22. Brewing and baking

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The nature of bread and beer

For most ancient Egyptians, the seasonal routine revolved around the husbandry of the cereal crops. For many, the daily routine was centred on the transformation of these cereals into staple foods. The importance of both bread and beer is widely attested in many documentary sources including offering lists, proverbs, scribal exercises and administrative records (Breasted 1907: 103; Drenkhahn 1973; Helck 1971). The frequency with which well-furnished tombs were provided with bread loaves and jars of beer, and the many artistic scenes of baking and brewing in tombs, demonstrate how the ancient Egyptians aimed for an equally abundant supply in the after-life. No meal was complete without bread and beer, and everyone in ancient Egyptian society partook of them, from Pharaoh to the labouring peasant. Bread and beer played a number of key roles in ancient Egyptian society. At the most fundamental level, they made a major contribution to nutrition. Together with raw cereals, they were an important part of internal trade, commerce and rations (Kemp 1989: 126). Ritual practice made use of both foods (Darby et al. 1977: 503; Helck 1971: 82–94).

Beer and bread are also modern staples and therefore are familiar foods in many societies today. It is thus easy to make assumptions about what these foodstuffs are and how they were made. The variety of beers and breads produced in the present day, though, demonstrates that there is no simple definition for either of them, and that they can vary considerably in production, from raw ingredients and processing methods to final product. Given this great modern diversity, there is no reason why ancient bread and beer should necessarily resemble any particular present-day type. The very familiarity of these foods makes the study of their ancient counterparts a challenge, because ingrained assumptions must constantly be made explicit and reassessed.

Attempts to define beer and bread are unlikely to be wholly comprehensive, but some definitions are needed, in order to establish a base line for discussion. Beer can be considered to be a liquid made from starchy ingredients, usually cereal grain, which has been fermented into a beverage with at least some alcohol content. Bread may be thought of as a product cooked by direct exposure to dry heat — baked — and normally made wholly or in part from a starchy ingredient, usually cereal grain. Both beer and bread may be made from ingredients other than cereal, or have other ingredients added. Both foodstuffs share many characteristics, most obviously cereal as the usual major ingredient, and may have some preparation steps in common.

Sources of evidence and methods of analysis

Traditional sources

The investigation of ancient Egyptian baking and brewing techniques has relied heavily on the artistic record, which includes wall-reliefs and paintings, statuettes and models. A few examples are given here for each period. Wall decorations and statuettes of baking and brewing figures are most abundant in the Old Kingdom. A group of Old Kingdom statuettes is on display at the Cairo Museum, including a female brewer from the mastaba of Meresankh at Giza (JE66624) and a man working with a pottery vessel from the mastaba of Ptahshepses at Saqqara (CG112; Saleh and Sourouzian 1987: nos. 52 and 53 respectively). Perhaps the best-known depiction of baking and brewing is the relief in the tomb of Ty on the west wall of Room II (the ‘provisions room’; see Epron and Daumas 1959: pls. 66–7, 70–1; Montet 1925: 230–36; Wild 1966), while the reliefs from the Saqqara mastabas of Heteperakhthu now at Leiden (Mohr 1943; Wild 1966: pl. 10) and Kaemrehu now at Cairo (CG1534; Saleh and Sourouzian 1987: no. 59) are also quite widely cited.

Several Middle Kingdom wall-paintings show baking and brewing. Some of the most notable are at Beni Hasan in the tombs of Amenemhat (BH2; Newberry 1893a: 30–1, pl. 12), Khnumhotep (BH3; Newberry 1893a: 68, pl. 29), Bakht III (BH15; Newberry 1893b: 48, pl. 6) and Khety (BH17; Newberry 1893b: 55–6, pl. 12), as well as the Twelfth-Dynasty Theban tomb of Intefqer (TT60; Davies 2009: 103; 2016: 10–17).
and Gardiner 1920: 11-12, 14-16, pls. 8-9A, 11-12A). Models are the most common method of depicting these processes at this period, for example that from the tomb of Wadjjetbepet (no. 2106) at Sedment, dating to about the Ninth Dynasty, now at the Ny Carlsberg Glyptotek in Copenhagen (Mogensen 1930: 66, pl. 63, A.E.I.N. 1571; Petrie and Brunton 1924: 7, pl. 20 no. 3). In the New Kingdom, apart from a few statuettes of millers, certainly votive or ritual (for examples see Breastel 1948: 22-4, pls. 22-4; Gardiner 1906), there are a few wall-paintings. A detailed but damaged scene from the demolished ninth pylon at Karnak, now at the Luxor Museum, depicts bakers and brewers at work in temple workshops at Thebes (Lauffray 1979: pl. 16; 1980: 178-9, fig. 191). One of the latest known depictions is an elaborate but fairly poorly preserved scene in the tomb of Rameses III at Thebes (KV11; Darby et al. 1977: 523, fig. 12.14; Wreszinski 1923; pl. 374).

Publications which include funerary representations of brewing and baking occasionally contain a discussion as well as a description of the processes. Examples of these are Borchardt (1897) for various Old Kingdom statuettes in the Cairo Museum; Davies (1902: 26, pl. 20) for reliefs in the late Old Kingdom tomb of Rahenem (no. 72) at Deir el-Ghawawi; Moussa et al. (1977: 66-72, pls. 23, 26; 101-4, fig. 13, pls. 34-5) for reliefs in the Fifth-Dynasty tomb of Niankhkhnum and Khnumhotep at Saqqara; and Winlock (1935: 27-9, pls. 22-3, 64-5) for a model from the Eleventh-Dynasty Theban tomb of Meketra. In addition, a number of syntheses have been written, including those by Fakhry (1911 - Old Kingdom only); Klebs (1915: 67, 90-94, 1922: 94, 119-21, 1934: 171-9); Sist (1987: 55-6); Vandier (1964: 272-318) and Wreszinski (1926).

A variety of texts deal with bread and beer production. Many of these are scribal exercises, concerned with converting quantities of grain into loaves and beer of specific strength or quantity. Examples of these exercises can be found in the Rhind Mathematical Papyrus (Peet 1923: 112-22). Other documents record deliveries of grain to temple or palace kitchens and the quantities of bread and beer produced (see for example Helck 1961: 437-45, 1971: 33; Spalinger 1986). Deir el-Medina ostraca record that beer was brewed by villagers (Janssen 1980: 146-7). One of the most frequently cited Egyptian texts dealing with beer-making is not Pharaonic at all, but dates to the end of the third or beginning of the fourth century AD, written by the Egyptian Zosimus of Panopolis (Akhim, see for instance Borchardt 1897: 130; Darby et al. 1977: 538, Helck 1971: 40; Lutz 1922: 78). Among the other Classical authors who mentioned or described Egyptian brewing and baking are Herodotus (mid fifth century BC), Pliny (first century AD), Strabo (64 BC-AD 22) and Athenaeus (third century AD; see Darby et al. 1977: e.g. 537; Lucas 1962: 13). Helck (1971: 41) and Lutz (1932: 81-2) describe an unlikely sounding Talmudic recipe for ancient Egyptian beer using safflower and salt. Despite the same fairly limited pool of data (Wahren 1961: 1) however, there has been a general lack of consensus about ancient Egyptian baking and brewing methods. Few accounts tally, in major or in minor details (Samuel 1993: 277-8). This does not make the artistic and written records invalid or unusable. On the contrary, they are a rich source of valuable data. There are nevertheless a number of critical problems with these sources which have rarely been addressed. The modern observer, with a set of contemporary experiences and expectations, will view the artistic depictions differently from the Egyptians who made them and who experienced the actual processes. Also, it cannot be established with artistic and documentary evidence alone how widely the practices of the elite, who generated that evidence, can be applied to the technology of the majority of the ancient Egyptian population.

An area of confusion is the extent to which baking and brewing practices changed over time. General accounts often treat the whole span of Pharaonic cereal food production as unchanging. Others have acknowledged that changes did occur, but mechanisms and causes have rarely been investigated. Use of Classical texts to investigate practices during Pharaonic times is likely to be particularly misleading. At least two major changes in cereal processing technology took place in Egypt during Greco-Roman times: emmer, the sole wheat of the ancient Egyptians (see Chapter 21, this volume), was replaced by free-threshing wheat (Crawford 1979: 140; Nesbitt and Samuel 1996: 77; Tackholm et al. 1941: 240-1), and the technology of milling switched from saddle to rotary querns (Forbes 1954: 274).

As this brief survey suggests, a great deal has been written about ancient Egyptian bread and beer. This chapter, however, is written on the premise that much of their production has been misunderstood. Discussion has often been heavily based on various assumptions: that ancient Egyptian bread and beer ingredients were similar in character and physico-chemical behaviour to ingredients commonly used today in the Western world; that ancient Egyptian food making technology was fairly crude; and that the limited evidence of artistic depictions provides most of the information needed to understand production methods. As the evidence presented in this chapter makes clear, such assumptions are wrong.

There is actually little consensus for the precise sequence of activities involved in flour production, as Figure 22.1b suggests. Nearly all accounts assume that the cereal which was processed was clean grain with no attached husk. Since this was not the case, as explained later in the chapter, the technology of flour production in particular has been misinterpreted.

Broadly speaking, the most common interpretation of ancient brewing is based on the use of bread (Fig. 22.13). It has been thought that dough rich in yeast was prepared and lightly baked so that the yeast would not be killed by heat.
Richly yeasted dough

(Dag may or may not have been used)

Dough lightly baked into beer loaves

Semi-cooked bread crumbled, strained through sieve with water

(Dues or extra yeast added?)

Broken bread suspension fermented into beer

Beer decanted into jars for storage or transport

Figure 22.1a Generalised summary of interpretation of ancient Egyptian brewing, based on and adapted from several different sources (see for example references in text). Steps in brackets and broken lines indicate activities which are not widely included in modern accounts of ancient brewing practice, but which are sometimes mentioned.

These loaves were then crumbled and rinsed through sieves with water into vats. In them, fermentation occurred due to the action of yeast from the bread.

In order to take a fresh approach to the subject, the artistic and philological records have been referred to, but have been set aside as primary data sources for the purposes of this chapter. Both have a great deal to offer and their integration with archaeological, ethnographic and experimental evidence will add valuable and unique perspectives. There may now be enough data available from a range of sources to re-evaluate the historical development of ancient Egyptian baking and brewing. Such a study, though, has not yet been undertaken. The evidence for baking and brewing in the New Kingdom is currently the most extensively studied using scientific methods, and is therefore the main focus of this chapter. Figures 22.2 and 22.3 summarise the interpretations presented here, which are based on the sources of evidence set out below.

Archaeological evidence

Sites, tools and installations

The archaeological record has the potential to provide comparable information for all periods, and can give the most direct evidence for ancient Egyptian baking and brewing technology. In the arid Egyptian climate, organic remains are especially well preserved. Archaeologists are beginning to recognise the potential for a much more detailed understanding of cereal processing and food preparation in general (Samuel 1996a). As a result, the deliberate targeting and recording of food-related evidence should become more detailed and precise. At present, there are relatively few excavations which have been published or investigated in sufficient detail to draw accurate conclusions about the technology of cereal food preparation. The following are some of the main available sources.

Glimpses into the roots of Pharaonic brewing have been obtained from two Predynastic sites, those of Abydos and...
Hierakonpolis. Excavations at both have uncovered installations which may well be connected with brewing (Geller 1992a: 21-4; 1992b: 104–12; Peet 1914: 7–9, pl. I no. 6, 8; Peet and Loat 1913: 1–7, pls. I, XIV/no. 3). They consist of double rows of large vats, supported by distinctive fire-bricks (see p. 79) and surrounded by an elaborate mud-brick shell. Such fire-bricks unassociated with installations have been found at a number of other Predynastic sites. The large quantities of ash and charcoal surrounding the vats, as well as the reddening of the ceramic, attest to the application of fire and the function of these structures as heating installations of some sort. In some cases residues of the vat contents have been preserved. Peet (1914: 9) submitted samples for chemical analysis which determined they were carbon-rich and therefore organic; further study indicated the grain embedded in residues was wheat (Peet and Loat 1913: 7). Residue from the Hierakonpolis vats was also submitted for archaeobotanical analysis, which indicated the major components were emmer chaff and grain (Geller 1989: 47, 1992b: 110).

Although Peet and Loat (1913) suggest these installations were kilns for parching grain, this interpretation is unlikely (for parching see p. 562). Geller (1989: 47–52, 1992a: 21, 1992b: 139, 142–3) has interpreted these structures as brewing installations, probably for mashing – that is, heating the beer ingredients at a moderate temperature for some time. This is based on chemical analytical data, not fully published, purporting to show that the residues are rich in sugars (Geller 1989: 47–8). Geller (1992b: 111, 183, table 8) reports and Maksoud et al. (1994) assert that fermentation products can be detected in these residues. The analytical chemical work published to date is unconvincing because the effects of degradation of ancient organic molecules (and therefore the possible presence of molecules that were not part of the original contents) has not been considered. Also, the possibility that micro-organisms contaminated the organic remains after abandonment has not been eliminated.

Nevertheless, the interpretation of these installations as kilns used at some stage in the brewing process is likely for the following reasons.

1) The Abydos residues contain wheat – almost certainly emmer rather than ‘common wheat’ (Triticum vulgare), as stated in the publication (Peet and Loat 1913: 7) – while the residues found adhering to the interior of the Hierakonpolis vats are rich in cereal grain and chaff. Emmer spikelets are clearly discernible in a photograph of residue published by Geller (1992b: 196, pl. 7). The abundant chaff indicates the food being prepared was not related to bread, porridge or other human food (for chaff in food see p. 545), while the roughly broken nature of the chaff indicates it was coarsely processed.
2) Geller describes the remaining contents as 'a vitreous black residue' (1989: 45), 'in which emmer wheat and possibly barley was embedded' (1992a: 21), but states that this residue was not charred: 'numerous uncarbonised grains, spikelets, and rachillas of emmer wheat [were identified] in [the] sediment from . . . the vat features' (1992b: 110). The thick fused masses caked onto the inside surfaces of the vats are clearly visible in photographs published by Geller (1989: pls. 4, 5). This description indicates that reasonable amounts of water must have been part of the mixture in the vats, because the uncharred residue has fused into a solid mass, something that could not occur by heating dry or damp grain alone (see p. 550).

3) The abundant ash and charcoal surrounding the vats at both Abydos and Hierakonpolis, together with the slight but not extensive reddening of the ceramic, clearly indicate that gentle heat was produced in the structures and applied to the mixture of coarsely broken spikelets and water inside.

4) The Early Dynastic written records indicate that beer was very important at that period, and therefore it must have been well-established in ancient Egyptian culture by that point. It is highly likely, therefore, that Egyptian brewing had its antecedents in Predynastic times.

Recent excavations at Giza, directed by Mark Lehner, have uncovered an Old Kingdom bakery (Lehner 1992: 3–6, 1993: 62–6). This provides valuable insights into baking practices associated with a royal project of some kind. The Giza data currently available throw light on the end process of Old Kingdom bread production, the baking stage.

Excavations at Middle Kingdom Abu Ghalib uncovered ovens, elongated conical moulds and platters in close association (Larsen 1936a, 1936b: 48, 73–6, figs. 2, 4, 10 nos.)
for the humbler members of society.

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ure is very well preserved and has provided vital evidence

for ancient processing methods. For example, starch gran-

ules and yeast cells can clearly be distinguished by micro-

scopy.

Several descriptions and studies of surviving ancient

Egyptian bread have been made (e.g. Borchardt 1932;

Bruyere 1937: 106–7; Darby et al. 1977: 517–22; Glabau

and Goldman 1938; Gruss 1932; Leek 1972, 1973; Täckholm


Wittmack 1896, Wittmack 1905: 6–7), but it is not gen-

erally recognised that several hundred such loaves survive

from ancient times (Fig. 22.4). They are now scattered in

museums throughout the world. The loaves vary greatly in

size, shape and texture. They have thin crusts which are

darker on the upper side and paler on the base, showing

that they were definitely baked.

