ENCYCLOPAEDIA OF BREWING
ACKNOWLEDGEMENTS

I must first thank my publisher, Wiley, especially Andrew Harrison and Catriona Cooper for their patience and professionalism. I owe much to colleagues past and present. The brewing industry is unique in that sharing of knowledge and experience is seen as a virtue and not divulging secrets. Long may this attitude continue.

Writing a book is most suited to solitary hermits and not those with responsibilities to family and friends. This is particularly the case where work has to be fitted in the spaces that the day job doesn't fill. I am indebted to my wife, Wendy, to whom this book is dedicated, for her forbearance, not to mention many hours of sub-editorship in putting it together.
The Shorter Oxford Dictionary defines encyclopaedia as ‘a work containing information on all branches of knowledge usually arranged alphabetically or a work containing exhaustive information on some one art or branch of knowledge arranged systematically’. An author who seeks to deliver a product that tries to fulfil these definitions knows that it will be a Sisyphean task. This is especially the case with a subject such as brewing, with its long and rich history, its diversity of processes and products, not to mention the usually strong opinions of its practitioners. In this respect I am well aware that this book will contain errors and omissions and probably an overemphasis on my own particular enthusiasms. For all of these shortcomings I apologise and take full responsibility.

With regard to content, I have tried with each alphabetic entry to give a short initial definition which should provide the reader with all the essential information necessary for understanding such that further time need not be wasted. The remainder of the entry is aimed at those who might wish to have further knowledge. Hopefully, the system of cross-referencing will provide greater context. If there is a related entry the linking word is in **bold**.

Brewing and mainstream science have been inextricably intertwined for much of its history as an organised undertaking. Indeed in its first industrial heyday many fundamental discoveries were made by brewers. For this we should be justifiably proud, although it makes for some difficult decisions when deciding what should be included in a book such as this and what should be omitted. This is all the more so when current scientific advances underpin many of the new processes and plants being introduced into brewing. I have tried to steer a course which I am sure many will disagree with but one in which I hope that additional descriptions will serve to help with better understanding.

Finally, I have tried to encompass all parts of our industry, large and small, traditional and modern. For this I do not offer any apology. I see no distinctions.
**Abbey beers**
Abbey beers are those produced commercially, largely in Belgium, and by statute solely within monasteries either directly or under the supervision of monks. The popularity of Trappist beers in the period following the Second World War provided the impetus for arrangements under which commercial breweries produced beers that used the names of existing, or in some cases fictitious, abbeys as a marketing tool. Commonly the use of a real abbey name involved a licensing agreement. These products are collectively termed Belgian abbey beers. Typically the beers ape the stronger *dubbel* and *tripel* true Trappist beers and in consequence are strong in alcohol, very flavoursome and made by top fermentation prior to bottling and a period of lengthy secondary conditioning.

See [*Trappist beers*](#).

**ABD medium**
Microbiological growth medium (advanced beer-spoiler detection medium) designed by Asahi Brewers of Japan, for the cultivation of difficult-to-grow lactic acid bacteria. The medium comprises *MRS* broth supplemented with beer (to inhibit non-beer spoilers) cycloheximide (to prevent the growth of yeast) and sodium acetate (shown to be stimulatory to many lactic acid bacteria).

**Aber yeast biomass monitor**
Apparatus used for the automatic determination of viable yeast concentration (http://www.aber-instruments.co.uk; last accessed 7 February 2013). The device depends on the dielectrical properties of microbial cells when suspended in fluids that are conducting because of the presence of charged species. When the cells, in this case yeast, are subjected to electrical fields, the charged species in the suspending medium (wort or beer) and those which are intracellular migrate towards the electrode bearing the opposite charge. Since the cell membrane is non-conductive the cells function as capacitors and the magnitude of this can be measured. The total yeast cell membrane area, or biovolume, within the operating field of the electrode can be related to yeast biomass. Providing the sample is well-mixed the derived value of capacitance measured by the instrument can be expressed in the usual units of yeast concentration...
such as viable cells per millilitre or viable yeast mass per unit mass or volume. Dead cells, which have a disrupted cell membrane, do not function as capacitors and are therefore not detected. In this respect the measured capacitance correlates strongly with the fraction of a yeast sample scored as viable by a conventional vital staining approach such as methylene blue. Similarly gas bubbles and non-yeast solids do not generate capacitance and are not detected. A corollary is since dead cells are not detected it does not provide any indication of viability.

