Fuel in ancient food production
Robyn Veal

Introduction

Fuel was an essential commodity in every ancient society, as it is today. It was required every day in industry for manufacturing metals, ceramics, glass, lime and other products. It was also required in every household for cooking and heating. While industrial needs have often dominated scholarship (in particular, considerations of the production of charcoal for metal smelting and smithing), fuel used in food production was a significant consumer of both raw wood and charcoal fuel. Non-wood fuels also played a part in food preparation, including some plants that acted as both food and fuel. This article aims to highlight the scale and scope of food preparation under different circumstances, especially in relation to fuel consumption, and to look briefly at demand and supply issues of fuel.

The nature of archaeological charcoal
Historical sources are complemented by evidence provided by the identification and interpretation of archaeologically collected charcoal. Charcoal may be collected during excavation by hand or by dry sieving. It is also collected through flotation (wet sieving).[1] It is then fractured by hand and examined in three sections under a reflecting stereoscopic microscope. Figure 1 shows a cross section of elm wood charcoal from Pompeii. In this example, the bottom half of the microphotograph shows the 'early wood', which starts with the sprouting of the first leaf in spring when a new growth ring and large vessels are produced to assist the flow of water and nutrients. Later, after a full growing season, when cooler weather arrives, 'late wood' vessels are produced. In elm these have a strikingly different pattern, as observed, of small groups of small vessels arranged in a typically dendritic pattern. Observance of 'early' and 'late' wood patterns can be useful for deducing the season of cropping.

Figure 1

Types of ancient food production

Large scale public ritual and feasting
Ritual sacrifice and cooking of meat is well documented in the historical sources, and some evidence suggests very large-scale events.[2] Complementary archaeological evidence of a similar scale has yet to be uncovered. While the formally sacrificed meat was distributed to the priests and important participants, the general masses received meat prepared separately. The fuel requirements for sacrificing and cooking large numbers of beasts, as reportedly occurred in Rome, bears some consideration. After preparation of the carcasses, fires would be lit in pits and allowed to blaze up, then after stabilizing, the meat would be added. A slower burning fire with rotisserie equipment is the best way to barbeque large cuts of meat, and cooking was long and slow.[3] Pigs, sheep, and goats, due to size and relative low cost, would be consumed (as opposed to cows and bulls, which would be served on very special occasions and only to a select few). The weight of the charcoal (and some wood to start the fire) must be equivalent to the weight of the raw meat carcass being consumed in order to cook it satisfactorily. We do not know the amount of meat served to the *plebs* at large feasts, although we may consider that portions would not have been large. Even so, if there were thousands of participants, the required charcoal fuel and the logistics to deliver it would have been considerable.

Feeding the army
The logistics of feeding an active army were also complex. While soldiers received formal rations of basics such as meat, oil, wine and grains, they also bought other foodstuffs from travelling vendors, and lived to a certain extent off the land. Feeding a large army implies the carrying or finding of very large quantities of fuel. Since all sorts of tools, weapons and personal effects were already being carried, it seems improbable that large quantities of raw wood fuel, in particular, were also carried. Wood fuel may have been gathered along the way where possible, perhaps being levied as a local tax. Supply line provision of charcoal, rather than wood might also be inferred due to its decreased weight (one-third of the equivalent volume of raw wood, but with 1.8 times the heat value). The army would have had to balance accessing local supplies with supply line provision, otherwise the local population would have been left with no fuel for their own cooking needs.

Commercial food production
Food processing on a commercial scale included pickling, smoking, grilling, cooking (on a stove top, or in ovens), for sale in a market, bar/shop, or potentially at an ephemeral food stand in an agora or amphitheatre. Such medium-scale commercial food preparation would require consistent provision of raw wood and charcoal fuel to the production site, and potentially, more charcoal, for example, to keep food hot in Roman *cauponae* or *thermopolia* (food and drink bars, common from the first century AD onwards in Roman towns). Figure 2 shows a modest grilling facility located in a small street front bar in *insula* VI.1 in Pompeii (AD 79). *Collegia* also provided fine dining to their members.