Virtually all surviving bread has been recovered from

elite tombs. This means that it relates only to the wealthier

members of ancient Egyptian society, and that it is only

representative of funerary practice. Without specimens

from settlement contexts, it is impossible to know if surviv-

ing loaves are the same as bread consumed in daily life, if

they were similar to bread baked for religious or ceremonial

occasions, or if they were types which were only produced

for funerary offerings. Beer residues, in contrast, have been

recovered both from tombs and from settlement sites, rep-

resenting both funerary and daily practice, for the elite and

for the humbler members of society.

Residues and loaves

Amongst the most informative archaeological remains are

desiccated loaves of bread and residues of beer. The com-

plete loss of water has prevented most decay processes

taking place, but the biomolecules making up the food-

stuffs have broken down through ageing. The microstruc-

ure is very well preserved and has provided vital evidence

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ules and yeast cells can clearly be distinguished by micro-

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recovered both from tombs and from settlement sites, rep-

resenting both funerary and daily practice, for the elite and

for the humbler members of society.

Beer residues are less clearly identifiable, because unlike

bread, they do not have an obvious appearance (Fig. 22.5).

Nevertheless, they have been recognised as contents within

whole pots (Bruyere 1937: 110; Gruss 1932a, 1932b, 1932c;

Petrie 1907: 23; Winlock 1932: 32), within brewing installa-

tions (Geller 1989: 45, 47, 49, 1992a: 21, 1992b: 108), and

as thin crusts clinging to pottery sherds (Samuel 1994b:

196b, 1996c: 488, fig. 1; Samuel and Bolt 1995: 29).

Other residues which have been called remains of beer are

less convincing, if only because they have not been de-

scribed in enough detail in publications, do not have known

parallels or have not been extensively analysed (Firdh 1915:

17; Mond and Myers 1937: 60–1; Petrie 1901: 32; 1920: 43).

No residues have so far been found in labelled beer vessels.

Residues most likely to have been beer or precursors have

some or all of the following characteristics. They contain

fragments of grain, cereal chaff or bran tissue, are rich in

modified starch, have large colonies of yeast cells and per-

haps lactic acid bacteria, and are found in small shallow

cups likely to have served as drinking vessels, in closed

vessels suitable for fermenting or storing beer or, in the

case of Predynastic installations, in large open vats used for

heating large quantities of processed cereal. The assump-

tion that residues with most of these features are indeed

associated with beer, rather than some other cereal food, is

based on the fact that beer was a staple food for the ancient

Egyptians. The interpretation of many cereal-based resi-
A rim sherd with a thin coating of beer residue (dark patches), from the Workmen’s Village, Amarna. The sherd comes from a long-necked amphora (Group 21, see Rose 1984: 155, 157), showing that beer containers could be those more conventionally thought to be for commodities such as wine or oil. This view shows the outer surface of the rim, with some fragments of chaff embedded in the residue. The typical cracked surface of such thin coatings can be seen in some areas. Sample TAVR32-36; scale bar is 1 cm.

Figure 22.5a Large irregular lumps of beer residue, now at the British Museum. They are composed mainly of coarsely shredded barley chaff, firmly stuck together with a dark orange-brown matrix.

Residues as beer-related is thus very likely but not absolutely proven.

No adequate survey of surviving residues has ever been carried out, but there may be hundreds in unwashed Egyptian pottery collections obtained from arid locations. Residues may derive from the finished product or the intermediate stages of brewing. Residues of finished beer are thin coatings with a few small fragments of cereal chaff or bran embedded in an orange-brown matte, or slightly shiny, crust of material, which is usually cracked over the surface (Fig. 22.5a). Intermediate products may look similar to the finished beer, or may be large masses of coarsely shredded chaff, sometimes with coarse pieces of grain, stuck together by thick or thin layers of matte or slightly shiny, orangey-brown matrix (Fig. 22.5b). In some cases, only the friable chaff is left, with very little or no obvious matrix binding it together.

Residues and loaves have been examined by a number of methods. Simple careful observation provides data on colour, texture and quantities of inclusions. For bread, information on shape, size, decoration and method of forming the loaf can be obtained. Ingredients can be identified based on the morphology of features on grain, seeds, chaff fragments and other plant parts and their comparison to modern known plants. Often, though, fragments are so small or abraded that there are not enough features with which to make identifications. In these cases, the anatomical pattern of cells making up the tissues may be useful. Shreds of tissue are carefully removed from the specimen, gently cleaned with alcohol and a fine brush, and the cells may be usefully highlighted with appropriate general stains such as safranin and fast green (Gurr 1953: 205; Jensen 1962). They are then identified by reference to modern tissue mounts from known plants and plant parts (for similar identification techniques see for example Dickson 1987; Hansson 1996; Hansson and Isaksson 1994; Hjelmqvist 1984; 1990; Holden 1986; Körber-Grohne and Piening 1980).

The light microscope allows observation of components such as starch granules, yeast cells and plant tissue (Griss 1928, 1929a–c). Several crumbs of specimen (from 0.5 to 1 millimetres or more in diameter) are crushed on a glass slide, mounted in a drop of water, covered with a cover slip and observed at magnifications of 100 up to 400 times. Polarised light helps to determine whether the ancient starch has been affected by heat, through the presence or absence of birefringence (French 1973: 1054–5; Goering et al. 1974). Appropriate stains can enhance the features viewed with the microscope.

Specimen crumbs can also be embedded in plastic resin and sliced into sections 1–7 µm thick. These are placed onto slides and stained with a variety of stains which can target starch, protein, lipid and other biomolecular components. The structures of starch granules and tissues, and their relationships to each other, can thus be accurately observed.

A highly informative technique to investigate the microstructure of beer residues and bread has been scanning electron microscopy (SEM) (Samuel 1994b, 1996b; 1996c; Samuel and Bolt 1995). Several tiny crumbs from each specimen (from 0.1 to 1 millimetres or more in diameter) are removed and mounted on stubs with double-sided sticky tape. Each stub is then coated with about 20–30 nanometres of gold or gold palladium, to permit conductivity of electrons in the microscope. No further preparation is required, because the material is already completely desiccated. Apart from coating the ancient material with a thin...
metal layer. SEM is non-destructive. With careful storage, the mounted samples can be archived and re-examined as often as required.

**Archaeobotanical recovery and analysis**

As Murray (Chapter 21, this volume) has stressed, archaeobotanical recovery and analysis is essential for the accurate understanding of plant resources. At sites where remains are preserved by desiccation, the rare opportunity exists to investigate primary deposition (the places where plant remains were dropped as they were being used) and therefore to locate specific activity areas within constructed spaces. By itself, the function of, for example, an isolated oven or milling stone is difficult to interpret. Set in the surroundings in which it was used, and in relation to other equipment, detailed information can be gathered about cereal-processing methods. The plant remains associated with cereal-processing areas are also invaluable evidence for the reconstruction process. For example, the full assemblage of shredded chaff and whole spikelets lying on the floor of an ancient village house, adjacent to a mortar, has not only allowed the archaeological link to be made between mortars and pounding whole spikelets, but has also provided clues about how the spikelets were pounded, based on the appearance of the shredded chaff (Samuel 1989: 280, 1994a: 117–18).

Some microscopy (e.g. Hallam 1973: 140–1; Palmer 1995; Whymper 1913a) and chemical studies (Barton-Wright et al. 1944; Shewry et al. 1982; Whymper 1913b) have been made of desiccated Egyptian cereal grain. This work has shown that although raw grain microstructure is remarkably well-preserved, profound biochemical changes have occurred over time. Because DNA and proteins have been badly damaged over the passage of time, it is impossible for desiccated ancient Egyptian grain to germinate now, despite its excellent outward appearance.

In damp areas, in the river flood plain, only charred plant material will survive. Most of this will not be deposited in the area where charred remains were first generated, but was moved in ancient times to rubbish deposits, scattered on floors or other secondary areas. Careful recovery of charred material nevertheless can provide valuable information about ancient foodstuffs, such as the raw ingredients and their distributions.

**Ethnographic analogy**

Murray (Chapter 21, this volume) has emphasised the importance of ethnographic information about the traditional use of plants. This extends to the study of food processing, although less ethnoarchaeological work on food preparation has been done compared to post-harvest cereal processing up until storage. Preservation, recovery and recording of archaeological and bioarchaeological remains may be excellent, but the interpretation of food processing may be inaccurate if the sequence of activities linking ingredients and tools unfamiliar to the archaeologist is not understood. Traditional methods of preparing foods can only be observed amongst people who still use tools and materials similar to those found archaeologically.

Geographical proximity of ancient and modern cultures is not necessarily an appropriate criterion. In Egypt, for example, the type of oven used today (Rizqallah and Rizqallah 1978) is of very different construction to the cylindrical form used by the New Kingdom Egyptians (Währen 1960: 92). The sole use of geographical proximity as a measure of similarity ignores potential cultural changes that can occur, either as a result of indigenous development, or through new cultures introducing new techniques.

Appropriate ethnographic analogy for ancient cereal food processing involves the same or similar tools and raw materials. This can only be established by careful reference to both archaeological and ethnographic evidence. It requires an understanding of the biology and physical structure of the raw ingredients as well as the end results of specific processing methods. The ethnographic analogies used here are those which involve the same type of tools and installations as those found in the ancient Egyptian archaeological record, or which relate to cereals of the same species or structure as the hulled cereals of ancient Egypt.

**Experimental reconstruction**

Experimentation is valuable to test hypotheses about ancient processes which have been developed from detailed archaeological analysis and carefully selected ethnographic analogies. It can indicate gaps, demonstrate what is impractical, and provide greater insights into specific processing technologies. Experiments must be designed and carried out with great care in order to be valid, making use of all available archaeological, ethnographic and ethnobotanical data. Methods and equipment must be justifiable on the basis of both archaeobotanical and ethnographic evidence. It is best to use authentic ancient or modern materials if possible. With care, experimentation can be an excellent direct method of assessing and experiencing the results of specific processing activities with the tools and ingredients used in ancient times.

For ancient Egyptian baking and brewing, detailed experiments have been undertaken for producing flour from cereals taken from storage (Samuel 1989: 264–70, 1993; 1994a: 143–66). Some work has been done on baking, but authentic experimental brewing has yet to be carried out. Wherever possible, ancient tools have been used. If these were not sufficiently robust, replicas were constructed with direct reference to the ancient originals, as were installations such as ovens. For steps with no clear indication of the relevant ancient tools, models were taken from appropriate ethnographic analogies. All bread-making experiments...
were carried out with modern emmer wheat, the cereal which has been found in much of the ancient Egyptians' surviving bread.

Raw materials

Bread requires two essential ingredients: flour, usually from some type of cereal or other starchy food, and water. Leaven is frequently assumed to have been used for baking in ancient Egyptian times, but is an optional bread ingredient. Beer is made from cereal grain, fermenting micro-organisms and water. Extra flavourings can be used for both bread and beer. In the following section, only cereals and leavening will be discussed. Additives will be dealt with separately in the sections on beer and bread. The supply of water is a separate technology which cannot be dealt with here.

Cereals

Murray (Chapter 21, and Fig. 21.1, this volume) describes emmer wheat and barley, the two cereals cultivated by the ancient Egyptians, and their hulled nature which requires extensive processing to obtain clean grain. As Murray explains, there is good evidence to show that emmer and barley grain were stored still hulled, that is, still packaged in a tight envelope of chaff (the 'spikelet' of emmer wheat). Both barley and wheat chaff must be removed during human food processing otherwise the huge amount of coarse roughage introduced into the digestive tract prevents absorption of nutrients (Miles et al. 1988; Schweizer and Würsch 1991: 184–5). The extra processing needed to remove chaff is an important distinguishing characteristic of hulled cereals. The wheat used for most bread and pasta today easily breaks up into naked grain and loose chaff when threshed, and only requires the type of sieving and winnowing described by Murray to separate the two fractions.

Cereals are staples for agricultural societies in temperate zones throughout the world (Zohary and Hopf 1993: 15). Their primary contribution to diet is food energy, although they are also important for vitamins and minerals as well as protein (Ranhotra 1991). Cereals, like all other plant foods, lack some essential components for human health, and cannot on their own provide a balanced protein intake. Food energy is supplied by starch, which makes up 69–79 per cent of the cereal grain (Ranhotra 1991: 850).

Starch is composed of two long molecules, the building block of which is the simple sugar glucose. These long molecules must be broken into much shorter chains in order for cereal products to be digested or fermented. Whole starch is stored within the grain in the form of lens-shaped or spherical granules, embedded in a protein matrix (Fig. 22.8a). The outer part of the grain is composed of several layers of tissue, collectively known as the bran, in which much of the vitamin and mineral content is concentrated (Fig. 22.6). At one end of the grain is the embryo which, when exposed to adequate conditions of warmth and moisture, will germinate and develop into a new plant. Concentrated in the embryo and the tissues surrounding it are vitamins, minerals, and much of the fat content of the cereal grain (Angold 1984; Barnes 1989: 374–9; Bradbury et al. 1956: 334, 336; Mattern 1991: 15–19; Winton and Winton 1932: 190–201).

**Fermentation agents**

*What is fermentation?*

All cells need to generate energy for activity and growth. Many cells, be they unicellular organisms or part of a complex creature such as a wheat plant or a human being,
do this by a complex biochemical pathway which requires oxygen. Fermentation, also known as anaerobic respiration (Raven et al. 1981: 94), is the chemical pathway by which some cells are able to provide themselves with energy in the absence of oxygen. Without oxygen, the cellular production of energy is much less efficient. The precise chemical pathways of fermentation vary according to cell type, and alcohol is not always an end-product. As with respiration in the presence of oxygen, a major product is carbon dioxide (Raven et al. 1981: 94). This gas produces the effervescent or spongy quality of fermented foods.

Alcoholic or ethanol fermentation is the anaerobic respiration process used by the yeasts (Berry 1982: 10–11). In this system, one of the main products is ethanol. The effects of alcohol on human beings are well-known: in moderate quantities alcohol produces a pleasant sensation, in larger amounts it has adverse effects on the body and over the long term, large intake is fatal (Duffy 1992; Hurley and Horowitz 1990). For food preparation, alcohol can be advantageous for preservation and storage by improving keeping qualities. Alcohol is a poisonous substance, at greater or lesser concentrations, for all living things. As yeast cells produce alcohol, to which they have a degree of tolerance, they create an environment toxic to many other bacteria and fungi, preventing food-spoilage organisms from flourishing (Wood and Hodge 1985: 265).

A group of food micro-organisms associated with many cereal products is lactic acid bacteria, of which there are many species. One of their main fermentation by-products is lactic acid (Prithoda et al. 1993: 31; Steinkraus 1985: 337–8). The sour taste can be very pleasant and refreshing if carefully controlled, as in sour dough bread. The build-up of lactic acid creates an acidic environment, which many food spoilage micro-organisms cannot tolerate. Thus, lactic acid fermentation also helps to preserve foods (Cooke et al. 1987; Holzapfel et al. 1995; Steinkraus 1985: 338).

Both yeast and lactic acid bacteria use simple sugars for their nutrition. Yeast prefers glucose but can use a range of sugars (Brown 1993: 67; van Dam 1986: 122), while many lactic acid bacteria grow on maltose and other complex sugars (Ponte and Reed 1982: 284). Both may also require a range of other nutrients such as certain vitamins and minerals (Berry 1982: 10). When long chains of starch are broken down in the cereal grain during growth or food processing, large quantities of sugars such as glucose and maltose are released (French 1973: 1056; Palmer 1989: 179). These are suitable for both yeast and lactic acid bacteria growth. In many modern commercial baking and brewing systems, manufacturers try to keep very pure yeast cultures and avoid lactic acid bacteria. There are exceptions, such as San Francisco sour dough bread (Sugihara 1985: 251–4) and Belgian lambic beers (De Keersmaecker 1996). Prior to the introduction of large-scale controlled conditions in industrialised times, however, yeasts and lactic acid bacteria were both present in baking and brewing substrates in varying proportions (Sugihara 1985: 249; Wood and Hodge 1985: 280).

