebted.

corners for reinforcement of walls and to facilitate cleaning. Ground-level vats have a spigot near the bottom; floors of buried vats slope to a central declivity designed for the same purpose. The vats in our prototype are c. 10' (3m) square and c. 8' (2.5m) deep, but the size (and, for that matter, the shape: at Baelo in Spain the vats are cylindrical) may vary; the size of a 'batch' of salt fish or garum is technically irrelevant. Only the proportion of salt added is essential. There is some evidence, however, to suggest that larger vats in the same facility are for curing salt-fish and smaller ones for *garum* production.

At one end of this fermentation room is a rectangular room for cleaning and processing the fresh fish, probably equipped with wooden tables or benches, though the evidence for this is long gone. Outside one wall of this room is a large waterproofed reservoir which has been interpreted as a holding tank for live fish; alternately, holding ponds (*piscinae*) cut into the rock nearby and connected by channels to the sea perhaps functioned in the same way. A separate shed, several hundred feet away, has a roof but walls completely open to the elements to provide maximum ventilation. Holes in the ground in this room are interpreted as receptacles for braces of the drying-racks for salt fish. Immediately adjacent to the fermentation room, opposite the processing room, is a furnace room for supplying supplemental heat during cool, humid weather or for boiling smaller batches of *garum* to speed up the process of decomposition.

On the landward side of the saltery is a villa, perhaps for the saltery's owner or manager or both, but, significantly, there are no permanent quarters for the numerous saltery workers, a fact which reminds us that salt-fish processing is a highly seasonal activity. After a brief period of intense labor, ancient workers had to engage in other work locally, perhaps agriculture, or migrate along the coastline along with the fish. Attached to other salteries are baths, temples, aqueducts, and dye factories, this last because the *Murex* was processed along with other shellfish for *garum*, and an analogous technology used to extract the precious purple dye from the shells.

In these salteries, to reiterate, three basic foodstuffs could be produced: salt fish, fish sauce, and fish paste. Concerning their methods of production we have a relative wealth of information: explicit ancient testimonia, archaeological evidence, and modern comparative methods, especially in Southeast Asia but including, tenuously, an apparently continuous production of all three products in the

Mediterranean.[110] Salt-cured fish (*salsamenta*) probably represented a significant portion of a poor urban Roman's consumption of animal protein; for comparison, in parts of Southeast Asia today the figure is upwards of 80%. In colder climates fish may be simply cleaned and dried, sometimes with a light smoking as well, but in the hotter regions such as Southeast Asia and the Mediterranean a combination of salt cure and dehydration is used. Fresh fish are gutted and cleaned, split, thoroughly rinsed of blood, brined for a short time, then air-dried and smoked to produce a soft but highly corruptible product, or hard-salted and air-dried to a board-like 'stockfish' used in soups or reconstituted before use in cooking or fermentation. Efficient drying, usually under a well-ventilated shelter, takes two to three days in good weather.[111] For a hard cure of the sort practically required in the subtropics, huge quantities of migratory fish are taken and their heads, thin belly fats, and viscera are removed. Essential to the process is the thorough removal of blood by means of a freshwater soak or a soak in a light brine. Several changes of water may be necessary if blood is still present. Then the fish are split and thoroughly drained or pressed. If fatty fish are to be preserved, an antioxidant such as lemon peel may be added to the brine soak to prevent rancidity. Splits are then typically placed in containers layered with sea-salt, alternate layers being placed at right angles; the vessel is then topped up with salt, and a follower and heavy weights imposed to expedite exudation and salt penetration. 'Slack-salting' uses 10–20% salt to fish weight but preserves for only 7–20 days. 'Hard-salting' uses 30% salt by weight or more and preserves fish indefinitely. Fish in the latter case are left in their own brine for several months, and may actually be shipped this way; alternately, they are removed and rinsed and hung to dry for upwards of a week in good weather, and at the 'tacky' stage are hung in a cool, hardwood smoke. Stockfish of this sort are so dry and salty that at the time of consumption they require two days under water to reconstitute and several changes of water to reduce salinity of the flesh to a palatable level.[112]

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[110] Curtis (1991): 9, n. 54: *Pissala*, French *garum; garos*, Greek and Turkish *garum*, etc.

[111] Mollinson (1993): 33.

[112] Mollinson (1993): 141–43.

Curtis conjectures[113] that the Roman analog, *salsamenta*, came as splits but for larger fish such as tuna was cut into cubes, squares, triangles, or irregular shapes. Whole splits were preserved with scales on or off, 'slack-salted' and therefore soft and moist but perishable, or 'hard salted' and therefore tough, hard, and indestructible. Like its modern analogs, ancient stockfish was so tough and salty that it had to be soaked in several changes of water for several days.[114]

The ancient process itself is described by Manilius in his first-century AD poem, *Astronomica*.[115] Manilius' account is for a small-scale operation, basically a group of fisherman using an informal method, but he describes graphically their part in the tuna *mattanza*, the butchering of the tuna into various cuts, each cut designated for a particular use, and no part wasted. The best description of the cure itself, ironically, is Columella's account of the hard cure for pork pieces already described,[116] where he alludes to the fact that the process is the same for *salsamenta*. To reiterate, the meat is cut into small portions, layered with dry salt in a vessel, topped up with more salt, a follower and weights imposed, and the meat left in the natural brine created by exudation. Left in its own brine, Columella avers, pork pieces and *salsamenta* will keep indefinitely. No ancient author describes explicitly the drying and smoking of salt-fish, but for what it is worth, this is the same passage in which Columella describes the light smoking of pork, in this case flitches and hams. Presumably fish pieces, like their analog pickled pork, remain in their brine until removed by the consumer, whereas splits, like hams and flitches, are dried and smoked.

We have now seen many times that ancient food processors went to considerable lengths to utilize every possible part of their 'raw material'. Small fry, too small to make splitting feasible, as well as fish heads and many of the internal organs, have enormous food value and therefore cannot be wasted. The genius of traditional methods is in using natural metabolic processes to minimize waste. Ergo the proteolytic ferment of these fish and fish parts alluded to before.

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[113] Curtis (1991): 10–11.

[114] Cf. Plautus, *Poen.* 240–44.

[115] Manilius, *Astronomica* 5.656–81 = Curtis, App. I–3.

[116] Columella, *DRR* 12.55= Curtis, App. I–1.

Though Curtis[117] thinks production of fish sauce and paste was exclusively hydrolytic proteolysis, this is highly unlikely, since conditions for natural, especially lactic, fermentation are excellent in fry and viscera. Typically today the ferment at salt concentrations of 20–30% progresses from yeast-dominant to bacteria-dominant. Typical yeasts are *Rhodotorula mucilaginosa, R. minuta, Cryptococcus spp.*, and *Sporobolomyces.* Bacterial agents are Staphylococcus and Lactobacillus species. Additionally, in Japan and other Pacific Rime areas the mold *Aspergillus oryzae*, the agent of *sake* ferment, is prominent.[118]

On the other hand, as Curtis correctly emphasizes, it is totally incorrect to describe *garum* and *allec* as the products of 'rotten' fish, as do many modern authors; modern readers who equate autolytic proteolysis with rot might do well to remember that, by their own definition, that prime rib of beef they so love, aged for several days to tenderize and develop flavor, is 'rotten' beef. And, assuming that *garum* and *allec* are fermented by microbial action as well, they are 'rotten' in this sense to the same extent as a fine Camembert or Reblochon. But moderns who describe *garum* and *allec* this way may perhaps be excused, given the penchant of ancient authors, especially writers of comedy and Roman satirists, for describing *garum* and *allec* as "putrid."[119]

A huge variety of fish and fish byproducts were used in making *garum* and *allec*. Pliny[120] says the mackerel (*scomber*) was the most popular species for the purpose—in fact, served no other purpose—but other species used included tuna, murry, sprat, mullet, smelt, and *corcinus*, as well as oysters, sea urchins, sea anemones, and various other shellfish.[121] Small fry were doubtless used whole, as today. For larger fish, all fats and gallbladders will have been removed lest they spoil the taste of the product. Byproducts used today are livers (especially rich in proteolytic enzymes), roe, milt, stomachs, gizzards, pyloric caecae, intestines, but not gills, kidneys, blood, or fat. Today

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[117] Curtis (1991): 23: "The production of fish sauce involves entirely enzymic proteolysis, primarily from enzymes of the digestive tract (pyloric caeca). In the best production there is little or no bacterial involvement except in so far as what appears between catch and initial stages of processing."

[118] Mollinson (1993): 132; C. G. Beddows, "Fermented Fish and Fish Products," in Wood (1998): 425–7.

[119] Cf. Curtis (1991): 3, n. 6 for bibliography.

[120] E.g., Pliny, *NH* 31.94; cf. Curtis (1991): 14.

[121] Pliny, *NH* 31.95.

viscera are typically cut up into c. 1" (3cm) pieces, thoroughly washed in fresh water and rinsed in a light brine, where floating fats and wastes are skimmed off. These wastes today make excellent fertilizer.[122]

Several ancient descriptions, as well as modern comparative evidence, make the actual fermentation process fairly explicit. Actually, there were at least two generic methods, a slow and a quick method.[123] Manilius specifies vats (*lacus*) and wine dolia (*Bacchi dolia*) for fermentation of small fry, but again, the type and size of container will depend upon the scale of the operation. In Gargilius Martialis' (fl. 3rd c. CE) 'slow' method, layers of herbs and spices, fish, and salt are built up to the top of a "solid, well pitched vessel," and (presumably) weighted. After seven days the product has created a brine and is stirred, as it is two or three times daily thereafter for the next twenty-seven days. The ferment proceeds in the warm sun to expedite the process. At the end of the twenty-seven days the liquid portion is strained into storage vessels. That account comports quite well with the method prescribed in the *Geoponica*: Fish viscera are thrown into a vessel along with small smelt, mullet, sprats, wolffish, and other fry, salted together, agitated frequently, and fermented in the sun. No duration is specified; rather, "when reduced" a large, strong basket is lowered into the vessel, the sauce (*liquamen* is the term used, but at this late date that term is strictly generic) is strained into it and taken up. The refuse is *allec* (Gr. *hálex*) and is bottled separately. A variation is the Bithynian method in which sprats, wolffish, horse-mackerel, and/or *alica* are thrown into a baker's kneading trough and salted at the rate of two Italian sextarii of salt per modius of fish, roughly an 8:1 ratio, according to Curtis.[124] The mixture is thoroughly blended (by foot if our conjecture about the baker's kneading trough is correct) and left in the trough overnight, then placed in a vessel without a lid and heated thus in the sun for two to three months, being agitated at intervals with a pole. Next the vessel is stoppered and stored, apparently the sauce and paste together, a curious suggestion.

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[122] Mollinson (1993): 134.

[123] Pliny, *NH* 31.93–95 = Curtis, App. I–2; Manilius, *Astron.* 5.656–81= Curtis App. I–3; *Geopon.* 20.46.1–6 = Curtis App. I–8; Ps. Rufius Festus, *Brev.* (Förster, p. 23) = Curtis, App. I–4; Ps. Gargilius Martialis 62 (= Rose, "Aringus, der Herring," pp. 226–27) = Curtis, App. I–5.

[124] Curtis, p. 13.

Geoponica's quick method relies on artificial heat. Hard brine, made "so that an egg floats," is mixed with fish parts and oregano and, optionally, boiled-down must (Greek *hepsêma*, 'boiled down' is either *sapa* or *defrutum*) in a new pot, boiled over a fire to reduce slightly, cooled, filtered three times until quite clear, bottled and stored. A variation recorded by Pseudo-Rufius Festus, of Medieval date, describes the same method but specifies that the mixture is to be reduced by 2/3 and then strained into a gallon flask.[125]

The processes thus far described created sauces of different characters and, presumably, qualities, though identifying them with any degree of certainty with the numerous Latin terms used is hopeless.[126] The three generic terms for sauce are *garum*, *liquamen*, and *muria*; the term *liquamen* unquestionably originally designated a separate sauce but acquires by the fifth century CE a generic sense for any fish sauce. *Muria*, literally hard brine, is most likely the brine used in curing splits before they are removed and dried; the brine will have taken on a light 'fishy' flavor.[127] Today, for comparison, in the making of Vietnamese *nuoc mam*, more brine is often added to the solid residue left when the primary liquid is decanted; this secondary mixture is fermented for several months to produce a sauce of lower quality.[128] Perhaps an analogous process gave rise to the designation of Roman fish sauce as *garum/liquamen primum*, literally 'first sauce' though it connotes 'first-quality sauce'. We also hear of mixed fish sauces: *Oxygarum* (mixed with vinegar), *oinogarum* (mixed with wine), *hydrogarum* (diluted with water), and *elaiogarum* or *garelaium* (mixed with olive oil. Unfortunately these appear in literary notices which tell us essentially nothing about their manufacture or proportions.[129] All such products were packed for shipment in amphorae, stoppered in the usual way.