Figure 2

Bakeries
Bakeries were another commercial form of food production. Continuing with the extensive evidence from Pompeii, we know of around 39 commercial bakeries (and a number of *villae* with their own baking ovens). In terms of fuel consumption, bakery ovens were fired up very early in the morning with wood, or sometimes with olive pressings. The fire was stoked for 1-2 hours until hot, at which point the fuel was removed or pushed to one side, the oven watered/washed down, whereupon baking commenced and consecutive batches of breads, cakes and other goods were cooked until the oven was cold.[4]

Domestic fuel use
Domestic fuel use in the historical and archaeological record includes the well-documented Greco-Roman habit of banqueting where the elite entertained each other in their *villae*. Cooking was mostly carried out in the kitchen and could include the same large range of methods of preparation already noted above. In the Roman tradition, excavations of a number of *triclinia* have also brought to light portable cooking stoves, presumably for roasting tidbits right at the table. For the rich, these were made of metal, while for the poor, modest ceramic versions have been uncovered in Pompeii at the AD 79 level.[5]

Other forms of domestic fuel use included small ritual acts, such as the daily sacrifice to the *Lares* in the Roman world. These small bits of food burnt at a small altar probably required the use of a small amount of hot charcoal or wood embers. Other ritual domestic acts include those seeking the Gods' favor at important times, such as the construction of new buildings. In such circumstances sacrificial deposits are found under a door threshold, or in trenches dug to establish wall foundations. Typically such deposits include remains of the food offered: animal bones (often young animals); occasionally eggshells; charred fruits and nut remains, and wood charcoal. In the case of one ritual deposit from the House of the Vestals (Pompeii), the range of wood charcoals found correlated well with the fruits and nuts also identified.[6] Figure 3 shows a chart of the wood charcoals identified, which includes some fragrant woods. In terms of fuel, this deposit differs markedly from those associated with everyday cooking, which typically contain just three or four types of common deciduous woods, such as beech, oak or maple.

Figure 3

Types of fuel

Wood and wood charcoal
Both raw wood and wood charcoal have been mentioned as primary cooking fuels. Wood was the commonest fuel in the ancient Mediterranean, with petroleum products being less well known.[7] Agricultural waste products such as olive and vine pressings, threshing wastes, and nutshells were among other fuels, but these were not significant contributors to the fuel economy, except in wood poor areas, such as parts of Greece, and Africa, where olive pressings are in particular found as fuel waste. The importance of charcoal cannot be overstated, as it burns at a more steady temperature (whether high or low) with little or no smoke, and it is one-third the weight of wood by volume (as already noted) and is therefore cheaper to transport.[8] It is manufactured usually at the point of wood collection, i.e. in the forest. On a small cleared area, pre-dried wood is cut to a standard length (often about a meter), and a round or rectangular mound is built up two or three meters high. The whole is then covered in leaves, ash from previous charring episodes, and soil or mud. An oxygen-depleted atmosphere is created, and instead of burning, the wood is charcoalified so that water is removed, and most of the organic volatile materials escape. The result, depending on the length of process and size of wood, is a mostly carbon product. The cellular structures remain intact, permitting identification usually down to genus level, but sometimes lower (species), or higher (family, or sub-family). Further information about the archaeological charcoal may also be recorded (as well as wood type), such as probable diameter of wood, and tree ring patterns, counts and growth rates. This information informs our understanding of growth habits and ancient cropping strategies.[9]

Charcoal can be collected in and around hearths and ovens, but is usually ubiquitous in any urban site. Fuel associated with kitchens and cooking usually consists of small diameter (ca. 1-3 cm) woods, which for the most part have been quickly grown, perhaps under a coppicing or similar regime. In ancient Italy the commonest wood types employed in fuel in the Campanian region in the Republican to Late Roman periods were: beech (*Fagus sylvatica)*; oak (deciduous and evergreen – a range of species); the Corylaceae family (hazel, *Corylus avellana)*; two types of hornbeam *(Carpinus* spp.); and several types of maples *(Acer* spp.). Small quantities of cuttings from fruit and nut trees were also found (and escalate in numbers over the Imperial period).[10] Latium Vetus and Rome are showing similar patterns in ongoing work. In the northern provinces such as Roman Britain, the most common wood types found as fuel include deciduous oak *(Quercus* cf. *robur* or *pubescens),* and hazel as well as those that reflect the more moist environment (alder *(Alnus cordata)* and birch *(Betula* spp.). In hotter climes, where poorer soils and low rainfall predominate (such as eastern Italy, and Greece), macchian woods are found, for example evergreen oak *(Quercus* cf. *ilex,* or *suber),* pistacia *(Pistacia* spp.), and the strawberry tree *(Arbutus unedo).*