Yeast

Morphological characteristics do not give enough information to identify the species of micro-organisms which were used by the ancient Egyptians for baking and brewing. Grüss (1920a) named the yeast he detected in New Kingdom beer residues as a new species, Saccharomyces winlockii, in honour of Herbert Winlock, who excavated the vessel in which the cells were found (Winlock 1932: 32). Unfortunately, the contention that the ancient yeast truly is a species new to science cannot be sustained from the only available evidence, the appearance of the yeast.

The identification of yeasts is based on three major approaches (Déék 1991: 180–3). One is morphology, which includes shape, size, method of budding and other characteristics. Since many yeast species look very similar or exactly the same, the second approach (i.e. the differences in physiology and biochemistry) is essential for identification. Physiological studies involve establishing which particular nutrients must be available for survival, compared to nutrients which need not be present for the yeast species to thrive. This information cannot be obtained for the ancient yeast cells, which are dead, and therefore their precise identity cannot be established this way. Biochemical analysis is highly problematic for ancient degraded biomolecules.

The third approach – the use of genetic analysis through the examination of DNA and RNA – is now very important in the field of yeast taxonomy. In the future it may be possible to obtain more information about ancient yeast species through DNA studies as well. Three major requirements must first be met, however. Most importantly, since modern yeast cells are ubiquitous in the air and on all surfaces, the most stringent conditions of cleanliness and sterility must be maintained. Otherwise it will be modern micro-organism DNA which is isolated and analysed. In order to be able to interpret any results from ancient DNA analysis, the genetic code of modern yeast species must be known. Work is actively proceeding on yeast genetics (Déék 1991: 181) but much remains to be done. Finally, sufficient amounts of ancient yeast DNA, preserved in lengths which encode useable information, must be recoverable from the ancient residues.

Some authors have suggested that the ancient Egyptians scooped off the yeasty froth from the surface of actively fermenting beer, and used this to leave their bread (Kemp 1989: 120; Wilson 1989: 97). This is possible, but was not necessarily the case. The same species of yeast will change its metabolic activity depending on its environment, but does not adjust quickly. In high sugar concentrations, such as in fermenting beer, yeast behaves anaerobically even if oxygen is present. In low sugar conditions, as in bread made from ordinary cereal flour, yeast switches to aerobic
metabolism (Berry 1982: 11; Hough 1991: 115–18). Brown (1982: 58) comments that it was not until after AD 1700 in Europe that yeast from beer was used to leaven bread, but the technique was not reliable and often made the bread bitter.

Lactic acid bacteria

Only in a few samples of ancient beer have colonies of bacteria been observed. Each bacteria cell is about one micron (one thousandth of a millimetre) in length and usually rod-shaped. When present, they tend to occur in enormous numbers. Sometimes, however, only a few individual cells can be seen, usually in close association with yeast cells. Lactic acid bacteria are commonly associated with yeasts and are often part of fermented cereal foods (Nout and Rombouts 1992: 130S, 141S; Wood and Hodge 1988). Thus, the close association of these ancient bacteria with yeast in a cereal food, their abundance, their shape, their close association with the sample matrix and the usual lack of other types of micro-organisms, all suggest that the small rod shapes are lactic acid bacteria.

No micro-organisms which match lactic acid bacteria in appearance have been observed in ancient bread loaves. Techniques appropriate for the identification of low quantities of minute cells must be developed and applied to samples of ancient desiccated bread before it can be established whether lactic acid bacteria were present in ancient Egyptian loaves as part of their preparation.

Beer brewing

Ingredients

Desiccated residues of ancient beer provide the most direct evidence for ingredients used in ancient Egyptian brewing. The following discussion of ingredients is largely based on analysis of residues, mostly dating to the New Kingdom.

Cereals

Most residues so far studied come from the two workmen’s villages of Amarna and Deir el-Medina. They therefore reflect brewing practice of one particular stratum of society. From the evidence of these residues, in New Kingdom times barley appears to be most frequently used for village brewing, while emmer was sometimes used. Occasionally, other cereals were mixed in more or less equal proportions. However, both cultivated cereals were used for brewing but ale may have been more common for beer. These residues are too limited to conclude that the pattern holds for New Kingdom artisan-class domestic brewing in general, yet cannot yet be extrapolated to New Kingdom society as a whole. Further work on residues from other archaeological sites should help to clarify the question.

Grieco (1929a, 1929b, 1929c) identified only emmer in a range of New Kingdom beer residues. His published drawings, although definitely of cereal tissue, are unfortunately undiagnostic and cannot be assigned either to emmer or to barley.

The use of the two cereals and the proportions in which they were mixed may have been characteristic whereby the ancient Egyptians distinguished and named different types of beers. The flavour and character of modern wheat beers, primarily produced in southern Germany, but in other northern European regions as well (Jackson 1993: 49), are distinct from barley-based beers. According to Jackson (1993: 48), modern wheat beers tend to be more thirst-quenching and tart in flavour.

Fermentation micro-organisms

Yeast was certainly a key fermentation agent in ancient Egyptian beer. Many thin-crust residues, deriving from the finished beer product, contain large colonies of yeast cells. Cells have sometimes been preserved in the act of budding, showing that these colonies were in an active state of growth at the time they were desiccated. Individual ancient yeast cells are recognisable by distinctive bud scars (Fig. 22.7).

A number of features indicate that yeast cells in the ancient residues are original ingredients of beer and not chance contamination. The cells are of generally uniform appearance, both within individual residues and amongst all residues so far examined. Residues which contain yeast usually have many cells embedded in the residue matrix, not individual cells deposited loosely on the surface. Finally, budding cells, and therefore active growth, show there were abundant nutrients and sufficient moisture to support yeast metabolism for a fairly extensive period of time, up until the residues dried out completely. This would not have happened if, when discarded, the thin deposits on broken potsherds did not already contain yeast. They would have dried out too rapidly to allow large colonies of active cells to be established from chance contamination.

Bacteria, possibly lactic acid bacteria, have been detected with SEM in some beer residues. Lactic acid fermentation can impart a refreshing acidic flavour to beer. In a hot climate, such a thirst-quenching flavour would be highly desirable. If lactic fermentation was indeed a feature of ancient Egyptian beer, it may have had some of the character and flavour of modern-day African beers, in which lactic fermentation plays an important role (Dirar 1993: 86–9; Odunfa 1985: 167; Platt 1964: 70–1). The extent to which lactic acid fermentation occurred in ancient Egyptian brewing is currently uncertain, however, because the very small size of the bacteria makes their consistent detection uncertain. Even when abundant, they can be difficult to observe.

If lactic acid bacteria are uncontrolled in food systems, there may be over-production of acids and other metabolites, which can cause overwhelming and distasteful flavours (Stear 1990: 505). It is thus possible that lactic acid bacteria were important for brewing but that most brews
did not contain huge amounts. If this was the case, the small size of the bacteria together with their relatively low density would make them difficult to locate in the ancient residues. The close association of lactic acid bacteria with yeast in traditional and spontaneously fermented cereal foods today does suggest that ancient Egyptian beers (and bread) were also fermented by yeast-lactic acid bacteria systems. Another possibility which cannot be ruled out is that residues with notably large colonies of bacteria are the remains of beer which were contaminated with undesirable micro-organisms, and therefore discarded.

Other ingredients

Apart from cereals, fermentation micro-organisms and water, there is at present little direct evidence for other ingredients in ancient Egyptian beer. No New Kingdom residues contain obvious large non-cereal plant fragments and most show no microscopic traces of non-cereal tissues. If plant flavourings were standard additions, it would be reasonable to expect that some fragments of tissue from such ingredients would be consistently present and detectable. If extracts and liquids or syrups were added, methods other than microscopy would be needed to identify them. Very little chemical analysis has been applied to ancient Egyptian food remains. Some beers may well have been flavoured with various additives, but the dearth of non-cereal fragments and tissues suggests that, at the New Kingdom workmen’s villages, beer was not normally flavoured with extra ingredients.

Unlike most modern European-style beers, the ancient Egyptians did not use hops. The wild hop plant has a northern temperate distribution, growing in latitudes of about 35°–70°N (Neve 1991: 1). (The Egyptian Mediterranean coast is roughly 31°30′N.) Although the modern character of European beers is strongly influenced by hops, in many regions this flavouring was not widespread for brewing until the nineteenth century AD (Neve 1991: 26–7). Other beers, such as traditional African brews (see, for example, Dirar 1993: 224–304; Odunfa 1985: 170–7; Platt 1964: 70–1; Rooney et al. 1986: 335–7), do not incorporate any flavourings, and there is no reason to suppose that additives must have been an integral part of ancient Egyptian beer.

A few residues do contain microscopic fragments of plant tissue which are not derived from cereals. Grüss (1992a: 278) located tissue fragments which he identified as *Citrus aurantium* L., sour orange. The identification is unlikely, however. Like other citrus fruit trees, the sour orange probably originates in south-east Asia (Zeven and De Wet 1982: 62; Zohary and Hopf 1993: 173). It does not seem to have been generally known to the Mediterranean world until after the medieval period (Zohary and Hopf 1993: 173). No other reliable archaeobotanical identifications of sour orange in Pharaonic Egypt have been substantiated (Germer 1985: 105; De Vartavan and Asensi Amorós 1997: 79). The anatomical structure of this particular tissue has been published by Grüss, and should be reassessed.

A few plant tissue fragments have been found in residues from the Workmen’s Village at Amarna and from Deir el-Medina. Their small size and rarity make identification difficult. Microscopy of a range of known modern and ancient plant tissues which may have been beer ingredients do not match anatomically most of the tissue fragments found in these residues. These comparative plants include date fruit (Phoenix dactylifera L.), dom fruit (*Hyphaene thebaica* (L.) Mart.), common fig (*Ficus carica* L.), sycomore fig (*Ficus sycomorus* L.), Christ’s thorn fruit (*Zizyphus spina-christi* (L.) Desf.) and coriander seed (*Coriandrum sativum* L.).
It has been reported that dates and grapes were identified in Predynastic brewing residues (Geller 1992a: 21; Makroud et al. 1994: 221; but on dates in beer see below and p. 556). No identification criteria for these fruits have been published. Other archaeobotanists who examined the residues distinguished only emmer grain and chaff and possibly a small amount of barley (Geller 1989: 37, 1992b: 110). Unfortunately, no comparable residues dating to periods between the Hierakonpolis remains and New Kingdom material have yet been examined.

**Dates**

Date fruits are widely thought to have been a main ingredient in ancient Egyptian beer (Faltings 1991: 110, 114; Helck 1971: 23, 32–3, 1975: 790). This is based on three strands of reasoning: the interpretation of the word ṣmrs as dates; the appearance of ṣmrs in two brewing scenes, those in a scene from the Sixth-Dynasty Saqqara tomb of Iynefert (now at Carlsruhe; see Faltings 1991: 110; Helck 1971: 29; Viedemann and Pörnter 1960: 26–30, pls. 4–6) and in the eleventh-Dynasty tomb of Intefiquer (TT160; see Davies and Gardiner 1920: 14–16, pls. 8–9a, 11–12a; Faltings 1991: 10; Helck 1971: 33; Wreszinski 1923: pls. 217, 220, 221); and documents listing ṣmr amongst commodities associated with or used for making beer, such as the Moscow papyrusical Papyrus, Papyrus Bulag 18 and Papyrus Hurry 1326, amongst others (Helck 1971: 32–3; Nims 1958: alinger 1988: 258; Struve 1930: Wild 1966: 98). The action of dates is thought to have been both for flavour, more importantly, to add sufficient sugar to the mash for fermentation to take place (Darby et al. 1977: 547; Faltis 1991: 110; Geller 1992a: 131; Lucas and Harris 1962: Montet 1925: 250).

The tomb inscriptions may not refer to date fruits at all. There is some controversy about their meaning. Wild (1966: 97, n. 2), for example, suggests that in the tomb of Iynefert at Saqqara the word may not be related to activities but may be part of servants’ names.

The archaeobotanical record does not support the widespread use of dates as a standard ingredient in ancient Egyptian beer. In particular in the earlier periods. If dates were always added to this staple food, there should be vast quantities of the highly durable, easily identifiable, large date stones produced as a by-product of brewing. Despite large gaps in the archaeobotanical record, on current evidence this is not the case. Far from the ‘countless’ finds of dates claimed by Darby et al. (1977: 724), the fruit and stones of the date prior to and throughout the Pharaonic period have been found in remarkably low numbers compared to other food resources, as demonstrated by Murray’s tabulation in Chapter 24, this volume (see also de Vartavan and Asensi Amorós 1997: 193–9).

The low frequency of date stones in the Pharaonic period is particularly obvious at the site of Amarna. Here, systematic archaeobotanical recovery has been applied both to the New Kingdom Workmen’s Village and to more recent excavations of a Late Antique monastery. Preservation is mainly by desiccation in both areas and therefore the archaeobotanical assemblages are directly comparable.

As a case study for food preparation in the New Kingdom, the Workmen’s Village at Amarna was certainly an anomalous community, planned and supported by the state (Kemp 1987b: 43). Nevertheless, beer residues which have been recovered there, together with the tools for processing cereals and the enormous quantities of cereal chaff found in the village middens, indicate that the villagers prepared their own cereal foods, including beer. Plant remains have been recovered from across the site, in village houses, rubbish dumps, chapels and animal pens. Date stones were reasonably frequently found across the site, but were much less common than remains of dom palm fruits (Renfrew 1985: 184: and author’s unpublished data). The evidence suggests that dates were certainly eaten but not in great abundance.

At the time of writing, analysis of the plant remains from the Amarna monastery is on-going. Preliminary results by Wendy Smith (pers. comm.) show that food plants make up an important part of the recovered remains. In sharp contrast to the Workmen’s Village assemblage, at the Late Antique monastery date stones are ubiquitous, occur in large quantities, and have been recovered in caches of stones.

Examination of ancient and modern date fruit tissue using the SEM has shown that they do not match any of the tissues in the New Kingdom beer residues from either the Workmen’s Village at Amarna or Deir el-Medina. No pieces of date have been recovered from the large brewing masses rich in coarse chaff and grain fragments available from Deir el-Medina and elsewhere. If dates were a standard beer ingredient in New Kingdom times, fragments of fruit or
stone would certainly be expected in at least some of these residues. The suggested need for dates in beer processing is discussed further on p. 556.

Beer processing

At the beginning of this chapter, a general definition for beer was suggested: a fermented beverage made from starchy ingredients. It is clear from residues of beer that the ancient Egyptians brewed from both barley and emmer wheat. As discussed in the section on fermentation (pp. 555–6), to ferment cereal foods the complex starch in the grain must be broken down into simple sugars which are digestible by yeast and lactic acid bacteria, and in addition, these sugars must be made accessible. The grain must therefore be broken up in some way and mixed with water. These two basic transformations, modification of starch into sugars and break up of grain, are discussed in the following sections. In order to describe how cereals can be manipulated to achieve these changes, the modern commercial Western brewing process is first presented as an example of known processes producing known results. Next, the archaeological evidence is discussed and used to suggest how New Kingdom Egyptians made beer.

Modern malting

Modern commercial brewers use the natural process of grain germination to convert starch into fermentable sugars. Most beer today is made of barley, but the process can be applied to any cereal. When a grain is exposed to adequate moisture, a cascade of biochemical reactions is initiated (Esken 1990: 185–93; Palmer 1989: 93). Amongst these, enzymes stored mainly in the aleurone layer (Fig. 22.6) are released, and other enzymes are manufactured. Some of these break down the cell walls within the grain, while others degrade the protein matrix into amino acids (the building blocks of protein) and short amino acid chains. Another set of enzymes, called amylases, can then get access to the starch granules and cut up the long starch molecules. As the process continues, most of the starch is reduced to shorter molecules called dextrins, which in turn are mostly broken down into maltose and the simple sugar glucose, important for fermentation. In the normal sprouting grain, the amino acids and sugars are transported to the grain embryo. These nutrients are used by the young sprout until it is large enough to produce its own food by photosynthesis.