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[125] For modern comparative methods, see Mollinson (1993): 135–36.

[126] Cf. Curtis (1991): 6–8.

[127] Cf. Columella, *DRR* 12.55.4; Pliny, *NH* 31.83; Martial 13.103.

[128] Mollinson (1993): 136.

[129] Cf. Curtis (1991): 8.

CHAPTER SIX

CONDIMENTS

Our study has come full circle, starting with the cereals which formed the single most prominent part of the Roman diet. As we have seen, this was so because cereals provide the most fundamental short-term element of the human diet, carbohydrates, but require the least amount of processing, at least to achieve biological stability. We have proceeded through various other elements of the diet which are often problematic because they are so unstable in their natural form and so require extensive and often quite sophisticated processing, as in the case of animal proteins. We now come to those elements of diet which provide little if any nutrient value yet are equally essential because they are themselves the active agents in the processing of other foods. Today condiments—salts, sugars, acids, spices—are thought of simply as culinary elements which lend savor to foods—as indeed they do—and so in a sense are culinary lagniappe, a sometimes expensive extra added to foods to pique the appetite. There has been a tendency to regard condiments in this same light for the ancients as well. In particular aromatic spices are regarded as virtual symbols of effete Roman luxury, an attitude which some wealthy Romans such as Pliny share. But I think we do ourselves a disservice in this regard. Can it be strictly fortuitous that the same elements of diet which are universally regarded as savory are also the chemical agents available to ancient man to make his perishables biologically stable? Is it, in fact, irresponsible speculation to suggest that somewhere along his evolutionary path man developed a genetic predisposition toward those same salts, sugars, acids, and aromatics which tended to ensure the safety of his foods? To put it simply, isn't it possible that microbiological stability has defined for man, either genetically or culturally, palatability as well? At a minimum, it seems to me, the fact that salts and sugars have now become such excessive elements of the modern Western diet that a genetic predisposition, if it exists, has now become maladaptive, should not blind us to the possibility.

The difference in modern and ancient sensibilities is perfectly captured in the word *condiment* itself; the Latin term describes essentially a substance which preserves (*condere*) other foods.

Salt

The classic example of that dynamic, it seems to me, is our predilection for alimentary salt. Now there is no question that salts, particularly common salt, sodium chloride, are essential trace elements of human diet. Humans have been called miniature oceans encased in skin; we all 'float' in sea brine. Salts are necessary for blood, nerve impulses, and heart action. But to what extent supplemental salt, above that which is naturally derived from whole foods, is necessary, is highly controversial. It is well known that exclusive carnivores need no supplemental salt but that exclusive herbivores must seek out natural salt deposits—salt licks—to supply essential salts, and that domesticated herbivores deprived of salt will fail to thrive. Traditionally it has been thought that Paleolithic man, subsisting largely on a diet of raw or roasted animal proteins, needed no alimentary salt, but that the Neolithic Revolution which introduced almost exclusively cereal diets produced the necessity of salt supplementation. Now both parts of that equation are rather shaky. We now have reason to suppose that hunter-gatherer societies are more accurately gatherer-hunter societies; that is, that the bulk of the Paleolithic diet came from foraged plant materials, occasionally supplemented with (typically scavenged) meat. Additionally, it was once confidently assumed that humans on a largely cereal diet, supplemented with plant proteins, required something on the order of four pounds (9 kg) of alimentary salt per annum. Adshead[1] cites "conservative" contemporary medical estimates of three grams per day or three pounds (6.6 kg) per year. But Multhauf,[2] who has the best general discussion of the issue and review of the studies, finds that there is still no definitive scientific study that establishes the amount or even the necessity of supplemental salt, but estimates, based on

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[1] Samuel Adrian M. Adshead, *Salt and Civilization* (New York: St. Martin's Press, 1992): 7.

[2] Robert P. Multhauf, *Neptune's Gift: A History of Common Salt* (Baltimore: Johns Hopkins Press, 1978): 3–7. Cf. Forbes III (1965): 157.

anecdotal evidence of deficiency studies, a necessary per-capita consumption of two pounds (4.5 kg) per year.

Be that as it may, early on, salt consumption in Western cultures began to far exceed even the most liberally assumed necessary consumption, and most salt consumed to be expelled via urine as 'unneeded'.[3] As a point of comparison, in 1982 adult consumption of alimentary salt in the U.S. was about sixteen pounds (34 kg) per annum, and other Western nations and Japan had reached similar levels.[4] The fact leads Adshead to aver that "the consumption of salt . . . is a fact of culture rather than nature. Pliny described salt as a *necessarium elementum*, but necessary not for life, but for *vita humanior*. Thus salt has been called man's first addiction."

That statement is both untrue and uncharitable. Adshead's—and Pliny's—statements are strictly true; their implications are not. Every bit of 'excessive' salt consumption in traditional societies is easily accounted for by salt used in processing of foods, and in ages and stages without refrigeration and other preservative techniques, physiological necessity and biological necessity are two entirely different things. Thus salt was an element of a "more civilized life," not as the product but as the agent. To that extent the debate about how much salt is essential today should be totally divorced from discussions of consumption in antiquity.[5]

Certainly the ancients recognized the need for both nutritional and processing salts. Cato, for example,[6] allots a *modius* per slave per annum, since they live on a largely vegetarian diet, and Roman soldiers, as Pliny[7] famously reminds us, received part of their pay as *salarium*, 'salary', i.e., a salt allowance, since they subsisted on the march largely on cereals. And we have already seen that salt, because of its hypertonic action, was an essential element in the processing of Roman pickles, cheeses, meats and fish products.

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[3] Adshead (1992): 7.

[4] Adshead (1992): 141.

[5] Most excess salt is consumed in modern Western societies in processed foods as well, both to make them more palatable and to give them longer shelf-life. To what extent this salt is deleterious—is implicated, for example, in hypertension—is also quite controversial. Much recent research suggests that it is not so much the excessive consumption of salt involved as the imbalance in the diet of common salt with other mineral salts.

[6] Cato, *Agr.* 12.55.

[7] Pliny, *NH* 31.7.

How salt is itself processed is an ancient story as well—far older than the Romans. The oldest written work on the subject is contained in the *Peng-Tzao-Kan-Mu*, a Chinese treatise on pharmacology and pharmacognosy, which dates probably to around 2700 BCE. In Volume XI, Book V we find descriptions of "20 kinds of salt" and "27 additional kinds," including both pit or rock salt and sea salt. Solar processing of sea salt was invented in China prior to 2200 BCE, and rock salt deposits were systematically exploited there around 300 BCE.[8]

The history of Rome, both political and social, is inextricably linked to salt. One of the most significant reasons for the growth of early Rome was her proximity to the salterns at the mouth of the Tiber River. There were artificial salines on both sides of the river, the older, northern side controlled by the Etruscan city of Veii, the southern presumably a product of seventh century BCE Rome, if not perhaps of King Ancus Marcius himself, to whom the tradition ascribes them. When Veii fell to Rome in 396 BCE, Livy tells us, the more important northern salines were annexed to the Roman state as the *Salinae Romanae*.[9]

As Rome expanded, she gained access to a plentiful supply of salts from a variety of sources. Salt is obtained from natural deposits (rock or pit salt) either as outcrops or in mines; from salt springs, rivers and lakes, from maritime salt marshes and, of course, from the inexhaustible seas.[10] Imperial Rome was heir to the salterns of the Celtic and Hellenistic worlds. To name only the most prominent sources, rock salt came from the famous pits, at the time operated as brine wells, of the southern Alps (Hallstatt and Hallein, etc.). Herodotus also mentions large deposits of rock salt in North Africa, perhaps the oases of Kauar and Bilma in Libya, and this passage may have given rise to Pliny's account of houses in the region made of rock salt. The pit mines of Bu-Chemmase near Sabratha in Egypt were worked by the Romans, and Pliny mentions others between Egypt and Sinai. Others were located in Colupene and Camisene in

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[8] L. G. M. Baas-Becking, "Historical Notes on Salt and Salt Manufacture," *Science Monthly* 14 (1931): 435.

[9] Cf. Adshead (1992): 29 for the possible output and techniques utilized.

[10] The *locus classicus* on Roman salt supplies, which unfortunately makes only brief reference to techniques, is Pliny, *NH* 31.39–42.

Cappadocia; at Ximene in Pontus; near Centuripae in Sicily; in Dacia (beginning with the Roman period), and in Spain.[11] Additionally, there were large brine springs in Chaonia and Illyria, in Salins in Franche Comté, and salt lakes were worked in Utica and in various places in Asia Minor, especially at Lake Tatta. Salt rivers in the southern coastal regions of Spain, the River Indus, the River Werra between Hesse and Thuringia, and the River Salle between the Burgundi and Alamanni of Gaul all produced large salt yields.

The most famous sea-salt or solar works were those previously mentioned at the Tiber mouth, but Pliny also mentions those in Sicily at Lake Coranicus, probably a bay to the west of Agrigente, and at Gela; Solinus mentions others on the island at Pachynum. In Roman Egypt there were solar works along the coast; in Asia Minor near the mouth of the River Halys and along the coast at Caunus, near Aspendus, Salamis and Citium. In Greece famous salines were worked at Priene; and there were productive salines all along the Mediterranean coast as well as the Atlantic and North Sea. Even this cursory list will give some idea of the importance of salt works in the minds of ancient authors, and presumably in the lives of ancient peoples as well. Let it suffice to say that between them Strabo and Pliny mention over fifty sites in the Roman world, and another twenty-five can be supplied from other literary sources and from archaeology.

'Salt', of course, is a term which encompasses not just different sources but different physical forms and chemical compositions as well. Physically, salts occur either as crystals (e.g., rock salt) or as brine; chemically, salts include a variety of compounds of which sodium chloride is but one, albeit far and away the most important. The only people in the Roman ambit who systematically exploited other chemical salts were the Egyptians, in whose country natron, sodium carbonate or bicarbonate (ancient *nitrum*, not to be confused with nitre, saltpeter, potassium nitrate), usually in combination with common salt, may have been more prevalent than relatively pure common salt, both in culinary use and as a preservative. In classical

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[11] Jacques A. E. Nenquin, *Salt: A Study in Economic Prehistory* (Brugge: De Tempel, 1961): 102, for the testimonia and archaeological bibliography. For Bronze Age Crete, cf. Katerina Kopaka and Nikos Chaniotakis, "Just Taste Additive? Bronze Age Salt from Zakros, Crete," *Oxford Journal of Archaeology* 22.1 (2003): 53–66.

Rome, however, natron was not used in food processing, although it was used in cooking to preserve the colors and textures of vegetables, just as often today.[12]

The processing of rock salt needn't detain us long. Rock salt occurs as surface deposits in dry salt lakes or as outcrops. In either case it is almost pure sodium chloride and requires a minimum of processing for use. Evidence suggests that outcrops were first exploited until they were exhausted, and then followed underground ('following the vein') just as was done for other minerals. Here ordinary mining techniques with shafts and galleries were exploited, the supporting pillars of galleries most often nothing but the salt itself left standing during the cutting.[13] When salt banks were too deep or layers too thin to be mined economically, water was conducted to salt layers, the salt transformed to brine and this brine pumped to the surface to be evaporated,[14] usually via artificial heat sources, giving rise to the collections of clay pans, pedestals, and fragments collectively known as *briquettage* and common in many parts of Celtic Europe. Alternately, veins may descend below the water table, or the water table may rise, as happened most famously at the mines in Hallstatt and Hallein during the ninth century BCE. Fortunately, these deposits were close to enormous reserves of fuel in the form of wood and so artificial evaporation was feasible. In Egypt, in contrast, the hieroglyphic character for salt actually means 'a specific mineral,' i.e., a preexisting mineral ready to harvest, 'salt of the earth', and was harvested from the Wadi Atrun. The Egyptian priest caste enjoyed a monopoly on trade in this commodity as part of their prebends and therefore propagandized against rival sea salt as filthy and unfit for consumption. There was doubtless just enough truth to the selfish claim to make it credible.[15] Yet the comments of Pliny make it clear that Egyptian sea salt predominated nevertheless. Why?

The reason has to do both with supply and difficulty of processing. Rock salt occurred most commonly in the Roman world in

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[12] Pliny, *NH* 31.115; Apicius 3.1; Martial 13.17.1; cf. Forbes III (1965): 74–77.

[13] Nenquin (1961): 100; cf. Oliver Davies, *Roman Mines in Europe* (Oxford: Clarendon, 1925): 24.

[14] Pliny, *NH* 31.40.