When examining fuel in the archaeological record, discriminating charcoal that has arisen from burnt construction timber from that arising from kitchen fuel, can be undertaken through analysis of the annual tree rings. Flat rings generally indicate wood arising from large timber, and tight rings indicate small wood. The archaeological context is also important, as actual burn layers are usually very recognizable. We would also like to differentiate charcoal remains of charcoal fuel from those of raw wood fuel, since the use of charcoal implies a greater consumption of forest. Progress is being made with a scientific method called 'reflectance' that measures the shininess of the archaeological charcoal. This has been demonstrated to be directly related to its absolute burn temperature, and so, by measuring a range of charcoals in a context, a raw wood fire will show a 'normal' (bell-shaped) distribution curve of charcoals formed from temperatures starting at about 250°C, increasing in temperature and number of charcoal fragments from 350-550°C, and dropping off thereafter. A charcoal fuel fire will not produce low temperature charcoal remains, as all the fuel will have reached at least the temperature of the (prior) charcoal production process (about 350°C). A 'flatter' and irregular curve starting around 350°C will eventuate. This new method has much promise but is yet in early stages of testing.[11]

Relative values of different fuels
The use of agricultural waste as fuel has been briefly mentioned. Chaff and other threshing wastes provide fewer heat calories than wood (by weight), but are useful for flaming up a dying fire, or helping to start a new one. These agricultural wastes were (and are) also used as a binder in dung cakes.[12] We may compare the relative usefulness of different fuel types using a proxy of Specific Gravity (SG) or by burning the different fuels and measuring their heat outputs. In the case of SG, we find the denser the wood, generally, the greater its heat potential. Olive pressings (otherwise known as pomace), have recently received more attention as a fuel, being found in the bakeries in Pompeii, in a sewer at Herculaneum, and in general contexts in Pompeii *insula* VI.1 in such numbers as to suggest their presence due to use as fuel. Olive pomace provides more heat than most woods, and burns with little smoke. Differentiation of olive stones/endocarps representing food waste from those representing fuel is possible. Olive oil was, of course, also used for many purposes, including as fuel in lamps.[13] Charcoal of any sort provides nearly twice the heat value of standard dried, deciduous woods, regardless of the material from which it is made (threshing wastes, such as olive pressings can also be made into charcoal).

Supply

Supply sources
Supply sources may be inferred after identification of the charcoal and evaluation of the ecological niches from which the consumed woods may have originated. In some cases, if common woods are found, their specific origin may not be possible to infer, although indirect evidence such as urban density, and spatial requirements for other agricultural activities may assist. In others, if marker woods, such as those requiring specific altitude, or growing conditions (not found near the consumption area) are identified, then searching for the nearest locations where such woods may have grown becomes the next logical step. In this case we cannot completely discount the possibility of extra-regional importation of fuel, however, there is little evidence to support large-scale fuel importation into Italy, or even Greece, for the purposes of food production. The former on the basis of overall comparative advantage for growing wood, and the latter, from the brief historical references we have, which show that firewood and charcoal were brought in by donkey from nearby.[14] Transport of wood and charcoal forms a large part of the cost of fuel provision, and for the most part, evidence to

date suggests that most fuel was provided no more than about a day's journey from a major city.

Volumes of wood required

Elsewhere I have discussed a model for estimating a city's total fuel consumption.[15] This may be worked as follows: population is multiplied by raw wood consumption per head (with a modifying factor to allow for the raw wood that has been made into charcoal), to give the total amount of raw wood required per capita (per year). The total is then divided by the presumed productivity of the forest in order to obtain an estimate of the area of forest required. Figure 4 shows a graphical representation of the calculation.