Brewers wish to maximise the quantity of sugars available to yeast by preventing the developing embryo from using up any nutrients. In practice, a small quantity is lost (Lewis and Young 1995: 36). Enzyme production is maximised by spraying the grain with carefully controlled levels of moisture, temperature and other conditions (Briggs 1978: 526; Lewis and Young 1995: 51–8). Cell walls and much of the protein matrix are broken down while the concentration of amylases within each grain is raised as much as possible (MacLeod 1979: 222). The extent of amylase attack does not proceed very far. Then, the newly emerging sprout is killed by drying, usually by the application of gentle heat (Lewis and Young 1995: 83). The result is malt: slightly germinated grain in which much of the cell walls separating components has been removed, and which is rich in enzymes, partially broken down proteins and largely intact starch granules.

If the microstructure of malt is compared to raw grain (Fig. 22.8), considerable changes are evident (Dronzek et al. 1972; Palmer 1972; Pomeranz 1972). The cell walls which are clearly seen in raw grain are mostly gone in malt, as is much of the protein matrix. Most importantly for the identification of processing, the appearance of some starch granules has altered. The early action of enzymes on the granules causes a typical pattern of surface pitting. Where enzyme attack has been able to proceed further, the pits penetrate deeply into the granule and begin to extend to make interior channels. Most starch granules, though, are untouched by enzymatic action. The malt is friable because of the loss of binding materials—the cell walls and protein—which held the original grain firmly together.

Modern cooking

To produce large quantities of fermentable sugars from malt, modern brewers use a cooking process (Hough 1991: 58). Coarse grinding breaks up the malt into grit, which is composed of medium-textured fragments and large shreds of sheared chaff. This increases the surface area of each malt fragment, allowing better penetration of water and therefore more even and complete conversion of starch into sugar. The grit is then mixed with hot water and is held at 60–65 °C for about two hours. During this period, complex structural and biochemical changes occur. In the presence of water and at temperatures above 50 °C or so, starch granules begin to imbibe water, swell up, bend and twist. Eventually, in large amounts of water they rupture, dispersing the long starch chains into solution. At the same time in these elevated temperatures, the activity of amylases increases dramatically. The enzymes rapidly attack the dispersed starch molecules and freely floating starch granules, and almost completely break down the starch.

The excess quantities of water and the rapid changes which occur make it difficult to obtain samples of starch for microscopic analysis. Controlled experiments, however, show how starch granules progressively swell, dimple, bend and twist when heated in the presence of moisture, before merging together and, if water is present in excess, dispersing into solution (French 1973: 1055; Greenwood 1979: 132; Hoseney et al. 1977). The progressive action of enzymes on whole starch granules has also been separately documented (Palmer 1989). The outer surface of the granule may appear unchanged, with only a few pits visible. Inside, however, enzymes hollow out the
pitting is also typical, because some granules are more resistant to pitting than others. The lack of different enzymes upon the grain components. Fragments of cell wall (W) remain, but most has gone. Much of the protein has been broken down. Many of the large starch granules are pitted over most of their surfaces (M), or along their narrow edges (N). Some pitting is visible on the small starch granules (S), but this is less extensive than that of the large granules. The lack of uniform starch pitting is also typical, because some granules are more resistant to enzyme attack than others.

Figure 21.8a Scanning electron micrograph of the starchy endosperm of a modern emmer grain. Large disk-shaped starch granules (L) and small spherical starch granules (S) are embedded in a protein matrix (P). These are contained within long cells: some cell walls (W) are visible here. Scale bar is 10 microns.

Figure 21.8b Scanning electron micrograph of the starchy endosperm of a modern emmer grain which has been sprouted for 48 hours. In the lower left corner, part of the aleurone (A) layer can be seen. The marked changes which have occurred in the starchy endosperm – compare to raw grain, Fig. 21.8a – are typical for sprouted grain, and are caused by the action of different enzymes upon the grain components. Fragments of cell wall (W) remain, but most has gone. Much of the protein has been broken down. Many of the large starch granules are pitted over most of their surfaces (M), or along their narrow edges (N). Some pitting is visible on the small starch granules (S), but this is less extensive than that of the large granules. The lack of uniform starch pitting is also typical, because some granules are more resistant to enzyme attack than others.

granule in concentric layers until only a shell may remain. These interior concentric layers are highly distinctive.

Once most of the starch is converted into simple sugars by enzyme action, the temperature of the water is elevated still further to increase enzyme activity to the maximum, but in doing this, the enzymes are destroyed. Next, the cooked grist is usually transferred to another vessel, well stirred and the liquid drained off, naturally filtered by the shredded chaff. The liquid is called wort and is rich in maltose and glucose, amino acids and a complex mixture of flavour compounds from the cooked malt (Hough 1991: 93). Hops are added to the wort, the liquid is boiled and sterilised, and after cooling, yeast is mixed in and fermentation begins. From making grist to adding yeast, the brewing process normally takes a few hours. Fermentation proceeds over a few days, during which the yeast grows and gradually uses up the sugars, converting them to alcohol.

Ancient malting

Almost all the residues which have been examined using microscopy are very rich in starch. These residues include both large chaffy masses and thin coatings of residues from the two workmen’s villages (Samuel 1956b, 1966c), as well as beer remains from wealthy Theban tombs (Gruss 1929a, 1929b, 1933c). The starch granules range from being slightly pitted to heavily pitted to completely hollow (Fig. 22.7). The pitting and channelling matches precisely the pattern observed in modern malt and malt-based foods. These observations of starch in many ancient beer remains leads to the conclusion that New Kingdom Egyptians certainly used malt for brewing.

The evidence for use of malt is borne out by a few archaeobotanical finds from rubbish deposits at the Amarna Workmen’s Village (Fig. 22.9). One barley grain with delicate rootlets has been recovered. Two emmer grains were somewhat shrivelled, with deep furrows running along their backs. Such furrows are caused by the young shoot, which pushes between the tightly enclosing chaff and the soft, moist grain. Accidental germination of grain while the cereal crop is growing in the field can occur in moist climates (Barnes 1989: 384, 389; Derera 1989; Meredith 1983). This can be ruled out for Egypt though, where the climate is too dry to allow grain to sprout in the ear. Ancient Egyptians would not have chosen to build their granaries on flood-prone land, so germination in store is highly unlikely. The sprouted grains at Amarna must have been exposed to plenty of moisture. The length of the rootlets and shoot furrows shows that this exposure must have been for a considerable period (i.e. at least three to four days). The only process which fits this evidence is deliberate malting.

It is not surprising that sprouted grains have not been found before in the archaeological record. Rootlets are delicate, very easily broken off and destroyed. The lack of sprouted grain in tombs only indicates that raw grain rather
indeed malt cannot be confirmed. It is clear, however, that malt was a very important component of beer and it seems certain the Egyptians would have named it.

Since malt is produced from living grain, it must have been made from viable, intact and uncooked cereal. Malting would therefore have been an early step in the brewing process. The biology of barley and emmer shows that malting must have been done in the husk. The tightly adhering chaff of barley and the tough chaff of emmer make the husks difficult to remove (see Chapter 21, this volume). Large-scale dehusking treatment would damage the grain, particularly the vulnerable embryo. Without the embryo, the biochemical changes in the grain triggered by exposure to moisture will not take place. The deep furrows in the ancient sprouted emmer grains were caused by compression of the sprouts as they grew. Without the closely enfolding, rigid chaff, the elongating sprout would have curled away from the back of the grain. The observed morphology of the sprouted Amarna grains confirms that the chaff must still have been in place during germination.

It is difficult to estimate how long the ancient Egyptian malting process took, because the precise regimes of temperature, moisture, stirring, grain depth and other relevant factors (Palmer 1989: 129) are unknown. Also, little is known about emmer malting. Malt is best produced in shallow layers with good air flow. This encourages grain respiration and stops mould (Hough 1991: 21). Thin layers which are regularly turned prevent rootlets tangling and stimulate even germination. At least three days were probably needed to initiate germination in barley and perhaps a day or two longer for emmer, since the thick chaff would act as a barrier between water and the grain inside. If the length of rootlets and shoots observable on the germinated grains from Amarna are a good guide to general practice, then barley may have been sproted from five to seven days and emmer from six to eight days.

The available evidence shows that, whatever the precise treatment, malting was a considerable investment in time and required adequate space to produce enough for the large quantities of beer brewed in ancient Egypt. Malt may have been made by being laid out on mats, in wide shallow bins or in shallow ceramic or wooden vats. Wild (1966: 101) suggests that malting took place in big jars placed on their sides; Ian Forrest of Scottish and Newcastle Breweries (pers. comm.) has described how this could be an efficient malting method. The side-turned jar would create a larger surface area on which to spread a layer of grain. The jar could then be regularly rolled to aerate the grain and prevent the roots tangling. If the grain was to be soaked in water, the jar could be turned upright again. Ian Forrest pointed out that such a system would allow evaporation through the porous ceramic fabric, and that this would help to maintain an even temperature, at a somewhat lower than ambient level.

A further advantage would be that, although damp...
sticky at this stage, the malt would have been easily handled and kept reasonably clean. Such a method would have been suitable for both large-scale and small household production, simply by varying the size and quantity of ceramic vessels in use. If this was indeed the ancient Egyptian system of malt production, it would be difficult to distinguish in the archaeological record, unless distinctive wear patterns were formed on the sides of large ceramic vessels.

As Wild (1966: 101) points out, such a side-turned big jar, into which a man is stretching his hand, may be seen in the baking and brewing scene depicted in the tomb of Ty at Saqqara (Épron and Daumas 1939: pl. 70, top right). The man with jar is accompanied by an inscription but unfortunately it has been damaged and the verb is missing (Montet 1925: 247). Two Middle Kingdom tomb models from Beni Hasan show large vessels which could well be malting jars. A model from the tomb of Nefery (BH16) shows a line of six jars lying on their sides in front of three brewers (Garstang 1907; 73, 76, figs. 61, 62; Wild 1966: 109). Even more convincing are two jars set at a slant with mesh clearly depicted covering their mouths (Garstang 1907: 94). In a model from the tomb of Khnumnakht (BH385). Wild (1966: 101, pl. 11) suggests that two baskets shown in a scene in the Eighteenth-Dynasty Theban tomb of Kenamun (TT93; Davies 1930: 51, pls. 7, 58; Wreszinski 1936: pl. 301) may also contain malt, although there is no accompanying inscription. Drawing a parallel with the side-turned jar in the tomb of Ty, he suggests a tilted jar below these baskets, into which a man is reaching, may also have served to produce malt. If these suggestions are correct, it indicates that the malting method remained essentially unchanged throughout much of Pharaonic history.

Until now, no malting installations have been recognised in the archaeological record. In smaller households, malting may have had no special equipment nor dedicated area. With the knowledge that malt was a major component of beer, it may now be possible to identify specific malting areas, if they existed, in larger households and in state breweries.

Although the precise details of malt production remain to be clarified, some comments can be made about the malt itself. The quality of malt from barley and emmer wheat would have been about the same. Modern comparative analyses show that free-threshing wheat malt matches barley malt in quality, including diastatic power, a crude measure of enzyme levels and activity (Briggs et al. 1981: 136, able 5.9). Singh et al. (1983) successfully malted emmer with good diastatic power and enzyme levels. An experiment with emmer wheat created a malt which matched well with barley in most respects (Samuel and Bolt 1995: 30). Its diastatic power was relatively low, but this was partly due to a much larger proportion of husk material. The good quality of the enzyme activity was demonstrated by the strong beer (5 per cent alcohol by volume) which was successfully reved using a 1:1 mixture of this emmer malt and unmalled emmer. The beer was Tutankhamun Ale, made by Scottish Courage Brewers in 1996 to replicate ancient Egyptian brewing based on recent archaeological research.

**Milling**

Sprouting grain produces a packet of active enzymes and starch granules. The enzymes require water for their activity. The best way to allow enzymes good access to starch is to grind the malt into gist and then to mix the gist with water. By breaking up the grain, enzymes and starch can be released into solution, where the starch will be transformed into sugars, at a rate dependent on temperature.

There is good evidence that the ancient Egyptians milled their malt. The large fragments of grain and coarse shreds of husk in the loose chafly residues were produced by a shearing rather than a crushing action. The friability of the malted grain would not have withstood pounding in a mortar without being reduced to fine particles before the chaff was appreciably affected. Therefore, the malt must have been broken up by grinding on a saddle quern. This stage must have been rapid, with each batch subjected to only a few stokes, for the chaffy residues have a very coarse texture.

**Batch mixing**

The evidence from the residues shows that ancient Egyptian brewing was different from that of modern commercial Western brewing. Many residues contain starch which has been so extensively modified that it is completely merged together, often losing any trace of individual granule boundaries. To cause this complete fusion, the coarsely milled grain or malt must have been well-heated in ample amounts of water. The evidence suggests this stage may have involved heating a thick porridge or gruel-like mass of broken grain and shredded chaff. Such a mixture would contain both fused and completely ruptured granules but few undistorted or partially distorted granules. The amounts of relatively unaffected granules produced with this procedure would depend on the length of heating and extent of mixing.

In the same ancient residues which contain fused, glassy-looking starch, there are starch granules which, whether pitted or unaffected by enzymes, are completely undistorted by heat. They sometimes even retain the little indentations on their surface caused by tight packing within the starchy endosperm. These granules are often adjacent to, or even embedded in, the fused starch (Fig. 22.10). In beer residues, partially distorted starch granules are quite rare.

There are two possible processing treatments which can explain the extreme classes of microstructure, unaffected and completely fused starch, in the residues. The ancient Egyptian brewing process may have involved both processes. The first feasible reason is that cereal may have been treated inefficiently so that during cooking, some starch
much more susceptible to enzyme attack (Hough 1991: 58). The starch, however, would contain very little amylase in any case. Sprouted, there would have been little amylase in any case. The evidence fits an alternative interpretation, however. The evidence fits an alternative interpretation, however. The evidence fits an alternative interpretation, however. The evidence fits an alternative interpretation, however.

was completely fused while other granules were insulated from heat or water and were therefore unaffected. This is supported by some SEM views of residue microstructure, where there is a sharp transition between fused glassy starch and granules which completely retain their individual boundaries (Samuel 1996b: 9, fig. 7). The coarse texture of the large chaffy masses indicates that some granules were probably protected from water penetration and heat in the core of the grain fragments.

The very large quantities of fused starch, in which individual, undistorted starch granules are embedded, fits an alternative interpretation, however. The evidence fits well with the preparation of mixtures of two separately treated batches of grain (see Fig. 22.2). Some grain, perhaps all grain, destined for beer was malted. It appears that not all this malt was cooked; some was coarsely ground and set aside. It was then mixed with a batch of grain which had been well-cooked.

Although the ancient Egyptians would not have been aware of the biochemical basis for the success of such a method, this procedure is a very good way of converting starch to sugars without precise controls on volumes of ingredients and temperature. The batch of heated grain would contain very little amylase, because cooking would have destroyed the enzymes. If the cooked cereal was unsprouted, there would have been little amylase in any case. The starch, however, would be partially or completely dispersed out of the granules. Because the molecules of starch were no longer tightly packed together, they would be much more susceptible to enzyme attack (Hough 1991: 58). The malt which was not heated, but only coarsely ground, would have all its amylases and other enzymes intact, with some of the starch granules just beginning to be affected by enzyme attack. Once mixed together in water, the amylases from the uncooked malt would rapidly and effectively attack and chemically cut up into sugars the dispersed starch from the heated grain. Attack would also proceed on the starch from the uncooked malt, but this would be much slower. Just as in the cooked malt, some starch would not be pitted at all, because it would be protected from enzyme breakdown within the larger fragments of grain produced during coarse milling. The result would be plenty of sugars available for yeast fermentation, but also starch which had not been affected by enzymes at all, or which had not been completely broken down.