[15] Baas-Becking (1931): 438.

remote and inaccessible places and yet, if we discount the extraction, required little or no processing unless it was extracted as brine. But the supply was exhaustible, given the limits of ancient mining technology. Sea salt, on the other hand, was readily accessible all over the Roman world and is quite literally inexhaustible, but it requires extensive processing to become palatable. The reason for this difficulty is twofold: sea salt is a relatively weak saline solution—on the order of 3.5%, though this varies slightly from sea to sea, of which 2.5% is sodium chloride, the rest chlorides and sulfates of calcium and magnesium. Boiled to dryness, sea water deposits up to 28% hydrated magnesium salts and 4% calcium sulfate. Thus sea water has two limitations as a source of common salt. Its low concentration (salt springs, for comparison, may be saturated with salt; those at Lunneberg and Halle are 26% salt) requires huge amounts of energy, passive solar or active artificial, to concentrate it to about 90% to the point of saturation where salts will crystallize. Secondly, the other, 'bad' salts in sea water yield a bitter taste and must be removed. Fortunately, the Mediterranean climate provides ample passive solar energy for concentration, given enough surface area for the brine; fortunately as well, sodium chloride is sufficiently concentrated and soluble enough in sea water to precipitate before the solution is reduced to a very small fraction of its original volume.[16]

Sea-salt manufacture in the Mediterranean seems to have originated with the Phoenicians. The famous solar works at Setubal (ancient Caetobriga) in Portugal are said to have been founded by Hasdrubal in the third century BCE. The archaeological remains of the Carthaginian salt works at Salammbô date from the same period. The technology of sea salt production has as its end the concentration and purification of brine.[17] The cheapest energy source for

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[16] Multhauf (1978): 126.

[17] Multhauf (1978): Chapter 2, pp. 20–38 is a good introduction to traditional sites and techniques. Sea salt can compete with rock salt today only where a cheap source of energy is available; solar heat is still the primary source of energy and consequently sea salt is often called solar salt, though sometimes brine from rock salt springs and wells is solar evaporated as well. Thus 'bay salt' is sometimes used to designate solar-evaporated sea salt. The industry today thrives along coasts in tropical and semitropical climates; California, Italy, Spain, and Portugal, the Adriatic coasts, Mediterranean France, Egypt, coastal China, Japan, India, Brazil and the West Indies are the major sources. Cf. Donald Kitely Tressler, *The Wealth of the Sea* (New York: Century, 1927): 16.

concentration is solar evaporation, and this source is practicable in areas where summers are hot and rainfall highly seasonal. In other places artificial heat must be used; in most places in the Roman world this meant wood or charcoal.

Obviously the latter can be a relatively expensive proposition, especially along coastal areas where maritime forests are not frequent and where, over time, timber supplies are exhausted. Several techniques were therefore utilized to concentrate salinity of sea water before it was fired.[18] One method involved the leaching of sand impregnated with salts from salt spray and tidal action. Proper sand for the purpose was easily identified by the brilliant white coating on its surface. The sand was placed on a filter bed, often of reeds or seaweed which were themselves suffused with salt. The salt water or fresh water was poured over the sand and the concentrated brine collected beneath the filter bed. Alternately, the sand was boiled in fresh or sea water and then the sand allowed to settle out. In either case, fresh water was preferable to sea water; the sand had been largely leached by rainwater of calcium and magnesium salts and use of sea water reintroduced these 'bad salts'. This is doubtless the significance of Pliny's description of a salt produced "mari infuso, non sine aquae dulcis rignis."[19] The method was still used along the Norman and Atlantic coasts of France until quite recently, and a variation is still used in the Philippines.[20]

Concentrated salines can also be produced from salt plants such as salt brush, salt grass, kelp, etc.[21] Actually, two similar but separate techniques are involved, the leaching of salt brines through burning wood or ash, and the burning of salt plants to obtain a saline ash which is then boiled in water to obtain a characteristically black or gray salt.[22] Comparative evidence suggests that, in the latter case, plant ash was boiled in fresh or sea water until a density was achieved in which an egg would float, then another twenty-four hours of boil-

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[18] Nenquin (1961): 105–06.

[19] Pliny, *NH* 31.7.

[20] F. Gidon, "L'ancien lavage des sables salés sur les côtes normandes et atlantiques," *Bull. Soc. Antiq. de Normandie* 49 (1942–45): 406–23; Tressler (1927): 17–18 (Philippines).

[21] Nenquin (1961): 10–11 for comparative methods in Medieval and later times.

[22] For the former method, Pliny, *NH* 31.82–83; Tacitus *Ann.* 12.57; for the latter, Varro, *RR* 1.7.8; Aristotle, *Meteorol.* II (III) 359a (25).

ing would achieve concentration at which common salt would precipitate, or 'grain', and could be removed from the 'bitters', the magnesium salts.[23] Pliny attests that the method was used in Gaul and Germany in his own day. The method was already well known in China in the third millennium BCE and seems to have spread from there to the whole Orient. The same method was also used for centuries in the lowlands of northern Europe except that peat was substituted for burning wood or plants.

But for most parts of the Roman world solar evaporation was far cheaper and less laborious; indeed, nature herself provides the method in this region. Sea salt is found in large quantities in surface deposits along the Mediterranean shores and natural salt pans are mentioned by Herodotus and Pliny at the mouth of the Dnieper as well as by Pliny along the shores of the Oxus and perhaps the Aral and Kara-Boga lakes.[24] During the wet seasons or high seasonal tides, these natural salt pans fill and then evaporate, partially or totally, during dry seasons. At some point in this evaporation salts become concentrated enough to crystallize. Then it is simply a matter of harvesting the salt in such a way as to extract as much of the pure sodium chloride as possible, as will be discussed momentarily.

Artificial salt-pans, salines, can be created anywhere along the coasts that the topography permits. A large, flat area is the only requirement, since the rate of evaporation depends largely on the surface area of brine. Steady, prevailing winds are also helpful, as Pliny recognized.[25] The basic procedure is quite simple: sea water is drawn up by Archimedean screws or is conducted by channels to 'pickle ponds' where it is allowed to evaporate and concentrate. The brine may be allowed to concentrate all the way to saturation in the same pond, at which point the 'hoppers', so-called because their shape is that of a hollow, inverted pyramid, 'corn', i.e., crystallize. Eventually the hoppers cluster on the surface and fall to the bottom of the brine. But early on in man's history it was discovered that a purer product could be obtained by conducting grades of brine to successive pans. Did the Romans know of this method? Adshead[26]

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[23] Baas-Becking (1931): 38.

[24] Herodotus 5.53; Pliny, *NH* 31.74–75.

[25] Pliny, *NH* 31.41.

[26] Adshead (1992): 49–50.

says that successive-pan evaporation was a Chinese invention of c. 800 BCE, but that it did not migrate to the West, nor was it independently invented; that indeed the only technological change in antiquity in the West was the increased exploitation of sea salt as against rock salt. A passage in Rutilius Namatianus' *De Reditu Suo*,[27] he avers, has been wrongly cited as evidence of successive-pan salines along the coast of Etruria at the time of the poem's composition (probably 416 CE). The phrase "mutifidosque lacus" he translates as "many small ponds," and asserts that "there is no suggestion that the brine was moved from one pond to another, nor that sodium chloride was distinguished from calcium and magnesium compounds. It would seem most natural, therefore, to interpret what the poet saw as a battery of single basins like those at Katwe [Africa] or, most probably, those at the mouth of the Tiber." But an argument from silence based on a poetic travelogue as opposed to a technical treatise is absurd. Moreover, Rutilius' use in the same passage of the phrase "Tum cataractarum claustris excluditur aequor" most certainly *does* imply movement of brine, not only from one place to another but from one state of refinement to another; *cataractae* are the sluices which figure most prominently in the Roman world in the refining of gold ores. In my opinion there can be little doubt that Rutilius' passage—meager evidence though it is—supports the notion of successive-pan evaporation.

If we posit this assumption, then the advanced technique will have proceeded thus: First, brine is allowed to remain in the pickle ponds until it reaches near-saturation. We have previously discussed the possibility of the use of the hydrometer in late antiquity, but the density of brines is such that no such device is required. The Romans, as we have seen, were well acquainted with the technique of testing brines for saturation by floating in them an object. In this case we have explicit comparative evidence for the use of the technique in saltworks; the Chinese Peng-Tzao says that the density of the first product must be sufficient to float a hen's egg or a lotus seed. Baas-Becking did a simple experiment with a sample of hens' eggs and determined an average density for such a brine of 1.074, corresponding to a concentration of 10–11%.[28] Not even this simple

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[27] I.478.

[28] Baas-Becking (1931): 439.

procedure may have been necessary, however; we hear repeatedly in the comparative literature that brine should be allowed to concentrate in the pickle pond until the color turns red, at which point the hoppers will soon begin to corn, overnight if the winds are steady. Many people assume concentrated brine to be sterile, an assumption which is far from true. Baas-Becking estimates well over thirty animal and plant organisms which thrive in hard brines, not to speak of numerous bacteria. Red color in brine may occasionally derive from iron oxides or extracts from marshy plants, but is far more likely to derive from pigments in pink, red and purple bacteria, most prominently saprophytic facultative anaerobes of the so-called 'codfish' species, or pigments of red yeasts. Dark red colors are usually due to purple bacteria, unable to live without light under anaerobic conditions, which contain a green pigment which decomposes to a brownish, water-soluble product. The latter organisms usually live close to a source of hydrogen sulfate, the 'black mud' of salt precipitates to be discussed below. These organisms are particularly prominent in the presence of niter and doubtless imparted their color to the deep-red salt of Memphis mentioned by Pliny, as well as the purple salt of Centuripae, Sicily, and the niter beds of Lydia. Numerous lakes in the Mediterranean are still called 'Red Lake' and, in the presence of high alkalinity, one may assume that their color derives from purple (sulfur-loving) and pink (codfish) bacteria. Alternately, reddish color may be imparted by a chlorophyl-bearing dinoflagellate, *Daniella salina*; when carotene of this species oxidizes it produces ionone, a substance used in perfumes today for its violet scent. Pliny[29] mentions that Cappadocian salt is saffron-colored and remarkably odoriferous, probably a reference to the same phenomenon. In any case, all these pigments become quite pronounced as brine concentrates, and an intelligent saltworker will have learned through experience how to recognize the tint which indicated near-saturation.[30]

When this concentration occurred, he will have conducted his brine from the pickling ponds to the salterns, away from sediments and calcium salts, many of which will have already precipitated. In the crystallizing ponds the hoppers will have corned and settled and then the bitter liquor containing residual sodium chloride and most

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[29] Pliny, *NH* 31.41.

[30] Baas-Becking (1931): 436.

of the magnesium salts conducted to the 'bitterns', where more salt may be allowed to precipitate, this of a decidedly poorer quality. Meanwhile the salt of the crystallizing pond is carefully harvested in such a way as to purify it.[31] This successive-pan technique required more capitol outlay and technical knowledge than single-pan evaporation, but was capable of producing grades of salt according to purity and size of crystal. In the latter case, fine, small-grained castor salt derived when the process proceeded quickly, coarse, large-grained granulated salt derived in the case of a slow process. The speed of the process, of course, depended largely on the weather.[32]

Unrefined sea salt is hardly fit for consumption, containing as it does large amounts of magnesium chloride, magnesium sulfate, calcium carbonate and calcium sulfate. It is also highly hygroscopic. Methods of purification rely on the basic chemistry of salts as well as helpful organisms present in brines. To address the latter first, during evaporation some of the bacteria alluded to above reduce large amounts of sulfate to form, in combination with iron, the 'black mud' typically found beneath common salt crystals. This muck contains large amounts of hydrogen sulfide and other sulfurs, substances which create the characteristic 'rotten egg' smell. Doubtless this explains the etymological connection in several languages between words for 'salt' and 'stench', a stench which Pliny mentions. In open-air salterns it becomes a fine art to separate the salt from the H_2S, the "skutch black as the scuttle fish," as one English treatise describes it. A master briner uses a flat shovel and skillfully scrapes the salts from the skutch so as to obtain the largest amount of salt without disturbing the black mud.[33]

Calcium salts have a lower saturation point than common salt and so should precipitate sooner as well, but are notorious for oversaturating brines. They can be partially removed mechanically with clarifying agents, just as wine is clarified, and sometimes using the same agents. Georgius Agricola, for example, in *De Re Metallica* 12 (1556), recommends bullock's blood and strong ale in ratios of 1:1500 and 1:1800. Baas-Becking thinks the ale was designed to hasten

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[31] Baas-Becking (1931): 446.
[32] Adshead (1992): 49.
[33] Baas-Becking (1931): 443–4.

crystallization of common salt, but does not explain the presumed mechanism.[34]

Our briner may also have received help here from an unexpected source. Brine worms, *Artemisia salina*, commonly occur in salt lakes, though they are rarely mentioned in the literature, and never by the Greeks or Romans. Baas-Becking thinks the knowledge extremely old among traditional briners, however, and recounts a fascinating firsthand experience in this regard. While he was at Stanford the foreman of a nearby saltworks came to his laboratory to request some brine worms to recolonize his works. When Baas-Becking was unable to accommodate him he resorted to the Great Salt Lake for the 'required' worms. Baas-Becking and his colleagues regarded the man as charming but foolishly superstitious until they learned that the worms were used by Old English briners and called 'clearer worms'. He then discovered experiments by Anselme Payen and Audoin in 1836[35] in which the worms completely clarified a solution of calcium carbonate. Baas-Becking repeated the experiment with modifications and discovered that the digestive tracts of the worms turn barium sulfate, calcium carbonate and calcium sulfate into small pellets which are excreted and settle to the bottom of the solution. Five *Artemisiae* cleared a 100 cc suspension of barium sulfate in 24 hours. Earlier researchers had remarked that it is practically impossible to precipitate all calciums salts from brine because of their affinity for colloidal suspensions. Baas-Becking remarks that it may well be that the lowly *Artemisia salina* by its incessant action on these same salts has made sea salt manufacture as we know it possible.[36]

Chemical purification of salt depends on fractionate precipitation, i.e., the fact that different salts precipitate at different concentrations. Thus the least soluble salt precipitates first, and so on. Discounting other factors such as that just discussed, the order of precipitation is calcium carbonate, calcium sulfate, sodium chloride, magnesium sulfate, potassium magnesium chloride, and magnesium chloride.[37]

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[34] Baas-Becking (1931): 444.