Figure 4:

This begs the question: how much fuel was used in ancient food preparation in comparison to other uses? More work is required here, but if ethnographic parallels can point the way, then we may examine domestic consumption patterns of wood in wood dependent developing countries, versus industrial consumption. An example is the modern Philippines in the 1970s where 0.73 tons per head per year of wood was consumed just for cooking. This represents a figure seven times that which was consumed in large logwood production.[16] Total wood fuel consumption (both industrial and domestic) therefore, is a much greater consumer of wood than timber production, representing about 70-80% of all wood consumed. Cooking makes up around a third to a half of all fuel consumption, thus representing close to half of all wood consumption of all kinds. These figures call us to acknowledge the consumption of wood fuel for food production as a very significant factor in the ancient economy and one worthy of further study.

Conclusions

This discussion has provided a brief overview of the role of fuel in food production and has shed light on the order of magnitude of the quantity of fuel required for this daily activity. The area is ripe for further study, in particular, refinement of the quantitative estimates discussed here. The longer-term value of this research will depend on the future routine collection of archaeological charcoal. Site directors are strongly encouraged to add charcoal to their excavation protocols.

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Abstract
Fuel is a little considered part of the ancient economy. The production and consumption of food constituted one of the major uses of fuel in the Greco-Roman world. It was required on an industrial scale in bakeries, temples and probably bars, but it was also required daily in people's homes mostly for cooking food (in the kitchen, and in the *triclinium*), and also for sacrificing to the Lares. Wood and wood charcoal were the main fuels in the Roman world, but non-wood fuels including agricultural waste (especially olive pressings), were also consumed. This paper reviews the types of fuel used in the preparation of food, both commercially and domestically, with reference to examples from the Greco-Roman world, especially Pompeii. The relative heat values of different fuels are discussed, together with an overview of the supply constraints and probable volumes required.

About the author
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in the ancient world, ancient landscapes, the economy, and ancient technology. Her research pages may be found at www.robynveal.com.

Figure captions

Figure 1. Cross section of elm *(Ulmus* spp.) (x5) from first century AD Pompeii (photo author). Scale bar = 1mm. The cross section (visible when a branch is cut in half and the raw end examined) is one of three sections used in identification, the others providing two different longitudinal views.

Figure 2. Modest grilling facility in a street front bar (Pompeii *insula* VI.1) (photo author). A metal grill was installed over the top of the (most probably) charcoal fire.

Figure 3. Graph of charcoal fragment counts for a foundation deposit made at around the time of the building of the House of the Vestals, Pompeii (ca. 200 BC). The woods found correspond well with some of the charred fruits and nuts identified, in addition to fragrant woods, such as juniper *(Juniperis* cf. *communis),* myrtle *(Myrtus communis),* and rose (Rosaceae family), (image: author).

Figure 4. Graphical representation of a model for calculating the total wood consumption of a city or region. Population multiplied by raw wood (adjusted for charcoal consumption), divided by forest productivity provides an estimate of the hectares required, (image: author).

Endnotes

[1] Collection methods for charcoal, and its various uses in archaeological interpretation may be found by downloading a file available here: http://www.robynveal.com/field-collection.html.

[2] Donahue 2003: p. 429, and references therein review the many hundreds of literary mentions and inscriptions on public feasting. Large numbers of participants are inferred for feast days to celebrate, e.g. Augustus' birthday, Saturnalia, and Compitalia (e.g. Virg. *Catal.* 13.27-30). Other public feasting days included: emperors' funerals, and priests' accessions.

[3] Cooking implements of all types are well described in Grocock and Grainger 2006 in their introduction.

[4] Baking bread: Monteix 2015; olive pressings and wood as fuel in bakeries: Coubray et al. forthcoming; Monteix et al. 2012.

[5] For the different types of portable cooking stoves: Veal 2012; for kitchens and their layout including stovetops, ovens, and general function: Foss 1994.

[6] On sacrifices to the *Lares* and the foods consumed: Robinson 2002; details of the House of the Vestals foundation deposit: Ciaraldi & Richardson 2000.

[7] Humphrey et al. 1997: pp. 43-44 provide details of the Romans' fairly scant use of petroleum products. This occurred mostly where such products were available on the surface (especially parts of the East).

[8] Diocletian's Edict mentions wood, charcoal and kindling as fuel, as well as transport costs. Prices are by weight, *(libra)* and distance.