The exact blending procedure used by the ancient Egyptians is difficult to define precisely. The cooked grain or malt and uncooked malt could not have been extensively heated during mixing or thereafter, otherwise there would be very few, if any, undistorted starch granules in the residues. If the fully cooked grain was added immediately after heating to the uncooked malt along with some water, the temperature of the whole mixture would probably have been warm enough to increase the rate of enzyme attack somewhat, without causing distortion of uncooked starch granules.

After mixing, the chaff was sieved out. The remains of brewed beer (i.e. thin, yeast-rich coatings) have only a few fine shreds of embedded chaff or bran. In contrast, since virtually none of the large chaffy masses with cracked grain fragments examined to date contains yeast, these could not be residues of the finished beer. These very chaffy, cereal-rich remains are well-explained as the material left in the sieve after the raw malt and cooked cereal had been mixed together.

Artistic depictions indicate the procedure. The cooked grain plus uncooked malt mixture was rinsed with water through a sieve into a large pottery vessel. This would wash through most of the soluble material and much of the free starch granules, while retaining most of the coarse chaff and large grain fragments. The squeezing stance of many depicted brewers suggests the effort made to remove as much water and soluble material as possible. The result was not bread loaves in the sieve as often suggested, but more-or-less fist-sized damp chaffy lumps.

For examples of models showing these little sausage-shaped chaffy masses around the edge of sieves see: the baking and brewing model from the Eleventh-Dynasty tomb of Meketra at Deir el-Bahari (Winlock 1955: 28–9, pl. 65 no. 5) now in the Metropolitan Museum of Art, New York (20.3.12); a model from the Sixth-Dynasty tomb of Niankhhepykhem at Meir (Borchardt 1897: 129, upper fig. no. 244, 152: 1911: 159, pl. 52.244) now in the Cairo Museum (CG244); and a model from the Twelfth-Dynasty tomb of Khety at Beni Hasan (BH366; see Bourriau 1958: 51).
That this squeezing method left behind fairly substantial quantities of palatable grain, starch and sugars is suggested by a scene from the Twelfth-Dynasty tomb of Intefiqer (TT160), in which a young child extends a bowl to the brewer working a mass over the sieve, and asks 'Give me some smt; I am hungry' (Davies and Gardiner 1920: 15). The scene suggests that the word smt might specify the chaffy mass produced at this stage. The large quantities of cooked grain left in many surviving chaffy residues bear out the idea that the first rinsing could leave behind a considerable quantity of edible cooked cereal. The cooked grain and malt may have given it a sweet caramel-like taste. At this stage, it would have contained no alcohol.

The cereal portion was likely to have been quite nutritious, but the large amounts of chaff would have made the whole mass indigestible (see p. 545). It may have been eaten, therefore, by chewing and sucking out the edible parts and spitting out the chewed fibrous debris. This is exactly analogous to the way that raw sugar cane is eaten as a snack in modern Egypt. Other fibrous foods are eaten like this in other parts of the world.

The liquid squeezed from the mixture of coarsely ground malt and cooked grain was the equivalent of modern wort. It would have been cloudy because it was full of suspended starch granules and small fragments of cereal tissue, as well as partially broken down starch and protein molecules. Amylases and other enzymes would still have been active, continuing to break down the starch, protein and other components into simple molecules.

One determinant of the strength of the beer would have been the quantity of water added at this stage. The more concentrated the sugar solution, the greater the final alcohol content would have been. If a strong beer was desired, limited water would have been used for rinsing, leaving relatively large quantities of whole and partially degraded starch behind. A weaker beer would have been made if more water was added. Perhaps warmed water was used to help rinse out as much starch and sugars as possible.

So rich in starch are some of the large chaffy residues that they would have been suitable for further rinsing to make a weaker beer. Such recycling was used in medieval and early modern English brewing, for example, to produce 'small beer', a thinner, less alcoholic beer (Sambrook 1996: 19–20). Recycling would explain some chaffy residues which have scarcely any starchy contents left; they may have been washed twice or even three times to make weaker beers. Documentary sources record beers of differing strength, although this relates to the quantity of starting material in relation to the volume of beer produced (e.g. Helck 1971: 43–52; 1975: 790–91; Kemp 1989: 124; Peet 1923: 2–21, 1931: 155–6).

In any case, the re-use of the first squeezings, either for other brews or for some other extraction of the residual pleasant-tasting cooked and malted starch, would explain some known aspects of smt. Some jar labels from Amarna excavated by Petrie and examined by Griffith (1894: 34. pl. 24 nos. 69, 70, pl. 25 no. 97) show that smt was stored. Indeed it could be used by the highest in the land: one inscription says 'good smt of the queen'. Gardiner (1947: 234, no. 563) points out that in written sources, smt is often associated with the adjective 'sweet', and that its determinative suggests the substance is grain-like or at least semisolid when dry. All these observations fit very well with the preserved chaffy masses. Together, the evidence explains very satisfactorily why such material was placed in tombs; it was apparently a valued foodstuff.

**Was bread a beer ingredient?**

Unlike most descriptions of ancient Egyptian brewing, which state that beer was made from lightly baked bread (Fig. 22.1a), the foregoing discussion does not include well-leavened bread as a beer precursor (Fig. 22.2). The evidence refuting the use of bread in brewing is the morphology of starch in the beer residues. If the large quantities of fused starch in the residues came from bread, the dough must have been very moist to allow such extensive merging. Also, baking temperatures would need to be relatively high and reasonably prolonged. In such conditions, very few if any undistorted granules would have survived, and such a regime would have killed any yeast cells or lactic acid bacteria. In the presence of adequate moisture, starch begins to fuse at 60–65°C (Banks and Greenwood 1975: 260; French 1973: 105), but yeast begins to die at temperatures as low as 40°C (Brown 1982: 71) and by about 67°C, all the key sugar-converting enzymes in yeast are damaged or destroyed (Stear 1990: 541; van Dam 1986: 127). Thus, active yeast could not be present in any loaves cooked to produce the well-fused starch seen in the desiccated beer residues.

On the other hand, if bread had been baked lightly enough to preserve the viability of yeast and to leave a proportion of starch granules morphologically unchanged, very little fused starch could have been produced. It is not possible to produce bread with large quantities of fused starch, some completely undistorted starch granules and hardly any partially twisted granules. Yet this combination is what is seen in the residues. As on p. 564, in the section on ancient Egyptian dough mixing, desiccated loaves contain many partially twisted granules. Bread of the sort placed in tombs was therefore not used for brewing either.

**Fermentation**

The stage at which the fermentation step occurred can be deduced by the presence or absence of yeast in different residues. Virtually all the large chaffy masses contain unfused starch granules with no signs of amylase attack, undistorted granules with pitted surfaces and some interior channelling, as well as fused starch, but they do not seem to contain any yeast cells. This is consistent with the interpre-
nation of this material as a mixture of cooked grain or malt with uncooked malt prior to fermentation. The high proportion of chaff shreds to grain fragments indicates that these residues are spent grain left from rinsing out the starch and sugars, while the lack of yeast indicates that fermentation took place later, in the resulting chaff-free but sugar- and amino acid-rich liquid.

There are a variety of possibilities for how fermentation was initiated, but no evidence has yet been found to suggest which is most likely. If the same vessels were always used for brewing and never washed, there would be plenty of the desirable yeasts and lactic acid bacteria left in the pores of the vessel walls to inoculate each new batch of 'wort'. This is common for traditional fermentation in many cultures (Dijen 1962: 31; Platt 1964: 71; Wood 1994: 271). The need for constant supplies of beer would have meant frequent brewing, maintaining the right environment to encourage the micro-organisms. Another common inoculation method in traditional fermentation systems is to keep back a portion of the last brew and add it to the fresh liquid (Brown 1962: 58; Odufa 1985: 171; Wood and Hodge 1985: 287). Again, this would provide a thriving population of desirable micro-organisms to begin growth and reproduction before any harmful microbes were able to get established. Leaving the vat of sugar-rich liquid open to the air would have allowed air-borne yeasts and bacteria to drop in, and could often have resulted in an acceptable brew. This technique is still used today to brew Belgian lambic beers (De Keersmaecker 1996). The method, however, is risky, since undesirable fungi, moulds and bacteria could also inoculate the liquid, producing an undrinkable result. Finally, a starter inoculum might have been prepared with ingredients which were rich in yeasts or likely to support active yeast growth, such as fruit whose skins often support a natural bloom of yeast cells. It is possible that inocula were freshly made for each batch of beer but these take time to prepare and are not always completely reliable sources of good fermentation micro-organisms. Given the quantities of beer required, it is likely that if used, such inocula were made from time to time as needed. All four methods may well have been applied under different circumstances and by different brewers.

The ecology of yeast-lactic acid bacteria systems is a subject of modern research and still fairly poorly understood (Wood and Hodge 1985: 287). Some systems evolve over time, with different species flourishing and then dying off as the metabolites of microbe activity change the acidity and available nutrients of the food (De Keersmaecker 1996: 60). Other systems are remarkably stable, the activities of the specific yeast and bacteria complementing each other to maintain good conditions for both, without allowing other, undesirable, species to thrive (Sugihara 1985: 251-3; Wood and Hodge 1985: 287). The nature of ancient Egyptian fermentation would, to some extent, depend on the ecology of the micro-organisms exploited, but there are no data available to draw any conclusions about this.

The type of fermentation and the species of micro-organisms involved would certainly have had an effect on the flavour of the beer. Lactic acid bacteria would have created a sharpness by fermenting sugars to lactic and other acids. This would be particularly desirable if other flavourings were not standard ingredients. Yeasts would have produced ethanol. Both micro-organisms generate other metabolites depending on the specific species and conditions (Brown 1993: 40; Prihoda et al. 1993: 31). Somewhat different fermentation systems may well have been maintained by individual brewers, and in different geographical areas. The characteristics which might have distinguished these systems cannot now be fully investigated. As biomolecular analysis of archaeological materials progresses, the chemical components of beer residues may help to reconstruct more precisely the details of fermentation.

Were dates necessary?

The putative role for dates in ancient Egyptian brewing can now be reassessed. There is strong evidence that malt was an integral and major ingredient of New Kingdom beer. The evidence for the production of amylases during cereal germination, and the subsequent action of these enzymes on the cooked and uncooked starch, shows that more than adequate quantities of sugar were produced for conversion by yeast cells into alcohol. Furthermore, the amino acids and other components of malt would provide further nutrients for the growth of yeast. The addition of dates, or any other fruit or sweetener, was not necessary for successful fermentation.

It is possible that dates were an occasional flavouring for special beers, but as discussed above (see p. 549), there is no evidence for the use of date fruits in any New Kingdom beer residues examined so far. The sweet taste of dates, combined with the sweetish maltly taste of the malted and cooked cereal, may not actually have been desirable in a beverage which was a staple and an important source of clean drinking liquid. A lightly acidic taste, possibly provided by lactic acid fermentation, was more likely to be refreshing and would have made the beer drinkable in large quantities. If inscriptions associated with brewing scenes in the Sixth-Dynasty tomb of 'Iynefert at Saqqara and of Intefiqer (TT60) of the Twelfth Dynasty at Thebes do indeed refer to date fruits (see p. 549), they may be references to the production of special, not everyday, beer, particularly as these depictions are from funerary contexts.

What of the interpretation of the word bnr? This is not the forum for a lexical investigation, and only a few comments can be made here. The word bnr has long been taken to mean date fruits; Waller (1962: 40-1) reviews the evidence for this. She relies heavily on textual evidence which indicates the commodity was edible, sweet and closely associated with the palm tree. Date fruits do indeed possess
These attributes. It is highly probable that the word did refer to dates, but given the unequivocally low frequency of archaeological date fruit and date stone remains, especially prior to the New Kingdom, this is likely to have been a secondary meaning. Wallis (1962: 44) herself states that the word also meant 'sweet' and so had more than one meaning.

It must be stressed that lack of date stones does not imply lack of the date tree in ancient Egypt. There is no doubt the date palm grew in ancient Egypt and just as today (Bircher 1935: 156–65), the date palm was an important resource for mastication, basketry and building materials (Bircher 1995: 24; Tackholm and Dirar 1950: 210, 225–36; see also Chapter 10, this volume).

A number of scholars have commented on the listing of barley together with other cereals, and due to its association with beer in mathematical problems, its apparent importance in brewing (e.g. Megally 1977: 229–30; Spalinger 1988; Wild 1966: 98). For these reasons, Gardiner (1947: 223) considered it might refer to some unknown sweet cereal, but ultimately rejected this possibility in favour of date fruits. This suggestion may deserve to be reassessed, however. Today, a wide variety of roasted malts are made for use in bitter stouts, sweet stouts, pale ales, lagers and these ingredients can be considered when thinking about the function of 'Bircher' 1995: 24; Spalinger 1988; Wild 1966: 98). For these reasons, Gardiner (1947: 223) considered it might refer to some unknown sweet cereal, but ultimately rejected this possibility in favour of date fruits. This suggestion may deserve to be reassessed, however. Today, a wide variety of roasted malts are made for use in bitter stouts, sweet stouts, pale ales, lagers and these ingredients can be considered when thinking about the function of these ingredients. Such roasted malts, ancient Egyptian brewing most closely resembles the production of merissa, a Sudanese fermented food beverage made of sorghum or millet, and summarises many of the recorded descriptions of merissa-making. This food involves three different grain treatments and complex processing and mixing. The production of good merissa depends on the skill and experience of the brewer. Similarly, the use of a two-part process by ancient Egyptians would have allowed for individual variations, skilful manipulation and the development of different flavoured according to the precise procedures applied. These suggested features of ancient brewing fit well with the sophistication of other ancient Egyptian techniques.

In summary, the evidence of the residues shows that ancient Egyptian brewing most closely resembles traditional sub-Saharan African methods. Modern Western brewing and traditional Nubian bouza-making are quite different techniques.

### Bread Baking

The following discussion of baking is divided into three parts. The available evidence for bread ingredients is first presented. Like beer, this relies heavily on the study of the well-preserved desiccated loaves themselves. Next, the removal of the chaff from whole spikelets and the production of flour is considered. As Murray has explained (Chapter 21, this volume), after the ancient Egyptians harvested their crops of barley and emmer wheat, the evidence indicates they were cleaned to separate out hulled grain which was then stored. To make bread, most of the chaff had to be removed from the grain in order to produce a dough which would stick together and to make a nutritious food (see p. 545). Finally, the baking stage is described. The evidence for the two phases of bread-making is wide-ranging and in addition to desiccated loaves, includes other classes of archaeological materials, ethnographic parallels and experimental replication.

#### Ingredients

**Cereals**

It is often stated that emmer wheat is poorly suited to bread-making (Meritz 1955: 71, Spur 1986: 11–12). In fact, although it is often suggested that emmer wheat is poorly suited to bread-making, this is not the case. It is well adapted to the conditions of the Nile Valley and has been shown to be a successful crop in ancient Egypt. The evidence from the archaeological record indicates that bread was a staple food in ancient Egypt, and the presence of emmer wheat in the residues suggests that it was widely cultivated. The evidence suggests that emmer wheat was used in ancient Egyptian bread-making, and its suitability for this purpose has been confirmed by modern archaeological studies. The ancient Egyptians were able to produce good quality bread using emmer wheat, and this was an important part of their diet.
able to conclude that these particular specimens were probably cells embedded in the crumb matrix. It is therefore reasonable to make them unrecognisable.

Some of the discussion about yeast, lactic acid bacteria, and inorganic compounds such as sodium bicarbonate, normally play three roles in bread-making. They create a porous, more easily masticated texture, they help develop dough gluten by moving the dough during rising, and they contribute desirable flavours (Brown 1982: 69). Since neither emmer wheat nor barley contain gluten-forming proteins, one of the modern functions of leaven, its dough mixing action, is not relevant to ancient Egyptian baking. Nevertheless, some porosity may be maintained. If yeast and lactic acid bacteria helped to leaven ancient Egyptian bread, they may have somewhat increased the loaf volume and enhanced taste and aroma, for example as sour dough does in modern wheat breads (Seibel and Brümmel 1991: 302).