[35] Payen and Audoin, *Ann. de Sciences Naturales* 6, 2n sér (1836): 219 (unavailable to me).

[36] Baas-Becking (1931): 445.

[37] Forbes III (1965): 164; Baas-Becking (1931): 143–4.

In practice, the precipitations frequently overlap. Since magnesium salts precipitate after NaCl, large amounts are retained in the 'mother liquor' of salterns. Thus the practice in successive-pan evaporation of draining this bitter liquor from crystallization ponds to the 'bitterns' where a cruder form of salt can precipitate. But because of the overlap in precipitations, all sea salt in its crude form retains more or less of the magnesium salts. However, the reverse of fractionate precipitation is also true—last out, first in—so that these salts are far more soluble than sodium chloride. Thus piles of salt are simply exposed to rainfall over a period of time and the more soluble residual magnesium salts are thereby leached out. The fact (though not the chemistry, of course) was clearly known to Pliny[38] and the procedure continued in use, for example in tenth-century Venetian saltworks, in seventeenth-century French salterns, and in many other places.[39]

That much crude salt was also sold in antiquity with little or no refinement is obvious. Pliny[40] actually prescribes different grades for different purposes, more refined salt, for example, for culinary use and crude salt (which may possibly have contained saltpeter) for processing meats. Cato, thrifty as always, describes a way of refining one's own salt:[41] a clean amphora whose neck is broken off (Waste not, want not!) is filled with pure water and placed in the sun; a small bag of crude salt is placed in it to dissolve and the amphora periodically agitated and the salt supply replenished until no salt has dissolved for two days (i.e., the brine is saturated). Saturation is tested by floating an egg or a saltfish and this 'hard brine' poured into shallow pans and set in the sun to allow the salts to precipitate at their own rates and then the 'white salt' collected from the bitterns. A miniature saltern in operation.

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[38] Pliny, *NH* 31.40.

[39] Baas-Becking (1931): 445–46. Adshead (1992): 31, finds Pliny's reference to the necessity of fresh and rain water in the leaching of salt plants puzzling, but Pliny is simply being his usual discursive self. The fresh water is a reference to that used to concentrate salt sand and plants and the rain water, as Adshead correctly deduces, to that used to leach 'bad salts' from salt piles. Adshead's assertion that acceptance of this deduction implies single-basin evaporation directly contradicts comparative evidence. Pliny is describing a variety of techniques in the passage and is not here referring specifically to any one.

[40] Pliny, *NH* 31.86–87.

[41] Cato, *Agr.* 88.

Sugars[42]

Sugars are, of course, pure carbohydrates, and we have previously alluded to the difficulty in preindustrial societies of obtaining enough calories in the diet. Thus sugars *per se* represent a valuable nutrient in the ancient diet, unlike other condiments. But the fact is that until quite recently in most cultures sugars were expensive, far beyond the reach of most of the lower classes as a condiment, much less a staple. Even cane sugar was regarded in the West as an expensive spice until New World production and development of sugar beets as a source led to a collapse of prices in the eighteenth century. But sugars are equally valuable as preservatives, again, because of their hypertonic action, and it is likely that whatever sugars the Roman masses, especially the urban proletariat, obtained were largely in the form of syrups in conserves and in combination pickles.

Cane sugar was an exotic in the Roman world, and as such much too expensive to be used for anything but a medicament. Even a wealthy gourmand such as Apicius eschews it. Thus the two forms of sugars widely available to the Romans were honey and concentrated grape musts. It has often been stated—is, indeed, almost a commonplace—that honey was the most prevalent if not the exclusive, sweetener in Roman antiquity.[43] In my opinion this is a gross inaccuracy. It is perfectly clear from the Roman testimonia that honey was an expensive commodity available only to the wealthy in the urban centers. Varro, for example[44] has Accius gently chide Appius for parsimony because he doesn't drink *mulsum*—the honeyed wine drunk by the Romans as an aperitif—at home. Appius, who is by no means poor be it noted, counters that in the past he has not been able to afford *mulsum* for himself, though he has served it to guests; since he has received an inheritance he can afford to do so. Elsewhere[45] Varro's Merula says that a certain Seius lets out his beehives for 5,000 lbs (11,000 kg) of honey per year and mentions a story he has heard Varro himself tell of the brothers Veiani, who,

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[42] Cf. Curtis (2001): 417–9.

[43] E.g., Brothwell and Brothwell (1965): 79: "Of course, having only honey as the chief sweetening element in their cookery . . . (p. 80): "Honey quite obviously had the same wide use as sugar (sucrose) now, and perhaps an even wider one. . . ."

[44] Varro, *RR* 3.16.

[45] Varro, *RR* 3.16.10–11.

at their paternal villa near Falerii, earn a profit of 10,000 sesterces or more per year from hives standing on less than a *iugerum* (5/8 acre) of land.

That scenario has parallels in the other ancient cultures as well. For example, in Egypt honey was a very expensive commodity afforded only by the wealthy. At least in the early dynasties, in fact, honey was probably a royal prerogative. Commoners sweetened foods with condensed fruit syrups. A twelfth-dynasty tomb from Beni Hassan, for example, depicting the harvest, shows a liquid being stirred over a fire and strained through a cloth, and the scene is interpreted as the production of grape syrup.[46] Also used for the purpose were date and other fruit juices. Likewise, though it is almost indisputable that viticulture was practiced in Babylonia, the same must not be said for viniculture; the basic purpose of the grapevine here was for production of raisins and grape syrup. The Sumerian word *lal*, often translated 'honey', refers in fact to fruit syrups of dates, figs and grapes, most prominently the last. The Biblical phrase "flowing with milk and honey," likewise, is probably a mistranslation for "yogurt and grape syrup".[47]

Thus it is almost certain that grape syrups were the primary sweeteners of Roman antiquity, at least among the poor, who, let us remember, represented something on the order of 95% of the population. Modern researchers have been misled by their ignorance of the nature of such items as *sapa* and *defrutum* and by references to use of honey by Apicius and his interpolators. But we must remember that *De Re Coquinaria* is a gourmet cookbook aimed at the wealthy. And Apicius himself constantly prescribes grape concentrates as sweeteners as well as honey; my own quick survey finds well over 100 references to grape syrups and sweet raisin wine as culinary sweeteners.

These concentrates we have encountered before, of course, as the main source of sugars for chaptalizing weak wine musts and as preservatives in pickles and conserves for fruits and vegetables, cheeses and

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[46] Darby (1977): 430, 440 and Fig. 9.6.

[47] Marvin A. Powell, "Wine and Vine in Ancient Mesopotamia," in McGovern, Fleming and Katz (1995): 103. Cf. James A. Kelhoffer, "John the Baptist's 'Wild Honey' and 'Honey' in Antiquity," *Greek, Roman and Byzantine Studies* 45 (2005): 59–73.

meats. We hear of three products, though two predominate: *caroenum*, *defrutum*, and *sapa*. Their degree of concentration is often expressed as various fractional parts which don't always correspond from one author to another; in fact, Columella contradicts himself on the degree of concentration of *defrutum*, unless the error is ascribable to a manuscript error. The fault is not so much that of our authors, however, as it is that of the limitations of their conceptual framework. Roman musts varied enormously in their sugar concentrations by vineyard, by microenvironments within vineyards, by varietal, and by seasonal weather variations. Today to specify a particular final density the oenologist would simply say to "reduce to a final specific gravity of 1.104," or some such, and be confident that, regardless of initial gravity, the density of the final product was assured. Our ancient winemaker had no such measure unless we posit widespread use of our prototype hydrometer, and so 'rule of thumb' measurement combined with empirical observation was the order of the day; every competent cook knows what a loose sauce or a tight syrup 'looks like'.

In any case we are reasonably sure that the three products in increasing order of density are *defrutum*, *caroenum*, and *sapa*. Pliny[48] defines *defrutum* as must reduced by half, and *sapa*, also called *siraeum* and *hepsêma*, as must reduced by two-thirds. Columella[49] says some reduce by 1/4 and 1/3 and implies that these proportions represent *caroenum* and *defrutum*, and then specifies *sapa* as must reduced by half. Palladius[50] defines *caroenum* as must reduced by 1/3 and *sapa* as a 2/3 reduction, but resorts to a more natural empirical description of *defrutum* as "must boiled away to the point of being a dense reduction," a passage which has led some to think *defrutum* the densest of the three products. We are probably wise to take Brehaut's suggestion[51] to specify only that one product is more concentrated than another. In any case, the ancients knew perfectly well that the more concentrated the product, the more stable and therefore useful it became as a chaptalizing and preservative adjunct, but that the amount of fuel necessary to achieve ideal concentrations might

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[48] Pliny, *NH* 14.11.

[49] Columella *DRR* 12.19.

[50] Palladius 11.18.

[51] Brehaut, p. (1933): 102, n. 2 ad Catonis *Agr.* 107.

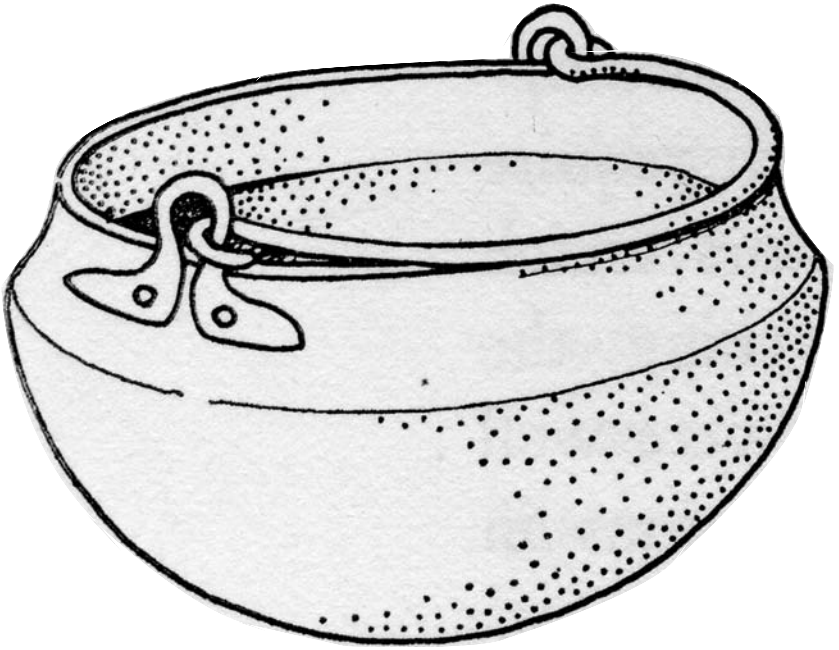

Fig. 31. A cauldron (*cortina*) in which must was boiled to make various grape concentrates. *Cortinae* were of bronze or lead, though the latter was the norm for making grape concentrates. The *cortina* was also used for heating milk in the cheesemaking process. (From White (1975): Fig. 36. Courtesy of Cambridge Universiy Press.)

make doing so impractical. Today, as a point of comparison, grape musts are always concentrated in a vacuum environment to radically reduce the boiling temperature. This is done partly to preserve the varietal character of the must (such concentrates are widely used for winemaking in areas where *vinifera* grapes do not thrive) but primarily to make the process cost-efficient.

