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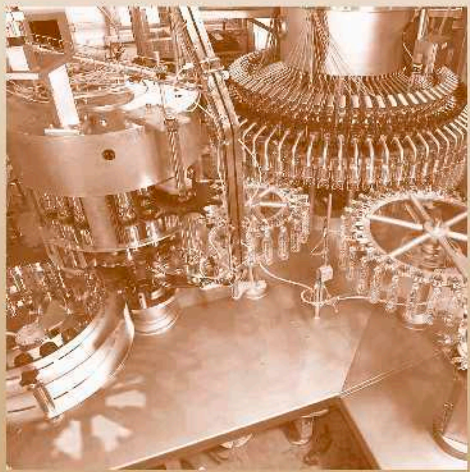

Brewing

New technologies

Edited by C. W. Bamforth

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Brewing

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1

New brewing technologies: setting the scene

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1.1 Introduction

The aim of this book is not primarily to tackle the science underpinning malting and brewing. Rather, the focus is on practical issues. In this chapter I will set the scene with some underpinning information, but those seeking the necessary basic scientific descriptions of everything from barley to beer should consult a text such as Bamforth (2006) or, at a more advanced level, Briggs *et al.* (2005). For immediate purposes Table 1.1 offers basic summaries of the processes involved in malting and brewing and the importance of each unit operation.

Table 1.1 The essentials of malting and brewing

Process stage	Description
Selection of barley[1]	Malting barleys (moisture content <12%) of relatively low total N content (e.g. less than 1.7% N), with high viability and with endosperm of mealy texture that hydrates readily and possesses cell walls that are readily degraded
Storage of barley	Sometimes important to allow barley to free up from innate dormancy
Malting: steeping	Staged addition of water at 14–18ºC separated by air rests to raise moisture content to 43–46%. Allows the embryo to start synthesising hormones (notably gibberellins); allows the aleurone to become receptive to the hormone action that will trigger enzyme synthesis; allows the starchy endosperm to become receptive to digestion ('modification')

Table 1.1 (continued)

Process stage	Description
Malting: germination	Controlled germination for 3–6 days at 16–20ºC to degrade the endosperm cell walls and much of the protein. Enzymes synthesised by the aleurone migrate from proximal to distal end, digesting cell walls (β-glucanase family of enzymes, pentosanases) and protein (proteinase family). Causes softening of grain. Amylases also developed or activated, but limited in action on starch granules
Malting: kilning	Drying of malt at successively increasing temperatures (mainstream malts max. 105ºC) to dry the grain (target <6% H_2O), whilst retaining much enzymic activity and developing colour and flavour through Maillard interactions between sugars and amino acids produced during modification
Malt: storage	2–4 weeks storage to avoid wort separation problems in the brewery
Milling and mashing	Generation of particles accessible to mashing water, mashing often starting at say 50ºC (20 minutes) to allow remaining action of thermolabile β-glucanase, then passing through 65ºC (e.g. for 1 h) for starch gelatinisation and action of amylase complex. Wort produced by conventional mashing has 20–25% starch left behind as non-fermentable digestion products called dextrins. Wort separated from grains
Boiling	Wort boiled with hops or hop preparations, typically for 1 hour. Isomerisation of bitter acids (main part of resin fraction) to increase their solubility and bitterness. Volatilisation of aroma components, including hop oils unless hops added late in the boil. Clarification stage follows to remove 'hot break' and residual hop material. Wort cooled and air or oxygen added
Fermentation	Ales typically fermented warmer (15–25ºC) and therefore faster than lagers (6–15ºC). Time range 3–14 days. Fermentation at a targeted rate of specific gravity drop and to a target 'attenuation'. Also diacetyl and pentanedione, which afford butterscotch/honey aromas, must be removed by prolonged contact of yeast with 'green beer'
Maturation, stabilisation and packaging	Minimum regime is -1ºC, usually for 2–3 days. Some hold longer. Insolubilisation and settling of proteins and polyphenols. Filtration (kieselguhr or perlite-based). Removal of residual haze precursors by polyvinylpolypyrrolidone (polyphenols) and/or silica hydrogels or tannic acid or papain (proteins). Removal of any microbial contamination by pasteurisation or filtration. Adjustment of CO_2 content, then fill vessels

[1] *Process stages in italics occur in the maltings, prior to the brewery.*
Source: Bamforth, C.W. (2004) Opportunities for newer technologies in the oldest biotechnology, brewing. *Applied Biotechnology, Food Science and Policy*, 1, 213–222.