There have been few experiments or ethnographic descriptions of barley and emmer bread-making, so that few data are available about the potential porosity of leavened emmer or barley bread. One Predynastic loaf (no provenance data) on display in the Dokki Museum, Cairo, is extremely open-textured, with large holes dispersed throughout the crumb. This is a very unusual specimen, however. Most surviving loaves are dense with very small air pockets. The highly aerated loaf may, however, be typical of Predynastic bread; Brunton and Caton-Thompson (1928: 65) mention the porous nature of Predynastic bread fragments from graves. The more usual small air pockets in loaves dating to much later times may have been formed by expanding steam as the bread baked rather than by carbon dioxide generated from fermenting micro-organisms. Experimental work would be helpful to resolve this question.

**Leavening**

Some of the discussion about yeast, lactic acid bacteria and their fermentation which is presented in the beer section (see p. 547) is also applicable to the leavening of bread. The extent to which New Kingdom bread was leavened, however, is not easy to establish with precision. The detection of small and scattered components like yeast cells or lactic acid bacteria - both of which may have been leavening agents - in the dense emmer crumb is a difficult task. Unlike in beer, yeast and lactic acid bacteria are dispersed in low concentrations in bread, partly because they are present in the fermenting dough for much shorter periods (hours as opposed to days) and partly because bread dough is a much more dense and concentrated matrix for the dispersal of single-celled organisms, in contrast to the liquid medium of beer. Furthermore, the baking process may damage or alter cells of yeast and bacteria enough to make them unrecognisable.

A few loaves examined with SEM certainly contain yeast cells embedded in the crumb matrix. It is therefore reasonable to conclude that these particular specimens were probably leavened. The current absence of evidence for yeast or bacteria in the other loaves cannot be assumed to indicate that these examples were unleavened. It is possible, however, that some types of ancient Egyptian bread were not fermented at all.

Leavening agents, be they yeast, lactic acid bacteria, or inorganic compounds such as sodium bicarbonate, normally play three roles in bread-making. They create a porous, more easily masticated texture, they help develop dough gluten by moving the dough during rising, and they contribute desirable flavours (Brown 1982: 69). Since neither emmer wheat nor barley contain gluten-forming proteins, one of the modern functions of leaven, its dough mixing action, is not relevant to ancient Egyptian baking. Nevertheless, some porosity may be maintained. If yeast and lactic acid bacteria helped to leaven ancient Egyptian bread, they may have somewhat increased the loaf volume and enhanced taste and aroma, for example as sour dough does in modern wheat breads (Seibel and Brümmel 1991: 302).

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**Other ingredients**

The most common macroscopic inclusion in surviving ancient Egyptian bread loaves is *Lolium* (rye grass). Several *Lolium* species are common weeds of cereal fields (Bot 1968: 90–9; Täckholm et al. 1941: 301–11). The species in the ancient bread has not yet been identified with absolute certainty, but based on the relatively small size, lack of turgidity and presence of an awn, is most probably *Lolium multiflorum* Lam. A few seeds are present in many of the loaves which I have been able to look at closely. The ubiquity of *Lolium* compared to the absence of other weed seeds is striking. The size difference between ancient Egyptian emmer spikelets (c. 18 by 7.5 mm) and grains (c. 10 by 3 mm) compared to *Lolium* seeds (c. 3 by 1 mm) is so marked that the sieving steps needed to clean the harvested spikelets (see Chapter 21, this volume) and the dehusked grain (see pp. 559–63, Fig. 22.3) should have removed all the *Lolium* contaminants. The high frequency of a few seeds of *Lolium* in ancient Egyptian loaves suggests the emmer crop...
may have been so infested with rye grass that a few seeds were consistently processed with the grain despite several cleaning steps. Another possibility is that the short awns of *Lolium* persisted throughout the processing sequence and allowed the weed grass seed to mimic the larger size of emmer grains and spikelets.

Unlike *Lolium temulentum* L., which is poisonous, *L. multiflorum* is not harmful. Although its husk is rich in silica, its low levels in the bread loaves would have caused no ill effects.

One ancient loaf from Deir el-Bahari (Cairo JE40942), gives an interesting insight into substitutions which the ancient Egyptians sometimes made. It was found at the temple of Mentuhotep, and was probably part of a foundation deposit. The loaf is a large triangular shape, pale in colour, and looks very similar to a foundation deposit loaf from the same area which is now in the Museum of Fine Arts, Boston (37,549). While the Boston loaf is a fairly clean, grain-rich bread, the dominant ingredient of the Cairo loaf is rye grass seed, together with many fragments of emmer chaff. It may be that this loaf was meant to represent edible bread, although it was made from very inferior ingredients - or it was deliberately passed off as such! Only the broken surfaces show that it is different in composition to the ‘real’ bread. The components from which it is made best correspond to a mixture of fine sievings of emmer spikelets, and sievings and winnowings after pounding whole emmer spikelets. These are the very by-products which are generated in the early stages of processing whole emmer spikelets into flour (see Fig. 22.3), and they would thus have been available during the preparation phase just prior to baking.

This category of material was probably normally used for animal feed. With the addition of a bit of flour from clean grain, there would be enough binding matrix to stick the chaff, grain and grass seeds together into the semblance of a loaf.

There is good, though rare, evidence that ingredients other than emmer were occasionally added to bread. A cone-shaped bread now in the Museum of Fine Arts, Boston (72,4737C, see McDonald 1982: 113 and fig. 97), is made mostly or entirely of figs (*Ficus carica* L.). The bread matrix is a dark dense material with no visible large fruit skin fragments. The figs were therefore probably cooked before being made into a loaf. The bread is densely studded with fig seeds and there is no evidence to show that grain or flour was added. A number of loaves from Deir el-Medina, now in the Dokki Museum, Cairo, had figs as an added ingredient (Bruyère 1937: 107; personal observations). In contrast to the Boston Museum example, in these loaves, cereal grain was also a component, probably the main ingredient. Bruyère (1937: 107) states these loaves were made from barley or spelt, but spelt was not grown by the ancient Egyptians (see Chapter 21, this volume) and all the Deir el-Medina loaves I have been able to examine closely are made from emmer.

A loaf now in the British Museum (BM EA5346), may have been made with a mixture of dates and cereal. Although no obvious date fruit fragments could be clearly identified, relatively large fragments of non-cereal tissue are embedded in the loaf, and it is decorated with two date stones and a date calyx. At least some of a set of semi-circular loaves from the tomb of Tutankhamun (KV62) and now in the Cairo Museum (CG644-5, illustrated in Darby et al. 1977: 525, fig. 12.16, Forbes 1965: 60; Hepper 1990: 53; Wahren 1961: 13; 1963: 26) contain coriander seeds, which appear to have been coarsely crushed prior to being added to the dough. These loaves also contain shreds of an unidentified ingredient which is not a cereal. The bread was made mostly of cereal flour, although the species has not been determined.

Kamal (1913: 241) states that some ancient funerary loaves were made with fruits of the Christ’s thorn (*nabk* in Arabic). He provides ethnographic details of *nabk* bread preparation. Manniche (1989: 158) states that two ancient loaves made from Christ’s thorn fruits have been recovered, but provides no further details. To date, I have not seen any ancient loaves made from this ingredient. The lichen *Evernia furfuracea* Mann. has been found in a Middle Kingdom tomb (Tackholm and Drar 1950: 247), a Twenty-first-Dynasty tomb at Deir el-Bahari (Schweinfurth 1883: 74-5) and in graves from the cemeteries of Antinoe (Bonnet 1902: 316, 1905: 6). This plant does not grow in Egypt; its nearest location is in Greece and Ethiopia (Schweinfurth 1883: 74-5). Bonnet (1902: 316) considered the Antinoe material must have come from Greece, due to the fir bark attached to it. Schweinfurth (1883: 74-5) and Tackholm and Drar (1950: 247) mention the modern use of this lichen for bread-making in Egypt, and the idea that lichen was used in ancient Egyptian bread is occasionally encountered. To my knowledge, no fragments of lichen have yet been identified in ancient bread. Thin layer chromatography tests on some ancient bread samples to detect lichen species known as ‘manna’, carried out for Leek (1973: 202), were negative. Germ (1985: 4) suggests the lichen was used in Egypt to perfume anointing oils. Given the lichen’s rarity, origin outside Egypt and modern day medicinal use, it was most likely not intended for bread, but considered a valued medicine in ancient Egypt.

**Initial processing: hulled grain to flour**

The traditional models of ancient Egyptian baking (Fig. 22.1b) do not take into account the fact that the cereals removed from store were still tightly encased in their husks, and that these husks had to be removed prior to making flour. For the discussion in this section, the reader should refer to Fig. 22.3, a summary diagram of ancient Egyptian post-harvesting cereal processing. The sequence has been reconstructed based on ethnographic, archaeological and experimental evidence. These sources show
that there were two basic technologies for flour production, with two intermediate products. There was first a pounding stage, which ultimately generated whole clean grain. This was followed by the second milling stage, the end result of which was flour.

**Requirements**

Whatever facilities were used to store the harvested cereal crop (see Chapter 21, this volume) and however those stores were distributed, the grain had to be treated in the same way by anybody processing it for flour. Whether bread was always or usually made from emmer, as is the case for most of the extant loaves so far examined, or whether barley was also used, the first processing step required was to remove the chaff surrounding the grain. Chaff and grain then had to be separated before the clean grain could be milled into flour. If the chaff was milled with the grain, the resulting fragmentation would make it almost impossible to remove all the tiny chaff pieces from the flour.

**Ethnographic parallels**

*Dehusking and cleaning grain*  Few societies still dehusk emmer or barley using traditional methods, and of those that do, it is often difficult to find detailed published descriptions. The regions where emmer is still cultivated are often mountainous with high rainfall, and in these areas, emmer is dehusked using a rotary quern driven by water power (for example, Pena-Chocarro 1996: 141–2). This is clearly an inappropriate analogue for ancient Egypt, since the rotary quern was unknown to the ancient Egyptians (see p. 938 and below). Hillman (1984: 129–30) describes the recent use in Turkey of wooden or stone mortars and wooden mallets or pestles for dehusking hulled cereals including emmer (and also rice). Harlaa (1967: 199, see his figure p. 200) makes a brief reference to the same tools for dehusking emmer in Ethiopia as well as in a number of other countries where emmer has been grown. Hillman (1984: 131, 134) describes a sequence of winnowing, sieving and hand-picking to remove the abundant chaff of different densities (as well as weed seeds and other contaminants) from the separated emmer grain.

An equivalent process is the removal of husk or bran from other types of cereals. A number of different cultures have used mortars and pestles to remove chaff or bran from whole cereal grains. In villages in Turkey today, bulghur, a partially-cooked whole grain or cracked grain food, is debranned by pounding with mortar and pestle (Hillman 1984: 135–6). Recent observations (Hillman 1984: 135–6; Nesbitt and Samuel 1996: 52) have established that the grain is first dampened with water prior to pounding. The moisture causes the grains to slide past each other without breaking and the bran to be stripped off. Dirar (1993: 78) describes precisely the same method of stripping bran from sorghum in Sudan. The grain is placed in a wooden mortar, it is dampened by the addition of about 20 per cent water, and then the bran is scraped off by gentle pounding with the wooden pestle. The mixture of bran and damp grain is dried in the sun, before winnowing off the bran to obtain the clean, branless dried grain.

**Milling**  The rotary quern was not invented until about the fifth to third centuries BC, somewhere in the western Mediterranean (Curwen 1937: 157; Robinson and Graham 1938: 332; Runnels and Murray 1983: 62). Prior to this time, the saddle quern was used for grinding. The saddle quern is a flat slab of stone with a more or less flat upper surface, but it can be an elongated basin shape. The upper surface is not perfectly smooth, but is kept somewhat roughened. Grain is milled by rubbing back and forth over the long axis of the stone with a smaller hand stone. The roughened surface grips the grain and helps reduce it to fragments and then into flour.

In the Old World today, the saddle quern is hardly used outside Africa, but it is still quite widespread in sub-Saharan Africa. A number of brief or detailed ethnographic accounts describe its use (e.g. Burckhardt 1822: 202; Dirar 1993: 74–5; Richards 1939: 39; Schön and Holter 1990: 363–4). Normally the quern is placed so that the end closest to the operator is slightly raised. As the hand stone is rubbed back and forth across the quern, the meal or flour is pushed to the farther end, and often caught in a shallow bowl or basket. There are different methods to produce grades of flour texture. Some women use querns of different coarseness, while others use different hand stones appropriate for the flour to be made (Schön and Holter 1990: 362). The very finest flour is ground by adding water to the grain on the saddle quern and wet milling it (Dirar 1993: 75–6).

**Archaeobotanical and archaeological data**

Mortars are common in domestic housing at the workmen's villages of Deir el-Medina and Amarna (Bruyère 1939; Peet and Woolley 1923; Samuel 1994: appendices A and B). Although they have not always been recognised as such, shallow limestone 'flower pot'-like vessels with interior parabolic curves rather than flat interior bases are most likely to be mortars. Archaeobotanical work has shown that one function of these tools was connected with processing emmer spikelets. Large quantities of shredded fine and coarse emmer chaff and some whole spikelets, still containing the grain inside, were recovered from the floor surrounding an emplaced mortar in one of the Amarna village houses (Fig. 22.11; see Samuel 1989: 281). The excavations directed by Peet and Woolley (1923: 68, 77–80, 86) recovered some examples of wooden pestles, sometimes closely associated with the limestone mortars. In the Amarna village rubbish heaps, huge quantities of shredded and broken emmer chaff indicate that
querns may have been a feature of such quern emplacements in the Village and elsewhere.

Experimental reconstruction
To test the ancient Egyptian sequence of cereal processing, from removal from store of cereal still in the hull through to milled flour, a series of experiments was undertaken at Amarna (Samuel 1994a: 143–66). The experimental reconstruction was based on archaeological and archaeobotanical evidence, together with ethnographic information. Since the structure of each cereal differs, each will behave somewhat differently when processed in the same manner. It was therefore essential to work with authentic cereal species. To find out how the ancient tools functioned, modern emmer spikelets were used for processing experiments.

Tools Actual ancient tools were still robust enough to be used for these experiments. The tools were a limestone mortar, a quartzite saddle quern and a quartzite hand stone. Replica mortar and quern emplacements (Fig. 22.12) were constructed from mud brick and mud plaster, closely modelled on ancient examples found at the Amarna Workmen’s Village (Samuel 1989: 262–3). A wooden pestle was closely modelled on an ancient pestle from house Main Street 6 of the Amarna Workmen’s Village, published by Peet and Woolley (1923: 78, pl. XIX no. 1). Particular care was taken to replicate the curve of the lower, working end as precisely as possible (Samuel 1993: 280, fig. 5, 1994a: 147, fig. 5.12).

The ethnographic record indicates that sieving and winnowing tools would have been used in the dehusking sequence to separate chaff from grain. There is no precise archaeological information to show exactly what type of sieves or winnowing tools might have been used by the ancient Egyptians at this stage of processing. Sieves and winnowing fans and baskets have been recovered from various excavations, for example at Deir el-Medina (Gourlay 1981: e.g. 73–4 and pl. VI showing baskets, 129 and pl. IX showing sieves), but there is nothing to link them specifically to cereal dehusking. Replicas of these tools were therefore improvised for the purposes of experimentation.