[9] Veal 2012; Veal 2013 provide greater details on charcoal making and the variations on the process. Charcoal making in the ancient sources is also discussed.

[10] See for example: Coubray 2013; Coubray et al. forthcoming; Moser et al. 2013; Veal 2012; Veal 2013; Veal 2014.

[11] McParland et al. 2009; Veal et al. 2011; Veal et al. 2016.

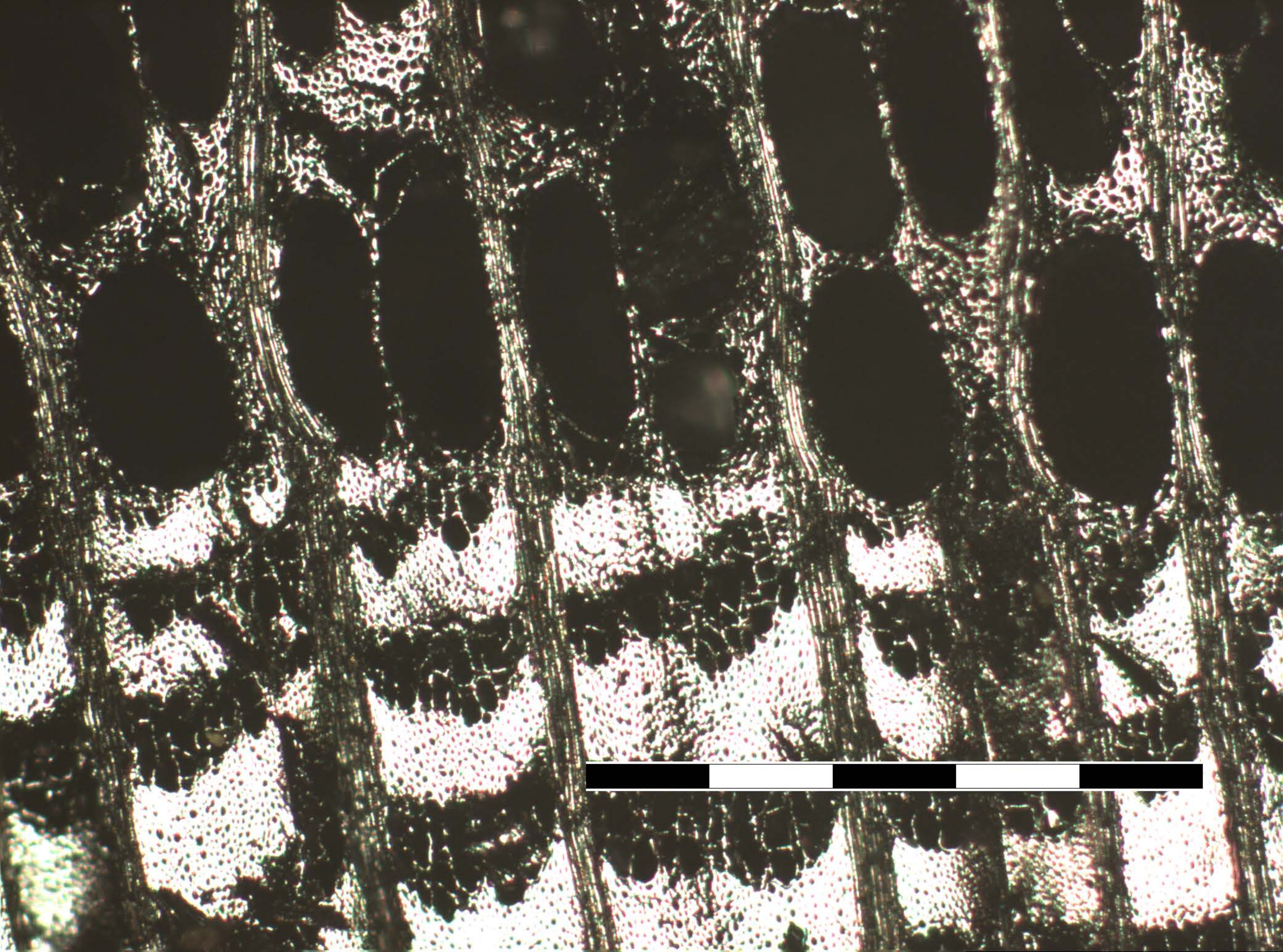
[12] Cf. Hansen et al., this volume.