1.2 The materials used in brewing

The larger proportion of the world's beers is produced from *malted barley*. It has been this way for perhaps 8000 years. Barley has been retained as the primary cereal of choice, not least because it retains its husk on threshing and this traditionally form the filter bed through which wort is collected in the brew house. As we shall see in Chapter 10, the mash filter does not depend on the husk in this way, which might in future open up possibilities for huskless barleys for brewing. However, these handle in the maltings much as does *wheat*, with a tendency towards stickiness. Wheat is the second most employed cereal in brewing, notably for the production of weissbiers and weizenbiers in Germany.

Barley is malted prior to use, in order that the enzymes that degrade starch to fermentable sugars are synthesised. Additionally there is a synthesis of the enzymes that degrade the cell walls and much of the protein in the starchy endosperm, thereby softening the grain and making it more millable. There is an unavoidable development of embryo tissue (rootlets and acrospire), and the maltster seeks to balance the extent of this with the need for adequate 'modification'of the endosperm.

Although there are beers that are produced only from malted barley e.g. those produced under the terms of the five-centuries-old Bavarian 'purity' law, the *Reinheitsgebot*, many brewers employ various adjuncts for reasons of quality (different colours, better foams, interesting flavours) or cost. In fact there may not be quite the cost savings anticipated from use of an ostensibly cheaper starch source, because the brewer may have to employ more expensive processing procedures if problems are to be avoided. The major cost components in brewing are illustrated in Fig. 1.1. It will be apparent that the costs of packaging, processing, taxation and marketing vastly exceed those of raw materials. It is only when there are political reasons or taxation reasons – e.g. Happoshu, see Chapter 3) – that there are major justifications to be made on a cost basis for the use of adjuncts.

Of particularly low relative cost to the brewer are the *hops*, yet these make a huge contribution to product quality and stability: apart from the bitterness from the resins and aroma from the oils, the resins also afford anti-microbial properties and foam stabilisation but also comprise precursors of staling and of the skunky aromas that develop in beer exposed to light. Despite the low cost of hops relative to that of the beer, there is a plethora of hop preparations available to the brewer, including those that specifically protect against this light sensitivity (Chapter 6).

The bulk of most beers comprises *water*, hence the scrutiny which brewers devote to this product. Vastly more water is needed to make a pint of beer than actually finds its way into the beer, perhaps five times more for a well-run brewery and 20 times more for a badly operated facility.

Most brewers maintain their own *yeast* strains. As the alcohol concentration of most beers does not become too high during fermentation, the yeast that multiplies in fermentation remains healthy and suitable for re-pitching into

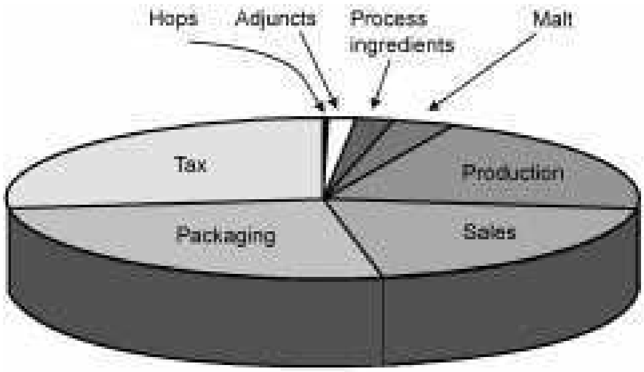

Fig. 1.1 A generalised breakdown of major costs associated with the brewing of beer.

subsequent fermentations. Some smaller brewers have done this in seeming perpetuity; however, the latter-day 'gold standard' is to re-pitch with newly propagated yeast every fourth or fifth fermentation. There is some interest in the use of dried yeast preparations of the type used *inter alia* in baking and wine making (Chapter 8).

As they will not be addressed elsewhere in this book, let us now consider miscellaneous process ingredients that may be employed in brewing. Not included in the discussion are the salts that may be added to adjust the ionic balance of the grist, e.g. calcium salts to increase the hardness ('Burtonisation'), and the zinc chloride or zinc sulphate that many brewers add to encourage yeast activity.