Experiments Even when well-cleaned prior to storage, cereals processed in bulk during the harvest always contain various contaminants including small stones, clods of earth, pieces of straw, weed seeds and chaff. De Vartavan (1959: 478–89) found some of these types of items, as well as various main crops, in baskets of plant offerings from Tutankhamun’s tomb. The first step in smaller-scale emmer spikelet processing is the removal of these contaminants. This was probably done by careful small-scale sieving and winnowing, but the last contaminants, of the same size, shape and mass as the spikelets, would have to have been picked out by hand. Such a hand-picking step...
These (Moritz 1958: 25; Sallares 1995: 95; Spurr 1986: 11-12). These experiments clearly demonstrate that parching is not necessary to dehusk emmer spikelets with mortar and pestle (see also Nesbitt and Samuel 1966: 43-9 for a detailed discussion of hulled wheats and parching). Similar experiments with emmer dehusking in Germany support this conclusion (Meurers-Balke and Löning 1992: 349, 357). These experimenters found that parching rendered grain brittle and easily crushed. The key to dehusking with mortar and pestle is not heating, but dampening of the spikelets.

The result of pounding is a damp mass of shredded fine and heavy chaff and whole grain. This was spread out thinly in the sun to dry, which took about two hours in March. Once dry, the fine chaff was winnowed away by careful shaking with a basket, but in ancient times, winnowing with wind may have been used instead or as well. Completion of this stage left many large and small pieces of coarse chaff mixed together with whole grain.

Much of the large chaff could be separated from the grain by shaking with the winnowing basket so that grain settled at one side and empty spikelets at the other. A three-millimetre-mesh sieve retained the remaining large chaff pieces and let most of the grain and chaff fall through (note that a three-millimetre-mesh sieve is roughly correct, given the size of emmer grain and chaff, see pp. 358-9). The last pieces of chaff were removed from the grain by hand picking, a step well attested in the ethnographic literature (e.g. Hillman 1984: 134). It was important to work with whole grain rather than cracked or crushed grain at this stage, otherwise the differences in density and size were not great enough to separate grain and chaff.

Overall, this cleaning phase was fairly tedious and time-consuming. The separation of chaff and grain was likely quite time-consuming in ancient times as well, although it would have been more efficiently conducted by experienced people. In larger-scale operations, such as large households and temple bakeries, each step may have been carried out by one or a team of people, making the whole process more
rapid. Such teams are suggested by the different people engaged in baking and brewing depicted in artistic scenes and models. On a small-scale domestic level, these jobs were probably carried out by several people, including children.

Once cleared of chaff, the emmer grain was easily and efficiently milled on the ancient saddle quern (Fig. 22.13a). There was no need to add grit to the grain in order to obtain flour, as has sometimes been asserted (Fleming et al. 1980: 74; Leek 1972: 131; Smith 1986: 45; and see p. 565). The ancient Egyptians may first have cracked the whole grain in the mortar prior to milling, but such a step does not seem to be necessary.

The use of an emplacement to raise and angle the stone makes milling much less onerous than might be expected. Little force is needed to mill effectively, and no strain is placed on the back because the lower body is fully supported, leaving the upper body free to rock easily from the hips. The texture of the flour produced is entirely under the control of the miller. A few strokes of the hand stone rapidly reduces the whole grain to a medium-textured meal, while a few strokes more creates a very fine flour without the need for sieving (Fig. 22.13b). The limiting factor in the production of flour is the quantity of grain which can be placed on the saddle quern at one time: only a small handful will fit without grains rolling off the edges. Depending on the construction of the surround, however, it may well have been possible to fit a heap of grain behind the mill stone, which could then be pushed forward onto the quern as required.

Secondary processing: flour to baked loaves

Compared to the evidence for grain processing, there is much less archaeological information from domestic contexts to show how baking was carried out. There are, however, the invaluable preserved loaves themselves. Like the beer residues, they retain a record of processing techniques in the microstructure of the starch granules, as well as in their overall texture and composition. Ethnographic and archaeological data also give some indication of ancient Egyptian baking practice.

Shape and texture of ancient bread

Virtually all of the extant ancient loaves which I have examined were hand-formed. Only two (Louve E 4084; from Eighteenth-Dynasty Deir el-Medina, and BM EA 5346, possibly from New Kingdom Thebes) appear to have been made with moulds, which were small and cup-shaped. The remaining hand-formed loaves come in a great variety of shapes and sizes, from one in the form of a fish measuring one centimetres in length, to heavy domed oval loaves sometimes over twenty centimetres in length. Both types can be found in the Turin Museum, from the Eighteenth-

Dynasty tomb of Kha at Deir el-Medina (TT 8; see Sist 1987: 58, fig. 61). Some of the loaves have been shaped into recognisable forms like the fish bread, or into human figures (Darby et al. 1977: fig. 12.17), while others are apparently abstract designs. Loaves can be decorated with slashes, pricked or indented holes, or bands of dough applied over the surfaces. For funerary occasions at least, making decor-
ated loaves seems to have been common. They may have played a role in medicinal or magical belief, as bread in the form of a man is mentioned in at least one spell (Papyrus Chester Beatty VIII, BM EA10688, Rt. 3, 5-5; 3; see Gardiner 1935: 67-8).

Despite the enormous numbers of conical bread moulds found in New Kingdom times, especially in temple contexts (Jacquet-Gordon 1981: 19; Kemp 1979: 11; Kemp and Boman 1984: 31; Rose 1987b: 119), there are few preserved conical loaves. I have observed three examples from Deir el-Medina now in the Dokki Museum, Cairo (inv. no. 4272) and illustrated in Darby et al. (1977: 520, fig. 12.12), the unprovenanced fig bread at the Boston Museum of Fine Arts (72.4775; McDonald 1982: 113 and fig. 97, see p. 559) and an unpublished specimen of unknown provenance now in the National Museums of Scotland, Edinburgh (1971.133). All these were definitely shaped by hand. In the case of the Deir el-Medina examples, the dough was rolled out into a tapered strip, folded over and the seams pinched together. The large specimen in the National Museums of Scotland was built up out of several pieces and carefully smoothed together. A conical loaf is illustrated by Wittmack (1896: 71, fig. 3), but it is not possible to assess whether this too was made by hand or in a mould.

Shape is not an indicator of bread type. Similar forms such as triangles can be made according to different recipes. As far as can be assessed without microscopy, the diverse range of loaf forms found in the tomb of Kha (TT8) all seem to have been made from the same type of dough.

The texture of ancient bread varies a great deal. Although loaves can be remarkably full of chaff, this is rare. None of the shaped and baked loaves which I have seen, or for which a description has been published, are nearly as chaff-rich as the residues found in pottery vessels or in large, irregular loose lumps. The very coarse and chaffy 'bread loaves' examined by Ruffer (1920: 354; 1921: 288-9) are almost certainly beer residues (see p. 543, Fig. 22.5b). Most loaves have a few fragments of chaff, usually quite small, which are undoubtedly unintentional inclusions. The ancient Egyptians were capable of producing flour and bread which was very well-cleaned of chaff, for some loaves have no trace of husk material. It is very difficult to draw conclusions from the surviving funerary loaves about the quality of daily bread. Perhaps bread destined never to be eaten by the living was sometimes made with less care. The quality of bread may have varied from baker to baker, according to skill, experience and aptitude.

The texture of bread also provides an insight into milling practices. A few loaves are made of such well-ground flour that the type of cereal cannot be determined on simple observation alone. It is possible that such fine flour was produced by sieving. Experiments have shown, however, (see above and Fig. 22.13b) that very fine flour can be produced with the ancient Egyptian saddle quern and hand stone, while ethnographic evidence suggests that very fine flour may have been wet milled. Many loaves are made from flour which is slightly mealy, containing fragments of grain from approximately 0.5 to 1.5 millimetres in diameter. This suggests efficient but not extensive grinding.

Large pieces of cracked grain or whole emmer grains are common in the ancient loaves. The microscopy evidence suggests they were pre-cooked, or at least well-soaked, and then added to the dough. It has sometimes been stated that ancient Egyptian milling was crude and did not grind very effectively (e.g. Leek 1972: 129; Ruffer 1919: 45; Strouhal 1952: 125; Wilson 1988: 13). It is clear from the disjunctive size of flour fragments and the different treatment of the whole grain that this was not the case. Whole or cracked grain was deliberately added into finely- or medium-milled flour. The resulting texture is similar to the popular 'granary', 'harvest grain' or 'multi-grain' breads baked nowadays.

Microscopic evidence from ancient bread Malt As with beer residues, the microstructure of ancient desiccated bread loaves preserves a record of past processing methods. In several ancient bread samples, heavily channelled starch granules make up part of the crumb. The typical concentric channels indicate that malt was an ingredient of these bread loaves. Because the action of heat has distorted much of the starch and because not all starch granules are affected by enzymes in sprouted grain, it is not possible to say whether these loaves were made entirely of malt or a mixture of malt and unspouted grain.

Since embryos are damaged by dehusking (see p. 552), the malt for bread-making must have been prepared in the spikelet. Effective removal of the husk was important for bread-making and therefore the sprouted spikelets must have been thoroughly dried down, prior to preparation into flour according to the sequence which has been described for untreated spikelets (above and Fig. 22.3). If soaked emmer in the spikelet were dried by spreading in the sun, it would have taken considerably longer to dry than the shredded chaff and grain mixture, because much more moisture would have been absorbed. If malt was used for bread, it may have been necessary or desirable to heat it artificially. Different treatments, such as light warming or more intense roasting may have been applied and may have been a way of creating a variety of flavours, including a type of sweet malt suggested for brewing (see p. 556). The evidence for such a practice is not clear, however.

Dough mixing and moisture The overall microstructure of ancient bread can be quite variable within each loaf. Some areas contain starch granules with no discernible distortion, while other parts of the crumb are made up of almost fused starch. This suggests that the flour and water were not evenly mixed in the dough, and that kneading was not extensive. There would be no point in kneading emmer dough for long, since the purpose of kneading is to develop...
Gluten was converted into an elastic mass which creates a nicely risen, spongy loaf. The variable texture of many of the loaves would also prevent water from fully penetrating larger grain fragments. When heated, starch granules in the dough which were protected from moisture would not have distorted.

In areas where starch granules appear to be glassy, it is possible to observe many of the boundaries of the much-swollen granules (Samuel 1966c: 489, fig. 3). This indicates that the starch is not completely fused. On the inner surfaces of small air pockets, starch granules are only dimpled or swollen. These features show that the original dough was quite moist, but that water was still limited compared to the amounts which must have been used to cook coarsely ground malt or grain destined for beer. This observation reinforces the interpretation that bread was not an ingredient for beer-brewing. Few dimpled or swollen starch granules, common in ancient bread air pockets, have been found in the beer residues.

Grit Leek (1972) carried out investigations on thirteen ancient Egyptian loaves, to establish reasons for the heavy wear observed on ancient Egyptian teeth. He hypothesised that, since bread was a staple, its composition may have contributed to the distinctive tooth abrasion. He found that the bread samples contained variable amounts of inorganic particles embedded within the bread crumbs, not just on the surface. Most such particles were rounded desert quartzitic sand grains but angular fragments and very fine inclusions were also present. Leek may not have observed that sometimes loaves contain remarkably large stone chunks, several millimetres in diameter. These must surely be fragments included through careless processing, perhaps because the bread in question was not intended for consumption by the living.

As Murray describes (Chapter 21, this volume), pre-storage grain-processing involved several sieving stages which removed inorganic fragments bigger than emmer spikelets, as well as finer sand, grit and dust. Experiments have firmly established that the addition of grit is unnecessary to mill flour of any desired texture.

There are therefore several possibilities for the source of grit in bread, most of which are discussed by Leek (1972: 31–2).

Spikelet-sized clods of earth attached to the harvested cereal crop were incorporated into the semi-cleaned grain and were not all removed during subsequent preparation stages. A mixture of angular and rounded mineral grains might be expected from this source. Small particles were abraded off the quern during milling. This would certainly explain angular fragments and fine particles, but the rounded sand particles are perhaps more likely to have come from wind-blown sand. If quartzitic sandstone querns were composed of such rounded particles, however, the saddle quern may also have been the source. More work on the characterisation of saddle quern stone, compared to grit in bread, might help to answer this question.

3) Windblown grit may have contaminated bread during preparation. In a country surrounded by desert such as Egypt, this is a reasonable supposition. The extent to which this was common, however, is questionable, as it is not always windy in Egypt. Villages were often located in the cultivation, not the desert, and the installations in ancient houses show that many processing steps were done indoors.

4) There is already good evidence to show that some funerary bread was made with little care. Grit in bread may be a further reflection of carelessness. A correlation between ‘gritty’ bread and other characteristics like unusually high chaff or weed content may support this hypothesis.

**Baking methods**

The archaeological evidence for baking during periods prior to the New Kingdom is still extremely limited (see p. 342). The main corpus of data at present is provided by the artistic evidence. This section therefore focuses on New Kingdom practice, which apparently differs in many respects from earlier baking methods. Tomb scenes indicate that prior to the New Kingdom, bread was baked in long, cylindrical moulds during the Middle Kingdom and in wider, much more robust moulds during the Old Kingdom (see also Jacquet-Gordon 1981). In addition, at least in the Middle Kingdom, hand-made loaves appear to have been baked on open hearths or griddles. Examples of preparing or baking such bread can be seen in the Beni Hasan tombs of Amenemhat (BH2; see Newberry 1893: 30–1, pl. 12, register N) and Khnumhotep III (BH3; see Newberry 1853a: 68, pl. 29, register O) Wahren (1960) provides a typology of oven types and baking methods over time based on artistic evidence.

**Ethnographic evidence** Emmer is used for human food on a small scale in parts of Europe (Perrino et al. 1996: 108–9). India (Bhatia 1938: 322; Howard and Howard 1909; Mithal and Kopper 1990: 201) and in Ethiopia (National Research Council 1996: 239). There are, however, very few detailed accounts of preparation and baking methods. Observations of traditional baking with other cereals are not necessarily good analogues, as different cereals can have quite different physico-chemical properties. Virtually nothing is known about emmer wheat baking characteristics, but the little information available (Le Clerc et al. 1918; Piergiovanni et al. 1996) indicates that emmer does not closely resemble other wheat species.

One feature of village houses at both Amarna and Deir el-Medina, as well as in larger Amarna city houses and temple bakeries, is the installation of cylindrical ovens (see
These ancient ovens closely resemble the modern tannour which is widespread in the Near East and parts of North Africa (but not in Egypt), particularly in rural areas (Darby et al. 1977: 513; fig. 12.8b; McQuitty 1984: 261, figs. 3, 5; Samuel 1994a: 276; Wahren 1961: 3). The tannour is constructed of mud brick or mud plaster, often with a thick wall of consolidated rubble. The interior is about fifty centimetres in diameter and is lined with a fine clay cylinder. The oven is heated with a fire built up inside, which is allowed to burn vigorously for about half an hour, making the inner clay lining very hot. At the same time, heat is absorbed by the thick outer oven wall. Then, the fire dies down to glowing embers in the base, while the baker quickly rinses soot from the internal walls with a wet brush or cloth. The baker forms flat discs of dough and rubs one side of each with milk or water before slapping them onto the hot inner wall. The discs adhere and bake in the stored heat of the oven lining and wall (Samuel 1989: 255, 1994a: 276–7). When ready, the loaves begin to peel away from the sides and are expertly caught and lifted out by the baker.

The round flat loaf baked in the tannour becomes distinctly curved in cross-section (Wahren 1961: 3). Many ancient Egyptian disc-shaped loaves are similarly bowed (see Borchardt 1932: pl. 3, for example), suggesting they may have been baked in a similar fashion to modern tannour baking.

At least one tomb has depictions of the baking loaves within the oven, that of Rameses III (KV11; Darby et al. 1977: 523, fig. 12.14). Other scenes do not actually indicate the loaves baking on the oven walls, but suggest it by showing a person reaching inside while holding a disc of dough or baked bread in the other hand. One example, from the Eighteenth-Dynasty Theban tomb of Nebamun (TT17) is shown in Fig. 22.14, while others are to be found in the Eighteenth-Dynasty Theban tomb of Kenamun (TT19; see Davies 1930: 51, pl. 58; Wild 1966: pl. 11) and the Karnak Amarna-period talatat scene showing temple activities now in the Luxor Museum (Lauffray 1980: pl. 16, third register up, far right – second section, second zone).