Like large-scale vinification, commercial production of grape concentrates was a relatively new phenomenon in classical Rome, and so our ancient agronomists are quite explicit about the process. The place where the must was reduced was a special room in the *cuvée* called the *cortinale*, so-named from the *cortinae*, the cauldrons in which it was boiled [Fig. 31].[52] Such cauldrons must have been quite impressive on a large villa farm; Columella specifies leaden vessels of 90-amphorae capacity, that is, some 620 gallons (2,344 L); cauldrons

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[52] Cf. Billiard (1913): 499; White (1975): 134–6 (*cortina*) and 161–3 (*cortinale*).

of this capacity would be some 6–8' (1.8–2.4 m) in diameter. They must be of lead, Columella insists, and not the usual bronze; again, the ancients knew well that bronze vessels in the presence of an acid throw off copper salt (*aeruginem*, 'bronze rust') which spoils the flavor of the product.[53]

As so often, Columella gives us our most explicit description of the process itself.[54] He recommends that Aminean grapes be used, but if these are not available, the grape varietals that tend to make the soundest wines (i.e., those with the highest sugar concentrations). To further ensure high sugar content, only the ripest grapes are used, harvested on a clear, dry day. They are taken to the *lacus*, trodden in the usual way, and the free-run must (again, the most concentrated portion of the must) is collected and transferred to the *cortinae* before the 'foot' is pressed for the lower quality wines. The must is decanted into the *cortinae* and boiled, a seemingly simple process. But Columella's vintager in fact has to proceed with great caution. For one thing, lead has an extremely low melting point and so becomes very soft at even lower temperatures; therefore extreme caution must be taken not to overheat the vessel or puncture it with stirring implements and strainers. Furthermore, highly concentrated sugar solutions such as musts and worts have a notorious tendency to boil over until they have reached a uniform rolling boil and impurities have been cast off. Along with this, sugars are so dense that they are prone to settle to the bottom of a solution, adhere to the cooking vessel and scorch, yielding an intensely bitter taste which taints the rest of the solution. Thus musts (and worts) have to be brought to the boil very slowly and stirred constantly.

Here Columella demonstrates perfectly the practicing farmer that he is. To prevent scorching Columella recommends that before the must is introduced the interior surface of the cortina should be rubbed with olive oil. Then the fires to heat the cauldron should be built with brushwood and small twigs so as to heat the must gradually to a slow simmer. At the same time our foreman is enjoined to have at the ready stirrers and strainers, all made of soft organic material so as not to taint the taste of the must or accidentally puncture the *cortina*. Stirrers, for example, should be tipped with a pliant material such as fennel stalk, fresh broom, or esparto grass. As the must

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[53] Columella, *DRR* 12.20.1.

[54] Columella, *DRR* 12.19–20.

gradually reaches a steady boil the workers stir and brush the 'lees' from the bottom of the cauldron and brings them to the top where they are skimmed off. When all impurities have been strained off and the must is heated through and boiling steadily, the fire is gradually stoked up to produce a full boil, though still not so lively as to endanger the vessel or scorch the syrup.

Even carefully made syrups of lower concentration are apt to sour, and so Columella recommends the addition of various aromatics as preservatives and (Columella implies) sometimes to mask the beginnings of acetification until the must can be sold. Quinces, for example, should be boiled with the must until they are soft and then removed. Resins, either liquid or solid, may be added as the must boils; these may include Nemeturian pitch, turpentine resin, and 'crude pitch'. When the must has achieved its final density and the heat is removed and the surface strained, other aromatics should be added, advises Columella. Perfect. Resins, which add tartness to the must, are boiled to extract maximum acidity. Aromatic oils, the active ingredients of spices, are highly volatile and will quickly boil away and should, therefore, be added at the end of the cooking process to steep. Aromatics recommended by Columella for the purpose are iris, fenugreek, sweet-rush (*schoenus*), spikenard leaf, Illyrian sword lily, Gallic spikenard, pulchuk (costus), dates (an odd inclusion), angular-rush (*cyperum*), myrrh, sweet-flag (calamus), cinnamon, balsam, saffron, and 'vine-leafed *cripa*' (still unidentified). These must be thoroughly stirred as the must cools to prevent them from sticking to the cauldron and scorching.

The concentrate is thoroughly cooled, decanted into the usual pitched amphorae, and sealed in the same way as wine before being cellared. Columella strongly recommends that it be aged for a year before use in chaptalization to ensure that it will not sour and thereby spoil the very wine it is designed to stabilize. Some idea of the relative importance of the product on the villa farm is the fact that a special cellar, the *defrutarium*, is designated for it.[55] A well made *sapa*, heavily concentrated and carefully sealed, might reasonably be expected to last for years. Huge amounts will have been used in chaptalization of wines as well as in pickles and conserves and perhaps in culinary use.

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[55] Cf. Billiard (1913): 499.

Thus there is little doubt that grape concentrates were the most important sugars in classical, if not archaic, Rome, on the basis of sheer bulk. But honey takes pride of place in ancestry and in culinary use. Honey is unquestionably man's oldest sweetener for the simple reason that bees have already done most of the 'processing' and packaging of this product, destined as it is for a subsistence foodstuff for the hive. Bees gather nectar from flowers and add to it the enzyme invertase to convert nectar's sucrose to dextrose and fructose. They then store it in waxen cells where it desiccates naturally and becomes highly concentrated. Nectar, for example, is 80% water, but a typical honey is about 35% dextrose, 40% fructose, 15% water, and 10% miscellaneous material.[56] At this concentration honey is not only famously stable, but also extremely hypertonic and therefore bacteriostatic and bactericidal. Honey is also quite acidic, with a pH of 3.91, and is bacteriostatic in this regard as well.[57]

Nevertheless, unprocessed honey is not sterile and will spoil, especially if weakly constituted, and thus we have Apicius' test of 'spoiled honey',[58] presumably prior to using it as a preservative: immerse elecampane in honey and then extract it and light it, and if it burns brightly, the honey is good. To disguise spoiled honey for sale, mix it with two parts good honey.

Traditional apiculture has changed amazingly little over the years, and we clearly recognize the steps in processing honey in the numerous literary references, especially those in Vergil's *Georgics* and in Columella. Roman beekeepers harvested honey two or three times per season, depending on length of the season and bee forage available. The spring harvest, called blossom honey, takes place in late spring, from mid-May to mid-June. A second harvest may be procured in mid-to-late summer, and a third in late fall, albeit a smaller one so that the bees will have ample supplies to overwinter.[59] The best guide is again empirical; Palladius advises that the fullness of the hive can be judged by the gentle murmur of the hive in contrast

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[56] Muller and Tobin (1980): 191.

[57] J. W. White, Jr., M. L. Riethof, M. H. Subers, and I. Kushnir, *Composition of American Honeys* (Washington, Superintendent of Documents, U. S. Govt. Printing Office, Technical Bulletin No. 1261, 1962): 11.

[58] Apicius 1.10.

[59] Varro, *RR* 3.16.34–35; Vergil, *Georg.* 228–40; Columella, *DRR* 9.14; Didymus in *Geopon.* 15.5.

to the harsh buzzing of an empty one, as well as the 'outlawing' of the drones. The latter guide Malcolm Fraser[60] regards as indeed useful, since the expulsion of drones actually happens when the nectar flow ceases, i.e., when the store of honey has reached its maximum.

The actual processing of honey must take place at some distance from the hives or at any rate in a carefully sealed room since bees, as authors as early as Aristotle[61] knew, can smell honey from a considerable distance and are attracted to it. Equipment necessary for the extraction chamber is minimal and includes an oblong, spatulate knife with a sharpened edge on both sides and a hooked scraper at the end, and a second knife, straight and sharpened on only one edge. The latter knife cuts the comb from the hive and the former cuts the waxy tops from the cells. A small terra cotta smoker has a small opening in one side and a larger one at the other. Live coals are placed in the pot along with galbanum or dried cow manure; the apiarist blows into the wider opening (a spout?) and smoke is blown out through the narrower one into the hive.[62] The only other implement besides receptacles for the honey is a conical strainer made of loosely woven withies and similar to a wine strainer.[63]

Columella's smoker is applied at the back of the hive, the cover of which is removable, and as the bees are smoked they move to the front of the hive or outside. The combs, attached to the top of the hive, are cut loose with the comb knife. Interestingly, Columella advises the harvesting of old and defective combs and the leaving of the newest, soundest combs, containing the brood, so that the hive may be propagated. The combs are carried to the extraction chamber, all doors and windows sealed, and the honey processed on the same day while it is still warm. Combs are opened with the designated knife, piled in the osier strainer which has been hung in a dark corner; as he does so the beekeeper culls remaining brood and impurities from the comb, both of which will spoil the honey. After the honey has flowed into the basin under the strainer it is transferred to earthenware vessels, the 'ripeners', and allowed to

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[60] H. Malcolm Fraser, *Beekeeping in Antiquity* (London, U. of London Press, 1951): 68. I have found this little book extremely useful.

[61] Aristotle, *H.A.* IV (viii) 534b, 19; cf. Columella, *DRR* 9.15.

[62] Columella, *DRR* 9.15.5–6.

[63] Columella, *DRR* 9.15.12. Cf. Fig. 26.

clarify for several days, "while the musty juice boils down."[64] What Columella means by this rather strange comment is that the denser sugars will naturally settle to the bottom of the solution and impurities and aqueous matter rise to the top, just as happens in boiling down must. The impurities are repeatedly skimmed from the top. Meanwhile, the combs are removed from the strainer and pressed (unfortunately we are given no specifics) to produce a second-quality honey to be kept strictly separate from the 'free-flow' honey.[65] It would seem that this 'free-run"'honey is graded as well; Pseudo-Aristotle remarks that thin, low-grade honey is skimmed off the top. Fraser remarks that modern apiarists prefer to draw off the top-quality honey through a tap at the bottom of the ripener, but the concept is the same: quality of honey is a function of sugar concentration.[66] How the honey was bottled we are not told. But properly refined and bottled, honey has preservative qualities which are legendary.

Honey processing produced several important byproducts. Beeswax was an extremely valuable commodity—almost as valuable as the honey itself, we are told—but is not our concern *per se*. But the ancients took the comb from which honey had been expressed and made a product called *mella*. At the time of the putting up of preserves (late summer), wax from the first pressing of the summer harvest is broken up and steeped in springwater or rainwater, then is pressed a second time; the resulting weak honey solution is boiled in leaden cauldrons to concentrate the sugars. During the boiling impurities are strained from the surface, doubtless just as for grape concentrates. When the solution has been reduced to the density of *defrutum* it is cooled and stored in pitched flagons (*lagoenae*) [Fig. 32A]. Columella recommends its use in pickles and conserves in lieu of *aqua mulsa*, 'honey water' or *defrutum* because it imparts a pleasant taste to food, but cautions against substituting it for *aqua mulsa* in medicaments because of its tendency to cause flatulence.[67]

In the same passage Columella describes the making of honey water, *aqua mulsa* or *hydromel*.[68] Several types of water may be used

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[64] Columella, *DRR* 9.15.11.

[65] Columella, *DRR* 9.15.10–13.

[66] Fraser (1931): 110.

[67] Columella, *DRR* 12.11–12.

[68] Ibid.; cf. Palladius 8.7; Dioscorides 5.15–31(probably mead in this case, since it brings on headache); Pliny, *NH* 14.17; 22.24.

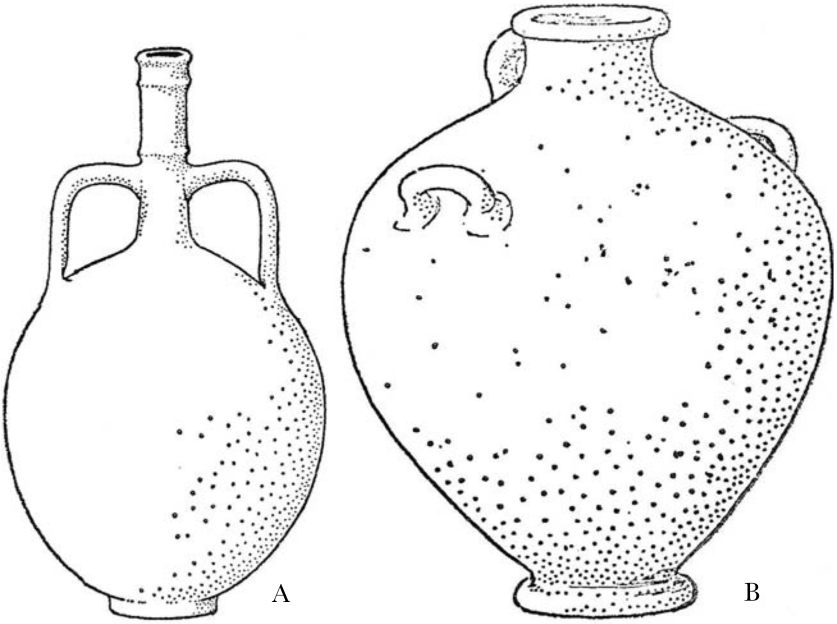

Fig. 32A. The flagon, *lagoena*, in which liquids such as vinegar were stored. Fig. 32B. The *urna*, a larger vessel for liquid storage. (From White (1975): Fig. 44 and 54. Courtesy of Cambridge University Press.)

for the purpose; some people put up rainwater many years in the sun and then clarify it by several rackings; others take fresh rainwater and boil it down to one-fourth its original volume. In either case the water is mixed with honey, a pound of honey per pint (*sextarius*) of water for a sweeter product, three-fourths pound of honey per pint for a 'harsher' flavor. Alternately, a pint of honey is mixed with two pints of boiled rainwater for the sweeter version, three-quarters pint for two pints water for the harsher version. The resulting solution is placed in flagons, sealed with plaster, and steeped (*insolatum*) in the sun for forty days before being transferred to flagons and stored in a loft (*tabulatum*) which receives smoke.[69]

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[69] Cf. Pliny, *NH* 14.17, Palladius 8.7: "During the days when the Dog Satr is rising, take pure water the day before from a spring. In three sextarii of water mix one sextarius of unskimmed honey and take care to agitate it diligently, the solution having been divided *per caroenarias* (?). It is agitated continuously for a space of five hours by naked slaves (?), then exposed under the open sky day and night for forty days."