1.2.1 Exogenous enzymes

Various 'brewing enzymes' have been marketed over the years with the intent of satisfying various demands of the brewer (Table 1.2). The majority of these enzymes are not pure, insofar as they contain a range of enzymic activities. During the growth of the organism, different enzymes will be successively released into the medium in the order in which they are needed. So the precise balance of enzymes that is packaged and made available to the brewer will very much depend on where the 'cut' was taken. Nowadays most of the brewing enzymes are made using organisms that are genetically modified so as to optimise the level and type of enzymes in the broth.

1.2.2 Isinglass

One of the great beer genres (*viz.* the English cask ale) emerged on the backbone of a 'natural' clarification process rooted in a protein preparation called isinglass. Isinglass is a very pure form of collagen obtained from the dried swim bladders (some call them 'maws') of certain warm-water fish, amongst them the catfish, jewfish, threadfish and croaker. These fish are primarily caught for food use and the functional property of the maw represents added value.

Table 1.2 Exogenous enzymes used in brewing

Enzyme	Stage of use	Function
β-Glucanase[1]	Mashing	Eliminate glucans that cause wort separation, filtration and clarity problems
Pentosanase[1]	Mashing	Support glucanases in digestion of cell wall polymers from barley and wheat
Proteinase[1]	Mashing	Ensure generation of sufficient yeast-assimilable amino acids
α-Amylase[1]	Mashing	Starch digestion
Glucoamylase	Mashing or fermentation	Enhance starch digestion, to the extent of allowing conversion to totally fermentable sugars of value in the production of light and low carbohydrate beers
Pullulanase	Mashing	Promote digestion of branched-chain dextrins
Acetolactate decarboxylase	Fermentation	Accelerate elimination of vicinal diketones in beer maturation
Papain	Beer in storage	Eliminate haze-forming polypeptides
Prolyl endopeptidase	Beer in storage	Selectively remove haze-forming polypeptides; of potential value in producing beer for coeliacs

[1] Of especial significance if malt replaced by high levels of grain adjunct, e.g. unmalted barley.

The bladders are removed, washed and dried. At the smallest scale in a fishing village the maws are sun-dried, but modern fish processing plants use commercial dryers. Dried maws are ground up, washed and sterilised before being ‘cut’ by weak acids such as sulphurous acid to disrupt the structure of the collagen molecules so as to generate the correct balance and orientation of positively and negatively charged sites that are responsible for its functionality.

Worldwide, few brewers use isinglass, despite the fact that it is very effective in settling the contents of conditioning tanks, thereby minimising the loading of solids onto the filter without the expense of a centrifuge.

Various other fining agents are sometimes used in the brewing industry. These may be classified as kettle (or copper) finings, which are added during the boil, and auxiliary finings, which are used alongside isinglass to aid clarification of beer. The best-known kettle fining agent is the negatively charged carrageenan (Irish Moss), derived from seaweed, and the most frequently used auxiliary finings are silicates and alginates, the former derived from sand and the latter from seaweed. Again, both are negatively charged and complement the action of the positively charged isinglass.

1.2.3 Filter aids

There are fundamentally two types of filter aid: kieselguhr or perlite. Kieselguhr, or ‘diatomaceous earth’, comprises silica-based shells of ancient unicellular aquatic microscopic plants called diatoms. Its heat resistance means that it can be used as an insulator, but its abrasiveness means that it has also formed a component of toothpaste and metal polishes. Apart from being widely used as a filter aid to clarify syrups as well as alcoholic beverages, it is used as a filling material in paper, paints, ceramics, soap and detergents. Alfred Nobel found that it is a great absorbant of nitro-glycerine in the manufacture of dynamite.

Huge beds of kieselguhr, between 40 and 50 feet (12–15 metres) deep, are found in Virginia, but also in parts of Germany and in Aberdeenshire in Scotland. The microscopic appearance from different localities differs considerably. The deposits contain varying amounts of organic matter together with sand, clay, and iron oxide, and the raw material is first incinerated (calcined) to destroy organic matter. The successive process stages in rendering bags of kieselguhr in the form needed by the brewer are mining, crushing, drying, calcining, cooling, air classification and packaging.