Such scenes have sometimes been misinterpreted. Klebs (1934: 175) and Vandier (1964: 310) suggest that the bread could only have been baked on the oven sides by being hung on little nails. No trace of such hooks have ever been found in excavated ancient cylindrical ovens, and ethnographic evidence shows that they are unnecessary. Borchardt (1936: 530), Erman (1894: 191), Ruffer (1919: 46) and Wilson (1988: 13) suggest bread was baked on the sloping outer walls of the oven. This is an impossible method, as clearly shown by an attempted reconstruction which is illustrated by Hepper (1992: 93). The ethnographic parallels explain what was being depicted: discs baked directly on the hot interior wall.

Archaeological evidence

I ovens New Kingdom cylindrical ovens are made from a thick shell of mud brick and mud plaster. They are commonly situated in the corner of a room, the walls making up part of the shell. The interior is lined with a clay cylinder, about three centimetres thick. Sometimes the floor is also lined with clay. A few centimetres above floor level, a small hole about ten centimetres in diameter is pierced through the wall of the oven (Bruyère 1939: 72–4). Occasionally, the oven consists solely of the ceramic shell without the outer lining (Kemp 1987a: 71, fig. 6.1, unit [2810]).

Microscopy of a whitish deposit from the interior of a cylindrical oven in Chapel 556 of the Amarna Workmen’s Village (unit [2810]. Kemp 1987a: 71) has shown that it contains a few starch granules (Samuel 1994a: 299). This fits well with the technique of baking on the pre-heated oven wall as practised with the modern tannour. The evidence of the starch granules, the ubiquity of cylindrical ovens and the distinctive bowed shape of ancient disc-shaped bread loaves, all suggest that cylindrical ovens often functioned as the Middle Eastern tannour does today.

Other thicker loaves were too heavy to have been baked on the sides of ovens. They must have been placed on some sort of horizontal support, either the oven floor or something inserted into the oven. There is currently little which has been recognised in the archaeological record to suggest what such a removable support might have been. One possibility, ceramic bread platters, are discussed below (pp. 567–8).

II bread moulds Jacquet-Gordon (1981) has traced the evolution in bread-mould shape from the Old Kingdom through to the New Kingdom. The form evolved from enormous, thick-walled coarse cylinders of clay with a
bowl-shaped interior (Fig. 22.15a), to coarsely and crudely made, but much smaller narrow conical in the New Kingdom (Fig. 22.15b). This type of vessel is identified as a bread mould on the basis of two observations (Jacquet-Gordon 1981: 12; Kemp 1979: 10). Firstly, many scenes of bread-baking which date throughout the Pharaonic era show precisely such vessels being used, and their form evolves in the depictions in tandem with the archaeological finds. Secondly, bread moulds are very frequently closely associated with ovens or cooking installations containing large amounts of charred material, for example, at the New Kingdom sites of the Great Aten Temple of Amarna (Kemp 1979: 7-12), the treasury of Thutmose III at Karnak (Jacquet 1972: 154, pl. 1, pls. 33-40, 1994a: 85-106, 1994b: pls. 36, 40, 46, for example) and at the Old Kingdom site of Giza (Lehner 1992: 1, 1993: 60).

At Amarna, the distribution of bread moulds near temples, chapels and altars suggests that, at this site, bread moulds were closely associated with specific ritual or official use. This is borne out by the lack of any known example of a preserved New Kingdom loaf which had been baked in a conical mould. In Old Kingdom times, however, it seems that bread should appear to have been standard practice, since the style found in a wide range of contexts (Jacquet-Gordon 1981: 13). The use and significance of mould-baked bread seems to have evolved over time as baking technology changed, from widespread establishment practice, to specifically ritual production.

**III BREAD PLATTERS** One ceramic form which has been associated with baking is the platter or plate (Aston 1956: 13). Platters are roughly made, poorly fired and fragile (P. Rose pers. comm.). They are most often recovered only as fragments. Remains of these vessels appear throughout all Pharaonic levels and into the Greco-Roman period, although little apparent change. For examples of Old and Middle Kingdom platters see Arnold (1982: 28, fig. 4 no. 1; 51, fig. 14 no. 2), for New Kingdom forms see Nagel (1938: 152–3) and Figure 22.16, and for Late Period finds see French and Ghaly (1991: 176–177). The platter or plate continued to be made in Greco–Roman times; many platter sherds from these levels have been found at Buto (P. French pers. comm.). The best depiction of baking with what appears to be a platter is that
in the Twelfth-Dynasty tomb of Intefiqer at Thebes (TT60; Davies and Gardiner 1920: 14, pls. 8, 9, 9A).

Despite their longevity and ubiquity, platters have hardly been studied in a systematic manner. It is therefore difficult to draw any well-substantiated conclusions about them. The one notable variation appears to be that they change in size from the New Kingdom onwards, becoming larger over time (Redford 1994: 71). Judging from finds at Amarna, platters appear to come mainly from domestic areas, but at most sites little work has been done to link them to contexts or other vessel forms.

The Amarna platters are roughly formed from coarse silt clay with an untreated surface (Rose 1984: 136). They very rarely have a thin gypsum coating which may result from secondary reuse (Rose 1987a: 134). Occasional specimens have a simple design on the inner surface (Frankfort and Pendlebury 1933: pl. 54: type XXI.14). They have been found in close association with cylindrical ovens. One fragment was found inside such an oven (Peet 1927: 177). A few platter sherds were found in fill from the Kom el-Nana temple bakery at Amarna (P. Rose pers. comm.)., but this association with a non-domestic context is unusual at Amarna.

In size and form, platters appear to be well-suited to baking loaves of a form too large and heavy to be baked on nearly vertical cylindrical oven walls. At Amarna, one of the largest recovered platters is about thirty centimetres in diameter (Rose 1987a: 134), and such a size could have accommodated the biggest of the ancient preserved loaves. The longest loaf that I have measured is thought to be Eighteenth-Dynasty in date, so it is broadly contemporary with Amarna. It is twenty-eight centimetres in length, a flat isosceles triangle-shaped bread now in the Egyptian Museum, Turin (no. 7019). The biggest loaves overall are over twenty centimetres in length, seventeen centimetres in width and ten centimetres high (Samuel 1994a: table 6.2), and could not possibly have been baked on the sides of cylindrical ovens.

The main reason that platters have been associated with ancient bread-making is the parallel with modern-day Egyptian vessels used for making ‘eish shams’, or sun bread (Aston 1996: 13). Dough is put on these in order to rise. Peet and Woolley (1923: 64) and Woolley (1922: 58) describe how modern villagers living near Amarna baked with such platters, stating that dough is placed on unfired platters and both platter and bread baked together in the oven. Since baking is carried out by women in the villages, it may well be that the excavators did not see this procedure themselves and relied on descriptions by villagers who did not themselves bake. On the several occasions I have been able to observe modern baking in the village near Amarna, platters were never used for the actual baking stage. A detailed account of modern Egyptian domestic bread baking is given by Rizqallah and Rizqallah (1978).

Despite the apparent modern parallel and the suitable shape of platters for baking bread, it is not at all clear exactly how the ancient platters might have been used. Bread made from emmer wheat does not rise like the spongy dough made from bread wheat (see p. 518), and thus an extended rising period does not seem likely. It is hard to imagine how such fragile platters, holding their heavy pieces of dough, could be placed in the bottom of very hot cylindrical ovens, often well over a metre in height. Even more mysterious is how the platters or the loaves were removed from the ovens when baking was complete. Unlike fired pots, they could not simply be left until the oven cooled because exposure to heat would cause the bread either to burn or to be completely dried out. The upper surfaces and rims of these platters are better fired than the undersides, which does not suggest these platters were placed on hot embers. All the attention to manufacture has been concentrated on the interior and rim while the underside of the base was left rough and unfinished; it therefore seems impossible that they were turned upside down so that bread could be baked on the underside (P. Rose pers. comm.). Note, however, that the object depicted in the Twelfth-Dynasty tomb of Intefiqer (TT60; Davies and Gardiner 1920: pl. 9A), which appears to be a platter, is shown ‘rim’ side downwards, against the fire.

According to archive notes for the 1920s Amarna excavations, one platter was found scattered with bran. This may actually have been part of the abundant chaff temper which was not burnt out because of the low firing temperature (P. Rose pers. comm.). There are no loose fragments of bran adhering to the crust of any surviving loaves which I have examined, and in most loaves, only occasional pieces of chaff, which are stuck to both upper and lower surfaces rather than just the underside.

These observations suggest that the so-called bread platter may be misnamed. The longevity and ubiquity of the form, the close association with domestic contexts, and the occasional find in or close to ovens points to a domestic use, very possibly connected to cereal processing or food preparation. The link with bread-baking, however, seems rather tenuous on current evidence. More contextual work might help to resolve this problem. Meanwhile, the method by which large loaves were baked remains unknown.

Experimental evidence To date, only very small-scale experiments on ancient Egyptian baking have been carried out: much more remains to be done. A few useful insights have been obtained, however. As earlier work has established, emmer has a very high water absorption capacity. To make a dough, 82 per cent water was used in relation to emmer flour, compared to 69.5 per cent for bread wheat flour (Le Clerc et al. 1918: 216). When the normal bread wheat flour–water ratio is used for emmer flour, the resulting dough is so stiff and hard that it is nearly impossible to work (Samuel 1994a: 280), and certainly cannot be formed.
into the variety of shapes made by the ancient Egyptians. As is the case for rye flour (Prihoda et al. 1993: 23), the high water absorption of emmer flour may be due to the molecular configuration of proteins and pentosans. The high uptake of water explains the considerable starch fusion seen in ancient emmer bread microstructure.

Experimental bread baked with sprouted emmer wheat resulted in a microstructure which most closely resembles that of the ancient loaves (author's unpublished data). When mixed with the same proportion of water, starch from emmer malt seems more susceptible to fusion than starch from unsprouted grain, under the same baking conditions. This may mean that the use of malt might have been more widespread than the evidence of heavily channelled starch granules currently indicates. There is very little modern comparative analysis of microstructural changes in bread made from malt, since any grain exposed to the least amount of germination is strenuously avoided in modern bakery, apart from a few speciality baked goods (Barnes 1989: 380; Pyler and Thomas 1991: 830). There are many details about ancient Egyptian baking which remain to be explored by experimental replication.

Comparison between ancient Egyptian baking and brewing technologies

The ancient Egyptians frequently depicted baking and brewing activities together. This is one reason why it has been thought that bread was a precursor to brewing beer. Bread- and beer-making were shown together because the same or similar technology was applied at many stages throughout the baking and brewing processes. In addition, the basic ingredients were the same. Bread and beer may well have been prepared in the same locations on large estates and in temple kitchens.

The first and most basic similarity between bread and beer is that they were made from the main agricultural produce, emmer wheat and barley. Although textual evidence suggests that barley was the predominant cereal in the Old and Middle Kingdoms while emmer was produced in greater quantities in the New Kingdom, to date there are not sufficient archaeobotanical data to test this hypothesis (see Chapter 21, this volume). At present there are also not enough data on the preserved foodstuffs to determine whether the cereals used to make bread and beer changed over time. Nearly all extant funerary loaves from the New Kingdom examined so far are made from emmer; there is little evidence that barley was ever an intentional addition. The few Middle Kingdom loaves which have been studied are also made of emmer wheat. There is no reason why barley could not have been a part or sole ingredient of bread, but it may be that barley was not considered appropriate for offerings. Until bread from domestic contexts is recovered, this question cannot be fully resolved. The surviving New Kingdom beer residues, on the other hand, show that beer was made from both cereals and sometimes a mixture of the two. Most residues examined to date are made from barley, but the sample size is too small to be certain that barley was more commonly brewed than emmer.

For brewing, and sometimes also for baking, cereals were malted. All examined beer residues contain evidence for the use of malt, but many of the loaves which have been studied have no evidence to show that they were made from sprouted grain. Again, the sample size is too small to establish whether malt bread was common, and whether it was eaten daily or reserved only for offerings.

Both bread- and beer-making involved milling. In the case of baking, this was preceded by dehusking so that only clean grain was ground to flour of varying textures. Both batches of cereal used for beer were coarsely ground, and the husk was included. Most of the chaff was removed by sieving later in the brewing sequence. Since grain milled for beer was only roughly broken up, grinding would have been rapid. The very fine texture of some loaves, in contrast, would have taken much longer to achieve. The cracked grain which was often added separately to bread dough may have been briefly ground on the saddle quern or perhaps was broken up with a few strokes of the pestle in the mortar.

Fermentation was a critical part of brewing, while at least some and perhaps all loaves were fermented. Microscopic examination shows that large colonies of yeast were actively growing in beer at the time of desiccation, and that lactic acid bacteria may well have been important for fermentation as well. The extent to which bread was fermented is not clear, but yeast was certainly an ingredient in at least some types of bread.

Heating and cooking played an important role in both baking and brewing. The methods which were used are not yet fully understood. There is good evidence to show that some flat breads were baked on the preheated sides of cylindrical ovens, but not all loaves could have been baked this way. Larger, thicker loaves may have been baked on clay platters, or in some other manner. Cereal for beer was not baked, but heated with sufficient water, perhaps to the consistency of a thick paste or porridge. Malt may sometimes or often have been heated when still damp to create caramel-type flavours. By the New Kingdom, heating may have been done in metal vessels, perhaps set over the mouth of cylindrical ovens. This method of cooking, not necessarily restricted to cereal foods, can be seen in several tomb scenes, for example in those of the Eighteenth-Dynasty Theban tomb of Rekhmira, (TT100; Davies 1943: 44, pl. 49; Wilkinson and Hill 1983: 89, 31.6.15, 31.6.30) and Kenamun (TT93; Davies 1930: 51, pl. 59).

Querns were thus certainly used for both baking and brewing, and cylindrical ovens probably were. Ceramic vessels were not always needed for bread-baking, and may not have been used to mix the dough either; mats or
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wooden containers might have served instead. Ceramic vessels were certainly used for brewing, as attested by the numerous examples with adhering residues of beer or beer precursors.

Vessels with residue have rarely been found on so-called beer jar forms of the New Kingdom. The identification of this particular ceramic type as a beer jar or beer bottle was made by Holthoer (1977: 86–7), for New Kingdom Sudanese Nubian pottery. He used this designation because these forms were often found together with what he called 'flower pots' and believed to be bread moulds, suggesting the two forms symbolically represented bread and beer as linked in a typical votive formula. There is no evidence to show such vessels were actually used for beer (Aston 1996: 13) although perhaps they may have been used for some stage of the brewing sequence. On the other hand, many other vessel forms, including amphorae, were certainly used for beer because beer residues have been found in them (e.g. Grüss 1929c; Winlock 1932: 32). There is some evidence which suggests that shallow bowls were used for drinking the final product. A number of such cup sherds from the Workmen's Village at Amarna contain classic beer residue with plenty of yeast. The shape - Group 5 in the modern Amarna corpus system, in the old system forms III 3, III 5 (Rose 1984: 135) - is common, and ideally suited to drinking.

There are still many areas of baking and brewing technology which are not yet understood. Various problems have been mentioned throughout this chapter. In particular, this discussion has focused primarily on New Kingdom practices. The development of beer- and bread-making over time remains to be properly investigated. The variations of bread and beer types according to region, class or occasion has hardly begun to be addressed. The whole range of tools and installations involved in brewing and baking has not yet been well established and sufficient archaeological evidence is still lacking or has not yet been fully examined. The suggestions which are presented here for ancient Egyptian brewing and baking technology, arising from the archaeological evidence, are not yet wholly applicable to the evidence from the artistic and documentary records. Adequate integration of all sources of evidence remains to be done. As a result, this chapter should not be seen as the last word on the subject. The study of brewing and baking throughout all Pharaonic periods is an active area of research which will continue to provide new insights into these key activities.
BREWING AND BAKING


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