The term *aqua mulsa* is frequently translated as 'mead', which of course is a fermented honey product. Was *aqua mulsa* mead? Most likely not. It is certainly true that a solution of honey and water will ferment spontaneously, but the fermentation relies on ambient yeasts in the air and is very unreliable; therefore, mead makers typically mix in a quantity of grape must or pitch a leaven to ensure proper inoculation. The first option is described by Columella as a separate product, and we hear nothing of the second. Furthermore, everything about Columella's description of the process suggests efforts to prevent, not promote, fermentation. Using stored water which has not soured for years and which has been carefully clarified certainly suggests a desire to use pure if not sterile water. And water boiled to one-fourth volume *is* essentially sterile. Secondly, the proportions mentioned by Columella and Palladius create a high-density solution whose hypertonic qualities will have inhibited if not killed yeasts; for comparison, modern meads begin with mixtures of one pound honey per quart of water—half the density of Columella's sweet product.

Furthermore, fermentation in pitched, sealed vessels is a recipe for an explosion. Moreover, a solution kept in a sealed vessel in the sun for forty days will almost surely have reached temperatures sufficient to kill even the hardiest wild yeast strains. Storage of the product in a *fumarium* could be interpreted as an effort to maintain high temperatures, unless it is aimed to expedite the 'aging' of the product on the analogy of smoked wines. Finally, Columella's recommendation to substitute *aqua mulsa* for grape concentrates in pickles and conserves suggests that it is a similar, unfermented, product. All in all, it is likely that *aqua mulsa* was nothing more or less than its name implies.

A third byproduct of honey which certainly was designed to ferment was honey vinegar. Pliny[70] says that honey pots and combs after the processing of honey are washed in water and the solution thus obtained boiled down to the proper concentration to make honey vinegar. A weak honey solution most certainly would ferment, either spontaneously or otherwise, and would inevitably acetify to produce a delicious vinegar. Fraser[71] cites an analogous modern procedure. Pliny confuses the issue, however, when he describes the

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[70] Pliny, *NH* 21.20.

[71] Fraser (1931): 79.

making of another honey vinegar by heating together vinegar, honey, sea salt, and rainwater.[72] If this solution was designed to ferment as well, then inclusion of vinegar will have provided an innoculum for the acetic fermentation. But the impression left by the passage is of a simple culinary procedure, the making of 'artificial' honey vinegar. Presumably this was also the case with other honey admixtures such as *oenomel*, 'honey wine', *rhodomel*, 'honeyed rosewater', and *oxymel*, another 'honey vinegar', all described in the *Geoponica*.[73] Also designed to ferment was a form of *oenomel* described by Palladius.[74] Here the product is created from a mixture of must and honey; here is our mead.

The only other sweetener mentioned with frequency in recipes for food preservation is *passum*, the raisin wine previously discussed (Ch. 3).

Acids

Honey vinegar reminds us that the best pickles usually combined sugars with an acid. The latter, of course, operates by lowering pH level to a point at which most pathogens and spoilage organisms cannot survive. Pathogenic bacteria are inhibited by as little as 0.1% of undissociated acetic acid, for example, micotoxogenic molds by as little as 0.3%. The effect in pickles is frequently enhanced by the hypertonic action of salt and sugars to reduce water activity. But it is not just the pH level that is operant; the undissociated part of the molecule can penetrate all membranes and disrupt membrane transport processes.[75] Acids are such a commonplace in modern industrialized nations that it is easy to forget how few were available before the nineteenth century. Indeed, the development of modern chemistry is directly linked to the quest for better acids at this time. For the Romans, vinegars and citrus juices were quite literally the only strong acids available, and citrus fruits were too rare to be utilized for food processing to any appreciable extent. Thus vinegars,

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[72] Pliny, *NH* 14.17.

[73] *Geoponica* 8.25–30.

[74] Palladius 11.17. Clearly there are two products described here under the same name, one unfermented and the other fermented.

[75] M. R. Adams, "Vinegar," in Wood (1998): 22.

and especially wine vinegars, were the Romans' acids of choice and necessity.

About this basic product there is an astonishing lack of literary evidence, both ancient and modern.[76] One might think that a condiment so fundamental in the pickling of fruits, vegetables and meats would have caused gallons of ink to spill, but that is far from the case. I perceive two possible reasons for this silence. One has to do with the basic chemistry of vinegar. Vinegar is the natural—indeed, inevitable—product of alcoholic fermentation when that fermentation is allowed to proceed uninterrupted. Thus, the problem for thousands of years has been not how to make vinegar, but how *not* to make it; i.e., to prevent it from generating and thus spoiling the desired products of alcoholic fermentation, most especially wine and beer. It was Napoleon III's charge to the brilliant young scientist Louis Pasteur to find a solution to the vexing problem of acetification of French wines which led to Pasteur's discovery of both Acetobacter and Saccharomyces species, as well as to his invention of the process we know by his name. In a sense the lowly little bacteria which metabolize alcohol to acetic acid, then, are the midwives, if not the mothers, of modern biochemistry and food science.

The primary reason for the relative silence of our ancient sources, I suspect, is the fact that vinegar was primarily a home product in the agricultural hinterlands and a cottage industry elsewhere. To my knowledge vinegar never became a major commodity in Rome itself. Even Columella's prescription to be discussed below was manifestly for the production of a condiment for pickling agricultural products produced on the villa farm itself. That account squares with comparative traditions in latter-day Italy and elsewhere, where a crock of vinegar was habitually kept in the house, on the surface of which a healthy culture of *Acetobacter*, the 'mother', floated. As vinegar was

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[76] For modern literature, M. R. Adams, "Vinegar," in Brian J. B. Wood, ed., *Microbiology of Fermented Foods*, vol. 1 (London: Blackie Academic and Professional, 1998): 1–44; H. A. Conner and R. J. Allgeier, "Vinegar: Its history and Development," *Advances in Applied Microbiology* 20 (1976): 81–133; R. N. Greenshields, "Acetic Acid: Vinegar," in A. H. Rose, ed., *Primary Products of Metabolism, Economic Microbiology*, vol. 2 (London: Academic Press, 1978): 121–86; W. Hoffman, "The Production of Wine Vinegars," *Fruit Products Journal and American Vinegar Industry* 5 (1926): 14–15; C. Llaguno, "Spanish Wine Vinegar," *Process Microbiology* 6 (1971): 27–8, 33; M. Plessi and D. Coppini, "L'aceto balsamico tradizionale di Modena," *Atti della Società dei Naturalisti e Matematici* 115 (1978): 39–46.

consumed, more wine or beer was added to be acetified. Because a good vinegar is its own best preservative, this sort of simple culture can remain healthy year after year.

Wine vinegar is simply a dilute solution of acetic acid, on the order of 4–6%, made by first fermenting the sugars of musts to alcohol and then exposing the alcohol to a bacterial fermentation. These bacteria are aerobic and therefore colonize the surface of the liquid; the larger the surface area, the more rapidly acid formation progresses, especially after the bacterial film, 'mother of vinegar', forms on the surface. If modern analyses are indicative of ancient microflora, a number of organisms are involved, most of which are members of the species of *Acetobacter* and *Gluconobacter* (formerly together as *Acetobacter* or as *Mycoderma*, the latter Pasteur's original term). The desired bacterial agents are those of *Acetobacter* species, but a variety of undesirable bacteria will effect a ferment as well.[77] Traditional vinegar production relies on porous vessels or a continuous replenishment of the same inoculum to favor the desired organisms over the undesirable.[78] In wine vinegars the surface colony appears as a thin, gray film, though the bacteria may be distributed throughout the wine as well. In cider and perry vinegars the acetic bacteria form a heavy greenish film, more correctly referred to as 'vinegar mother'.[79]

Columella describes the basic process as well as several variations:[80] Take forty-eight sextarii (3 gal. / 11.3 L) of 'flat' wine (*vinum vapidum*) and bray together a pound of leaven, a quadrans of dried fig, and a sextarius of sea salt, to which add 1/4 pound of honey. Dilute with some vinegar and then add to the bulk wine. A perfectly acceptable recipe. 'Flat wine' is wine of such low alcohol levels and acidity that it is likely to acetify anyway, and the thrifty Columella is therefore making a virtue of necessity. However, there is some possibility that the wine has fallen victim to an incomplete alcoholic fermentation, what the vintagers call a 'stuck ferment'. Therefore Columella pitches a leaven and adds some fermentables to feed a fresh fermentation, precisely what his modern counterpart would do in the same circumstance. The sea salt will have acted as yeast

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[77] Adams in Wood (1998): 15–19.

[78] Carl S. Pederson, "Processing by Fermentation," in Heid and Joslyn (1967): 508.

[79] Jackisch (1985): 268.

[80] Columella, *DRR* 12.5.1–2.

nutrient. The addition of vinegar as an inoculum, obviously one from a successful acetic fermentation, is actually quite proactive, since it ensures the rapid colonization of *Acetobacter* to the exclusion of any ambient strains. These latter produce noticeable amounts of ethyl acetate which has an odor described as "reminiscent of lacquer thinner."[81] Use of 'flat wine' is also indicated because most acetic bacteria grow very poorly in alcohol solutions above 13%; on the other hand, at levels below 10% less desirable acetic bacteria thrive and the result is a vinegar of noticeably poorer quality (ethyl acetate again). Today, for comparison, in the so-called Orleans process, wine is diluted to 10% alcohol and a one-fourth ratio of vinegar is added to the bulk wine as an inoculum. A barrel of this mixture is filled three-fourths full to create an oxidizing environment and the bung hole and several other holes in the barrel's top are covered with wire mesh to keep out insects but allow the culture to 'breathe'. The barrel is stored at 70–85°F (21–30°C) and about one-fourth the contents of the barrel is removed as aged vinegar every three to four months and the barrel topped up with fresh wine to the original level. The process allows for the aging of vinegar as well as acetification.[82] Freshly made vinegar is usually cloudy but can be clarified with the same agents as wine.

Unfortunately Columella mentions none of these details, doubtless because they were matters of common knowledge. On the other hand, he describes in some detail several variations designed to produce a superior product. Thus "some people" add four sextarii of toasted barley and forty "burning walnuts" (?) and a half-pound of green mint to an equal measure of vinegar. Others heat a lump of iron red hot and plunge it into the vinegar. Still others plunge burning pine-nut cones or fir cones into the solution. Apparently some Romans enjoyed vinegars with a smoky savor, perhaps to mask the unpleasant odor of ethyl acetate.

We hear relatively little of flavored vinegars, though they must have been quite common, given the Romans' predilection for aromatics. The basic process is infusion; a base vinegar is mixed with flavoring agents such as spices and/or members of the allium (onion) family, placed in a sealed container and agitated periodically. Herbs

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[81] Jackisch (1985): 268.

[82] Jackisch (1985): 269; Adams in Wood (1998): 20–23.

and other flavoring agents tend to mute the sharpness of vinegar and produce a mellower product.[83] Both Columella and Palladius[84] have recipes for squill vinegar, for example. The squill, *Urginea maritima*, is a member of the lily family and thus a cousin of onions, leeks, chives, shallots and garlic. Palladius describes the infusion process very nicely: squills are trimmed of stalks and outer, fibrous layers of the bulb; then the bulb itself is finely minced and submerged in sharp vinegar, a pound and six ounces of squill for two *urnae* (6 gal./ 22.5L) [Fig. 32B] of vinegar. The vessel is sealed and placed in the sun for forty days. The infused vinegar is then strained into pitched vessels. A variation, "good for digestion and general health," includes pepper, mint and cassia.