The interests of purveyors of perlite are looked after by the Perlite Institute (go to http://www.perlite.org/). Perlite is a naturally occurring siliceous rock that, when heated, expands from four to 20 times its original volume. When heated to above 871ºC, it pops like popcorn to produce many small bubbles, so perlite is very light and white.

There are many uses for perlite. Its insulating properties and lightness render it valuable as an insulator in masonry and cryogenic vessels. It is used as an aggregate in cement and plasters and for under-floor insulation, chimney linings, paint texturing, gypsum boards, ceiling tiles, and roof insulation boards. Perlite is used as a component of soil-less growing mixes, allowing aeration and moisture retention. It is also used as a carrier for fertiliser, herbicides and pesticides and for pelletising seed.

Apart from clarifying beer, perlite is also used for cleaning up pharmaceuticals, chemicals and water. Like kieselguhr, it can also be used as an abrasive.

1.2.4 Stabilisers

Silica hydrogels and xerogels have their origins in a pure form of sand. This is first converted into a soluble form by the action of alkali. Thereafter there is a controlled aggregation of sodium silicate from a sol form under acidic conditions. The washed aggregated particles are processed by techniques including micronisation, drying, milling and classifying to yield the desired balance of particle sizes and pore sizes, the range of which is taken advantage of by brewers (and others) to remove colloidal particles of various types from their products.

Polyvinylpolypyrrolidone (PVPP) is produced by a technique called 'popcorn polymerisation'. The monomer vinylpyrrolidone is heated with strong caustic and then cooled, in which phase the polymerisation takes place. Subsequently there are slurrying, filtering, hydrolysis (using phosphoric acid), washing, re-slurrying, and drying stages, in which any residual monomer and water are removed.

Alternative stabilisers are now in the market, including a PVP–silica gel composite.

1.2.5 Foam stabiliser

Propylene glycol alginate (PGA) is rather more relevant as a foam *protectant* than as a foam stabiliser. It helps prevent lipid and detergent damage at point of sale, without offering absolute protection. Alginates are polysaccharides extracted by alkali from brown seaweed. They have been known since their discovery by an English chemist in 1881. The seaweed is harvested on the coasts of North America, Scotland, Ireland, Norway, France, Japan, China, Korea, Chile, South Africa and Australia. Of these China easily generates the most, though the UK and the USA are the biggest processors, with one company dominating, at 70% of the market.

Insoluble alginate from the raw plant is solubilised by ion exchange, then filtered. The alginic acid obtained is partially dehydrated and then esterified by reaction with gaseous propylene oxide under pressure at 45–60°C. After washing with alcohol, the product is dried and milled.

Table 1.3 Issues of quality in brewing

Issue	Description
Foam	Most beers are expected to have an appealing, stable foam. However, increasing tendency for consumers to drink directly from the container. Impacting factors include amphipathic polypeptide survival from the grist, presence of bitter acids (reduced side-chain acids give more stable foams), levels of CO_2 and N_2, nucleation devices, absence of lipids and detergents.
Clarity	Most beers are bright (free from haze or sediment) – but not all. Insoluble materials can have diverse origins, including proteins cross-linking with oxidised polyphenols, residual grain polysaccharides, oxalate, micro-organisms
Colour	Derives from Maillard reaction in malt kilning and adjunct roasting and from polyphenol oxidation in the brew house
Absence of gushing	Principal cause is *Fusarium* infection of grain, with release of hydrophobin. But can also be cause by oxidised resins in hop bitterness preparations and insolubles in beer, e.g. oxalate
Package	Major determinant of impression customer gets of product – e.g. absence of scuffing on bottles, making returnable glass less appealing than one-trip glass
Flavour	Impacted by all the above. Pronounced marketing pressure to have beer in any coloured glass other than brown, but flint and green glass permit light passage that causes skunking of beer. Flavour impacted by all raw materials, demanding control of material selection and processing. Flavour instability the major unsolved problem facing brewers, in particular development of papery flavour. Stringent control of oxygen a major factor, but not alone. Cold shipping and stockholding of beer expensive but effective

Note: enhanced analytical capabilities (e.g. sensors) will permit increased control, with impacts on cost and quality.