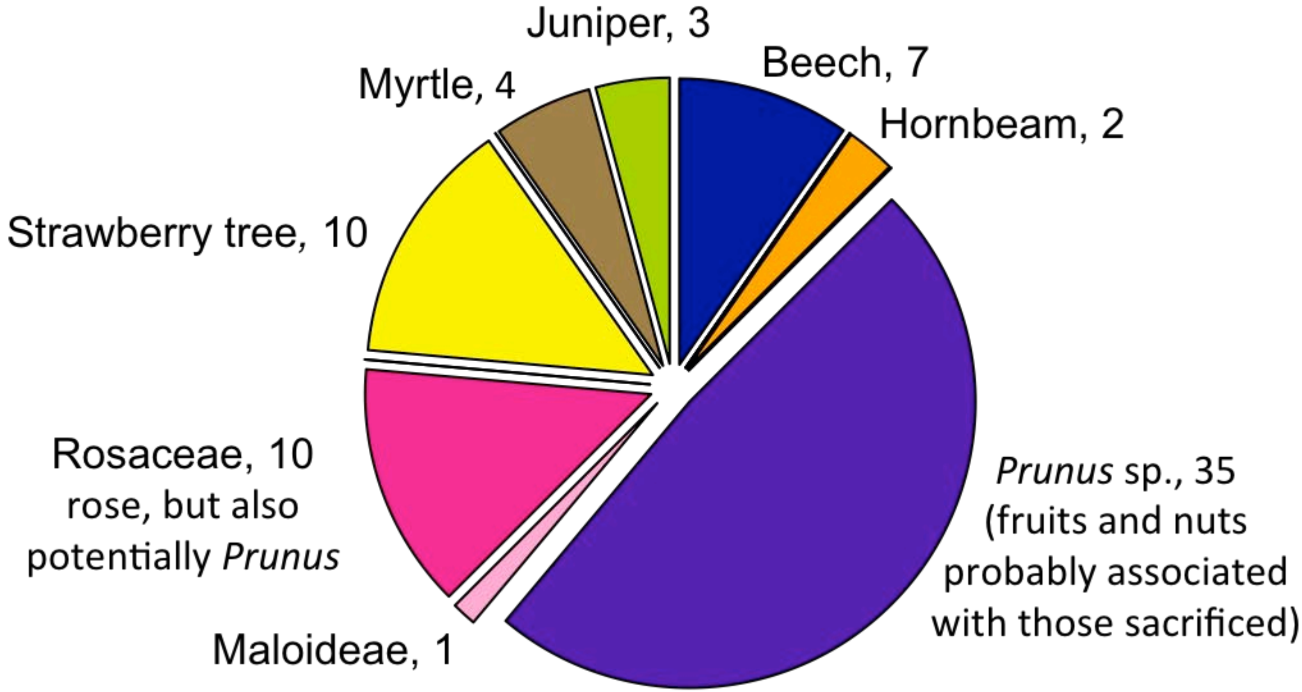
[13] Bakeries in Pompeii: Coubray et al. forthcoming; Monteix et al. 2012; Herculaneum sewer: Rowan 2015. Olive oil and other fats used in lighting: Griffiths forthcoming

[14] Fuel sources being located well outside the city area are demonstrated for the ancient cities of Rome and Pompeii with the presence of large quantities of beech *(Fagus sylvatica),* which in the ancient period grew in the mountains: Veal 2012; Veal 2014; Veal forthcoming. For typical ancient Greek supply see Olson 1991.

[15] Discussed in Veal 2013. A downloadable version of the model spreadsheet and discussion of the variables is available at http://www.robynveal.com/a-quantitative-model-for-the-ancient-fuel-supply-to-pompeii-ad-79.html.

[16] Hyman 1985: pp. 581-582, of course modern ethnographic analogues must be treated with care in comparison to ancient world conditions.




Juniper, 3
Beech, 7
Myrtle, 4
Hornbeam, 2
Strawberry tree, 10
Rosaceae, 10
rose, but also
potentially *Prunus*
Prunus sp., 35
(fruits and nuts
probably associated
with those sacrificed)
Maloideae, 1

X