Wine vinegar must have represented the norm everywhere in the Roman world that viticulture was practiced. But we also hear from Columella[85] that vinegar was made from figs in regions lacking the vine. Figs are picked at the peak of ripeness, stored in dolia or amphorae and allowed to ferment (presumably by ambient yeasts) and then to acetify (*exacuêre*) and deliquesce. The liquid is carefully strained into sweet-smelling, pitched vessels. It substitutes for very sharp wine vinegar, never becomes flaccid (vinegar can itself 'decay' when acetic acid decomposes to CO_2 and water) or ropy, provided it is stored in a dry area. This product, undiluted as it was, must have been intensely sweet and perhaps had something of the intensity—though not, of course, the flavor profile—of a modern balsamic vinegar. Some, Columella attests, prefer quantity to quality and therefore dilute the figs with water before fermenting, then strain it through rush baskets or esparto sacks and then boil the clarified vinegar as they skim the scum and impurities. They then add toasted salt to prevent the generation of "maggots and other animals." Other fruit vinegars utilized apples, sorbs, and pears.[86]

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[83] Jakisch (1985): 271.

[84] Columella, *DRR* 12.34; Palladius 8.6.

[85] Columella, *DRR* 12.17.

[86] Palladius 2.15; 3.25.

Spices

Modern readers who peruse the recipes of Apicius, not to speak of those for pickles and conserves of the technical writers, are astounded by the Roman predilection for spices. An Apician recipe not uncommonly calls for eight or more condiments, in addition to the fish sauces and paste which double as seasoning. Once again, however, it is important to understand the very practical considerations which may have predisposed this so-called 'refined' cuisine. Stated simply, aromatics were the ancients' antioxidants and antibiotics.

A word about definitions. The term *spice* is variously defined as an exotic aromatic seasoning as opposed to a herb, a native aromatic; or as the product of woody plant tissue as opposed to 'herbaceous' plant parts, or by some other distinction. I will use the term *spice* in its broadest sense, as currently defined in the industry as "any dried, fragrant, aromatic, or pungent vegetable or plant substance, in the whole, broken or ground form, that contributes flavor, whose primary purpose is food seasoning rather than nutrition, and that may contribute relish or piquancy to foods or beverages. . . . Spices may be the dried arilla, bark, buds, flowers, fruit, leaves, rhizomes, roots, seeds, stigmas and styles, or the edible plant top."[87]

Today the International Organization for Standardization lists some seventy legally recognized spices. By comparison, Miller in his groundbreaking study of the Roman spice trade[88] lists no fewer than 142 spice products mentioned in classical texts, of which 84 have been fairly securely identified. But how commonly available were they in our focus period? Miller thinks the majority were widely available, if still quite expensive in many cases. The period coincides with the first widespread exploitation of monsoon winds by Westerners and therefore direct trade links with India's Malabar Coast and Northern

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[87] Kenneth T. Farrell, *Spices, Condiments and Seasonings* (New York: Van Nostrand Reinhold, 1990): 17. The term *aromatic* as a generic term has much to recommends it, since the volatiles which create the aroma are the active ingredients, but the Greek and Latin term from which it derives, *aromata*, refers specifically to spices used in perfumery. On the other hand, *spice* comes from Latin *species*, used in this context to denote an exotic aromatic substance.

[88] James Innes Miller, *The Spice Trade of the Roman Empire, 29 BC to AD 641* (Oxford: The Clarendon Press, 1969): 28–29; 112–18. The latter section is an excellent tabular reference. Miller lists spices by common English names, Latin and Greek names, botanical name, native habitat, and ancient literary attestation.

India, sources for many of the spices. India was also the *entrepôt* for the world's spices at the time, especially those of China, Southeast Asia and the East Indies (the Spice Islands). As illustration, spikenard, the precious nard of the Gospels expended by the woman to anoint Jesus, fell in price in Pliny's time from 300 denarii per liter to 100. Both long and black pepper became easily affordable, even to those of fairly modest means. During the next five centuries spices from ever wider fields became more widely known and utilized, as evidenced by literary references, the Price Edict of Diocletian, use in medical prescriptions, reports of geographers and merchants, and elaborations of customs law.[89] Granting that Apicius' recipes are aimed at an up-scale audience, the spices he uses are still doubtless the most commonly available. Prescribed in the *De Re Coquinaria* for sauces are anise, asafetida (and possibly silphium), basil, bay leaf, capers, caraway, cardamom, cassia, celery seed, cinnamon, coriander seed, cumin, dill, fennel, garlic, ginger, hazelwort, horseradish, hyssop, juniper berry, lovage, mastic, mint, mountain catmint, mustard seed, onion, parsley, pennyroyal, white and black pepper, poppy seed, pyrethrum, shallot, thyme, and turmeric.[90] The list of spices used in food preservation is far more extensive.

How did man come to know that intense smells and flavors are salutary? In his wonderful study of ancient medicine, Guido Majno[91] makes a compelling case that the quest for aromatics is an adaptive behavior in man's evolutionary ascent because "substances that have a strong smell are also likely to have a physiological effect." But we needn't posit a genetic component; Majno also extrapolates perfectly logical reasons, at least from ancient man's own perspective, to use aromatics on wounds, two of which apply to foods as well. For one thing, the fact is that putrescence—in wounds as in foods—smells bad, and therefore the practice of using pleasant-smelling substances to combat the odor and ergo the infection is "as logical as putting out fire with water." Furthermore, man must have observed empirically that aromatics such as resins do not decay, and it was and is logical to suppose that they can impart some of this incorruptibility

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[89] Miller (1969): 23–25.

[90] Jon Solomon, "The Apician Sauce: *Ius Apicianum*," in Wilkins, Harvey and Dobson (1995): 116.

[91] Guido Majno, *The Healing Hand: Man and Wound in the Ancient World* (Cambridge, MA: Harvard U. Press, 1975): 207–27.

to wounds and foodstuffs. "In this, the sense of smell was truly prophetic, for antisepsis is a 'transmissible' property almost by definition: antibacterial substances do not themselves decay, and applied to organic matter they can preserve it too from decay." But how did man come to define putrid and pleasant? Again we are left with the suspicion that he is genetically predisposed to define strongly odoriferous substances with (*ipso facto*) preservative qualities as good smelling, and those which proceed from decay as putrid. After all, presumably to a vulture the smell of putrescent meat is ravishing. It may well be that spices smell 'good' to humans precisely because they are good for us, just as putrid things smell 'bad' because they are pathogenic.

If there was any serious doubt that spices do, in fact, have preservative and antimicrobial qualities, that doubt has been buried under an avalanche of scientific research in the last sixty years. Simply stated, spices have powerful antioxidant, bacteriostatic, and general antimicrobial powers.[92] The antioxidant action of spices[93] is especially important in preventing oxidative rancidity of oils and fats. This power of spices is so widespread as to suggest its universal action, though rosemary and sage exhibit the most pronounced effects. Citric acid has a demonstrated synergistic effect in this regard; one wonders if acetic acid may act synergistically as well.

The bacteriostatic action of spices is also now well attested.[94] Especially effective in inhibiting molds, yeasts, and bacteria are

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[92] Kenji Hirasa and Mitsuo Takemasa, *Spice Science and Technology* (New York: Marcel Dekker, 1985): 163–200; Donna R. Tainter and Anthony T. Grenis, *Spices and Seasonings: A Food Technology Handbook* (New York: Wiley-VCH, 2001): 167–9; Susheela Raghavan Uhl, *Handbook of Spices, Seasonings and Flavorings* (Lancaster, PA: Technomic Pub. Co., 2000): 40; Farrell (1990): 238.

[93] J. S. Pruthri, *Spices and Condiments: Chemistry, Microbiology, Technology* (New York: Academic Press, 1980): 17–24. The classic study is still that of J. R. Chipault, et al., "The antioxidant properties of natural spices," *Food Research* 17 (1952): 46ff, though augmented by dozens of others over the years. These are conveniently tabulated in Farrell's Table II.10, and include 32 of the spices used by the Romans, including all the most frequently mentioned. A good summary of the chemistry of spice antioxidant action, reasonably accessible to the layman, is Helle Lindberg Madsen, Grete Bertelsen and Leif H. Skibsted, "Antioxidant activity of spices and spice extracts," in Sara J. Risch and Chi-Tang Ho, edd., *Spices: Flavor Chemistry and Antioxidant Properties* (Washington, American Chemical Society, 1997 [= ACS Symposium Series 660]): 176–87.

[94] Cf., e.g., Pruthri (1980): 24–32, who reviews the older research; Majno (1975): 218–19.

mustard, cinnamon and cloves, all common in the Roman world. In all cases it is the essential and volatile oils which contain the active ingredients, so that the smell is indicative of preservative powers. In one study the preservative power of mustard, cinnamon, and cloves on ketchup was actually superior to that of commonly used modern chemical preservatives. Mustard oil was especially effective at preventing acetification of cider and wine; unfortunately it was also highly effective against *Saccharomyces cerevisiae* as well. But we should bear in mind that the Romans added aromatics in vinification after alcoholic fermentation and therefore, at least in theory, before acetic fermentation could proceed. Scientists conducting these studies have another common bacteriostatic lurking in their labs; today essence of thyme, crystalline thymol, is used on solutions to preserve them from bacteria and molds, just as it is used in meats as a preservative and all-purpose antiseptic.

Perhaps the most exciting research in this area concerns the antibiotic and possible therapeutic action of spices.[95] Spices have been shown effective against *Clostridium botulinum, Listeria monocytogenes, Campylobacter jejuni, Vibrio parahaemolyticus, Yersinia enterocolitica, Aspergillus parasiticus, Salmonella typhimurium, Staphylococcus aureus*, and *Bacillus subtilis*. In general spices are more inhibitory than BHA and BHT, today's most common food antibiotics. And the reader will have noticed that several of the microbes cited above are among the most common and dreaded of food-borne pathogens. The inhibitory action of any specific spice against any specific pathogen ranges from slight to strong; therefore a combination of spices is far more effective as a broad-spectrum application. On the other hand, some spices such as rosemary and sage act themselves as broad-spectrum antibiotics. Again, it is the essential oils, the 'sweet smell' of spices, which are the operant agents: aldehydes, sulfur, terpenes and their derivatives, phenols, and alcohols all exhibit strong antibiotic potential. On the other hand, crude spices frequently contain fungi, molds and bacteria themselves, including the pathogens *Bacillus cereus, Clostridium perfringens* and various *Salmonella* strains, as well as toxigenic molds *Aspergillus flavus* and *Penicillium citrinum*. For that reason they are often treated today with ethylene oxide. Again, a spice blend may eliminate

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[95] Pruthri (1980): 32–44; Uhl (2000): 38–39; Tainter and Grenis (2001): 171–74.

some of this risk. A recipe with six or more spices begins to sound rather shrewd.

Spices also have therapeutic value. Several spices used by the ancients Romans, especially ajowan, black pepper, cinnamon, garlic, nutmeg, cloves, ginger, cumin, caraway and asafetida, are used extensively in modern Indian medicine to treat a variety of intestinal disorders.[96] Especially effective here as well as against a number of other pathogens is allicin, the active ingredient of garlic. Allicin is effective against both gram-negative and gram-positive bacteria, the latter practically immune to the action of penicillin. Among the *Liliaceae* family (garlic, onions, etc.) a secondary antibiotic action has been noted for tannins and alkaloids, elements which contribute to the pungency of these foodstuffs; one wonders if man's quest for piquancy in food may not be related to its antipathogenic action as well. Additionally, moderate levels of garlic oils in the diet inhibit a number of pathogens including *Escherichia coli, Aerobacter aerogenes, Staphylococcus aureus*, and *Shigella sonnei*, while leaving lactic bacteria largely unharmed. Thus garlic in the diet shifts the balance of microflora in the gut in favor of lactic organisms, which generally promote absorption of minerals in the diet as well as numerous other nutritional benefits.

Little wonder, then, that the Romans were 'addicted' to spicy food and drink. Spices have little or no nutrient value, but they may have been among the most 'nutritionally' essential of ancient foodstuffs. And the very qualities which make them valuable as condiments make them easy to process as well. In most cases, for example, spices held in the whole form don't begin to deteriorate before fourteen months if kept sealed in a cool, dry place. Ground spices are far more unstable, but can be kept for considerable times in the same way as whole spices. But even old spices don't generally decay; they simply lose their savor (and biological effectiveness) as essential oils slowly volatilize.[97] Still, we are somewhat surprised by Pliny's statement[98] that even the most stable spice seeds are no good for sowing after four years, though still good for culinary use. But Pliny was

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[96] Pruthri (1980): 32–44.

[97] John H. Kilbuck, "Seasoning for the Food Manufacturer," in Heid and Joslyn (1967): 189.

[98] Pliny, *NH* 19.18.

no armchair academician here, correctly adducing that some seed spices keep longer than others, for example, coriander, beet, leek, cress, mustard, rocket, savory, and the pungent seeds in general, and that those less stable are the subtler orage, basil, gourd, cucumber and nigella.

Seed spices require little processing beyond minimal drying and careful storage in a cool, dry place. For that reason the ancients, even the compulsively inclusive Pliny, have little or nothing to say about the subject, though Pliny's statement that some spice seeds are still viable after four years clearly implies that the Romans were quite adept in this area. Leafy spices are more problematic, but if these plants are allowed to flower and seed the leaves and stalks can be hung in a warm, dry area and allowed to naturally desiccate and thereafter will remain aromatic for a year or more if left whole, longer if flaked and sealed. Pliny[99] attests that rue, mint, pennyroyal, and catmint are preserved in bundles, an obvious reference to the technique. He might have added several dozen other leafy species as well, though presumably the fact was so well known as not to merit comment.

Fleshy plant components such as stalks, flowers, flower buds, roots and rhizomes are even more unstable because high water content and relatively small surface area make desiccation proceed slowly. Here the Romans clearly preferred pickles, which would mask the aromatic qualities of the spice but guard the preservative action. Columella[100] prescribes a pickle of two parts vinegar to one part hard brine for capers, parsley, rue, alexanders, fennel stalks, fennel flowers, wild parsnip flowers and stalks, flower of bryony, house leek, pennyroyal, calamint, hoary mustard, samphires, and "the little stalk of what is called 'kite's foot'." The leaves of several of these, it will be noted, are the usual modern spice, but explicit reference to fennel and parsnip flowers and stalks reminds us that the Romans made use of parts of spice plants generally discarded today. It also clearly implies that reference to parsley, rue, pennyroyal and calamint in this passage is to the stalks and/or flowers of these spices.

Sometimes these plant parts were desiccated under dry salt before being pickled. Columella says bryony, butcher's broom, black bry-

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[99] Pliny, *NH* 19.157.

[100] Columella, *DRR* 12.7.1–3.

ony, asparagus, parsnips, calamint, and samphires are placed on trays, sprinkled with salt, and left in the shade for two days to exude liquids. They are then washed, preferably in their own juices or in hard brine, pressed to express as much juice as possible, then pickled in the prescribed mixture, stored in vessels stoppered with "a dry fennel stalk picked during the last year's vintage." Elsewhere[101] Columella says purslane and samphires may be cleaned, dried in the shade for four days, layered in vessels with salt, then submerged in vinegar.

Roots and rhizomes call for a slightly different treatment.[102] Before alexanders puts forth a stalk (i.e., in the winter months) the root is pulled up, cleaned, pickled in vinegar and brine for thirty days, then removed and the skin peeled off and the fleshy inner parts cut in segments and pickled in glass jars or earthenware vessels along with mint, raisins, dried onions, parched wheat (all brayed with honey), *sapa* and vinegar, these last two in a 2:1 ratio. Skirwort root can be processed in the same way.

Finally, tinctures and powders were made from the resinous or gummy juices of certain plants, most notably the famous *silphium* (also *laser* and *laserpicium*) and its substitute asafetida. The *silphium* was a wild umbilliferous plant native to North Africa and processed there in the Greek colonial city of Cyrene in such huge quantities that, according to Pliny, it became extinct during the reign of Nero, the last known *silphium* having been consumed by Himself. Identification of this plant is notoriously vexed,[103] but it is most likely *Ferula tingitana*, still found in parts of North Africa and the Levant, despite Pliny's claim, though now uncommon. The sap of *silphium* had a sweet odor and a pungent taste that ancient Greeks and Romans adored. Pliny[104] describes the processing: the juice was extracted from root and stem and was distinguished as such as *rizias* and *caulias*, the latter cheaper but liable to go bad. The sap itself was 'adulterated' with bran, "for it would have gone bad had this not been done." Pliny is being overly fastidious in his choice of terms for the process, but he is correct as to the reason; resins of this sort are commonly

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[101] Columella, *DRR* 12.13.2.

[102] Columella, *DRR* 12.58.

[103] Cf. Chalmers L. Gemmill, "Silphium," *Bulletin of the History of Medicine* 40 (1966): 295–313.

[104] Pliny, *NH* 19.43–44.

mixed with flour or some other edible powder to stabilize them. Whether the unmixed tincture was also sold as a liquid is difficult to say. Apicius[105] recommends storing *silphium* and pine nuts together in a sealed glass jar and using the infused pine nuts only, to make the precious spice go further; this recipe seems to imply a powdered form. Apparently early on the roots and stalks were also sold whole in the Greek world, since Aristophanes[106] refers to grating silphium over foods as a garnish in the same manner as cheese.

A second product, at first commonly and at some point consistently substituted for *silphium* was the sap of asafetida, *Narthex asafetida*. When the substitution was complete is also a vexed issue, but it was almost certainly after the time of Pliny. This umbilliferous plant, something like a giant fennel stalk, has sap with an unforgettable, pungent sulfurous smell which gave rise to its Medieval apothecary name, *Stercus diaboli*, 'Devil's dung', and a pungent taste which must have been similar to that of true silphium, so much so that at some point the naturalists, gastronomes and medical writers began referring to it by the same names, sometimes specifying 'sweet-smelling' and 'evil-smelling' *silphium/laser/laserpicium*. This plant is still harvested in Iran and Afghanistan and is used extensively in the cuisines of these countries and in India, both as a powder and a tincture. The smell cooks off, incidentally, and leaves an intriguing pungency. Today the plant is allowed to grow four years before harvesting; at the end of the fourth growing season, when the leaves are yellowing and the sap fallen, the stem is twisted off, the top of the root, still *in situ*, uncovered, a slice of the top of the root cut off and some of the precious sap collected as it oozes out. Then the stump of the root is covered with stems and leaves. Periodically the root is uncovered, another slice taken off, and more of the fetid, yellow resin obtained. The resin produces a clear liquid when mixed with alcohol and is used as a mild stimulant and laxative and a perennial condiment. Iranians think it food of the gods.[107] In India the resin is sold as a tincture but is also mixed with a gum and wheat flour and sold as *hing*.

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[105] Apicius 1.13.

[106] *Knights* 894; *Birds* 533–4; *Plutus* 925.

[107] Mollinson (1993): 91.

However constituted, Roman spices made their way into foodstuffs, not simply in culinary use but also, and perhaps more importantly, in the processing of oils, wine, fruits and vegetables, meats, fish products, and cheeses. And this most commonly not just individually but as elaborate spice blends. So great was the preservative power of spices that, as we have seen, they were even used to preserve other spices.

EPILOGUE

In Book 8 of his *Metamorphoses*, Ovid gives us a delightful set piece which defines perfect rustic hospitality.[1] Jupiter, god of hospitality among other things, has descended to earth in mortal guise, along with his favorite accomplice on such larks, Mercury, in order to test the locals' adherence to the strictures of hospitality, which the ancients famously regarded as much a religious obligation as a social nicety. Predictably, the two are turned away from house after house until they come to a humble farmhouse where lives a poor but pious and contented old couple named Baucis and Philemon, who receive them graciously. After seeing to their guests' comfort the old couple begin dinner preparations:[2]

> [Baucis] poked the ashes around a little,
> Still warm from last night's fire, and got them going
> With leaves and bark, and blew at them a little,
> Without much breath to spare, and added kindling,
> The wood split fine, and the dry twigs, made smaller
> By breaking them over the knee, and put them under
> A copper kettle, and then she took the cabbage
> Her man had brought from the well-watered garden,
> And stripped the outer leaves off. And Philemon
> Reached up, with a forked stick, for the side of bacon,
> That hung below the smoky beam, and cut it,
> Saved up for long, a fair-sized chunk, and dumped it
> In the boiling water. They made conversation
> To keep the time from being too long, and brought
> A couch with willow frame and feet, and on it
> They put a sedge-grass mattress, and above it
> Such drapery as they had, and did not use
> Except on great occasions. Even so,
> It was pretty worn, it had only cost a little

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[1] *Meta.* 8. 616–724. The motif is a regular literary *topos* in Roman literature. Cf. Nicola Hudson, "The Beast at the Table: Food in Roman Verse Satire," in Mars and Mars (1993): 204–20. The country meal, luxurious in its freshness and abundance, continues to be a popular motif.

[2] The translation is that of Rolfe Humphries, *Ovid, Metamorphoses* (Bloomington, Indiana U. Press, 1983).

> When purchased new, but it went well enough
> With a willow couch. And so the gods reclined.
> Baucis, her skirts tucked up, was setting the table
> With trembling hands. One table leg was wobbly;
> A piece of shell fixed that. She scoured the table,
> Made level now, with a handful of green mint,
> Put on the olives, black or green, and cherries
> Preserved in dregs of wine, endive and radish,
> And cottage cheese, and eggs, turned over lightly
> In the warm ash, with shells unbroken. . . . .
> No time at all and the warm food was ready,
> And wine brought out, of no particular vintage,
> And pretty soon they had cleared the table
> For the second course: here there were nuts and figs
> And dates and plums and apples in wide baskets—
> Remember how apples smell?—and purple grapes
> Fresh from the vines, and a white honeycomb
> As centerpiece, and all around the table
> Shone kindly faces, nothing mean or poor
> Or skimpy in good will.

Here we recognize the three courses of a proper *cena*: the *gustatio*, with its green and black olives, its cornel cherry preserves, its salads and eggs; the *prima mensa*, in this case a humble cabbage flavored with a generous chunk of bacon; and the *secunda mensa*, with the traditional fruits and nuts. It is during the *commissatio*, the after-dinner drinking, however, that the old couple realize just how distinguished their guests really are when the mixing bowl for the wine magically replenishes itself. At this point they decide to kill their old goose, who serves as a guard for the farm, in order to serve a properly 'citified' entree of fresh meat. The comic result is that the wily goose proves too elusive for the doddering old folk and the gods, who, we may imagine, appreciate the gesture far more than they would have this stringy fare, intercede to save the goose and reveal themselves. They offer the couple their hearts' desire, and it comes as no surprise that Baucis and Philemon, models of pious contentment, forego riches and status and choose instead to be guardians of Jupiter's temple and ultimately to die together to avoid the pain of separation from each other.

A pretty piece, the poignancy of which depends to a great extent on the absolute propriety of the meal and the generosity of the hosts in giving freely of their little. We are to understand that everything served here is homegrown, an offering from the heart. Indeed, Baucis and Philemon's Italian counterparts still reserve the homemade preserves, pickles and *salumi* for those they most wish to honor. Moreover, the meal makes up in its simple freshness and abundance any deficiency in effete ingredients. What could be more luxurious ultimately than a cabbage come fresh from the garden to the pot, not to speak of the variety of homegrown fruits and vegetables and the *piéce de resistance*, a tawny comb dripping with honey fresh from the hive.

Is Ovid's imaginary meal strictly poetic idyll or does it bear some resemblance to the reality of peasant life? And how much of this fare, in either case, will have been accessible to the urbanite in Rome? The short answer, as usual, is that we simply do not know, but I am convinced that we needn't be too pessimistic about the possibilities. Certainly the whole point of Ovid's idyll is that this rustic meal is a generous celebration which stretches the means of the old peasants to the limit. Perhaps the most telling evidence of this is the two foodstuffs conspicuous by their absence, namely bread and olive oil, foodstuffs that we may assume were so much the staples of every peasant meal that Ovid quite consciously omitted them. The fact that they, along with wine, were the daily staples simply gives counterpoint to the magnanimous liberality of our hosts' best offerings. On the other hand, the generosity would lose its effect if the old couple did not themselves have access, at least seasonally and in moderation, to all the items from their rustic larder.

And what of our urbanite? Certainly fresh farm products will have been relatively expensive even in periods of relative abundance. But if we may again take our cue from his modern Roman counterpart, he may well have foregone the meat, even in preserved form, from time to time in favor of the fresh fruits and vegetables in the markets. Nor need he have done without in any case; note that every single article in Ovid's menu has already been or could have been processed for consumption out of season and/or from the marketplace. Thus in the realm of processed foods, besides the bread and olive oil we must posit, we have bacon, table olives, cornel cherries in wine dregs, cheese and wine. And every fresh item mentioned we find among those processed on the villa farm of the agronomists. Even the very mint with which Baucis scours the table could have been processed for non-seasonal consumption and could itself be used in processing other foods.

That all of these items were shipped to Rome in a processed state also seems very likely. For example, products attested in imported amphorae, besides the wine, olive oil and garum/liquamen we should expect, are apples, cherries, grapes, plums, peaches, damsons, figs, dates, nuts, pepper, fava beans, lentils, honey, chickpea flour, barley groats, vinegar, and allec (fish relish).[3] Unquestionably there were many others for which we simply do not currently have evidence. And we should remember that the agronomists' formulae for processing of farm products is largely for export and profit, not home consumption. Thus it is reasonable to suppose that our urbanite sustained himself with a regular diet of cereals as bread or porridge, of olive oil and wine, supplemented, as supply and cost dictated, by a large variety of processed fruits, vegetables, animal products, and condiments.

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[3] Callendar (1965): 27–41.

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