Calibration involves setting zero and then determining the relationship between derived capacitance and viable biomass concentration. Strain-dependent differences in electrical properties require calibrations to be made for each individual strain. Once these are entered into the memory of the machine they do not need to be repeated. The linear range of the instrument is approximately $1 \times 10^5$ to $1 \times 10^9$ cells per millilitre. Since the calibration requires comparison of results with yeast concentrations measured using conventional yeast analyses such as methylene blue staining and microscopic cell counting, the absolute precision cannot be better than these relatively crude methods. However, the machine provides excellent repeatability.

Versions of the instrument are sold that are suitable for both laboratory and in-line analyses. The instrument comprises a probe bearing four electrodes, two of which generate the electrical signal and two of which measure the magnitude of the resultant capacitance due to viable cells. All living cells respond in this way and the magnitude of the measured capacitance is frequency-dependent. In the case of yeast cells a value of 0.3 MHz has been found to provide an appropriate response. The probe is inert and resistant to all brewery cleaning regimes. Via a system of electronics the signal can be used to generate a signal which can be integrated with output from a flow meter or load cell such that automatic systems for control of pitching and cropping can be used. In complex in-line systems several probes can be multiplexed via a single controller allowing outputs to be taken from combinations of multiple pitching and cropping mains. Integration of all outputs allows the concentrations of all yeast within the brewery at any given time to be monitored. Apart from control of yeast pitching and cropping the device can be used to control other processes such as krausening, cask beer re-seeding, yeast propagation and continuous centrifuge operation.

The laboratory version makes use of exactly the same technology, but the electrode is placed within an attemperated stirred chamber.

**Abrasion**

A treatment applied to barley grains in which the husk is damaged (but not totally disrupted) by the application of mild mechanical treatments; for example, the use of rotating wire brushes. The treatment enhances rates of germination either by allowing the more rapid entry into the grain of additives such as gibberellic acid but more likely via the increased efficiency of wetting and oxygenation. Abraded grains can be malted at relatively low moisture contents and thereby allow shorter steeping times and lower steeping temperatures.

See [gibberellic acid](#).

**Abscisic acid**

Abscisic acid is a plant hormone with the structure indicated in the following figure.
ACCELERATED BATCH FERMENTATION

It exerts global effects on plants; for example, it is implicated in stress tolerance, stomatal opening, response to pathogens, seed development, apoptosis and the maintenance of dormancy. Its involvement in the latter process is of the most direct relevance to brewing via the control of dormancy in grains that require to be germinated during malting.

The mechanisms by which it exerts its effects are at present not fully characterised, although it appears to have short-term effects as an effector of various cellular processes. In addition, it seems capable of exerting longer-term effects via the modulation of gene activity. Gibberellic acid has an antagonistic effect to abscisic acid.

See dormancy and gibberellic acid.

ABV
ABV is an acronym that stands for alcohol by volume. It is the usual method of denoting the alcohol concentration of beers. The value is provided on packaging as x% abv. Most beers fall within the ranges of 3–10% abv with the vast majority being between 4 and 6%. There are outliers. The Samuel Adams Brewery in the United States produces the beer Utopias, which boasts an alcohol concentration of 25% abv. In most countries there are legal definitions, expressed in terms of ABV, for low- and zero-alcohol beers.

Most countries use the ABV of beers as the mechanism for collecting excise duty. In this regard, it is usual to have bandings such that all beers falling within a certain range of concentrations will attract the same rate of excise duty. This reflects the fact that for many brewers precise control of alcohol content is difficult, and therefore a degree of latitude is given. Naturally, given this situation most brewers will seek to ensure that the actual mean alcohol concentration of any given beer is as close as possible to the middle point of the band. This avoids paying excessive taxation but also ensures that on average the product satisfies the legal requirements.

Since most excise payments are based on self-assessment and, bearing in mind the pivotal role of ABV, the analytical methods used must have suitable precision and repeatability. This has resulted in the adoption of so-called reference methods of analysis which have legal status. Many other methods may be used for routine analyses, based on factors such as rapidity or ease of automation; however, at some stage analyses must be performed using a standard reference method.

Accelerated batch fermentation
Accelerated batch fermentation is an umbrella term that covers a wide variety of approaches which have been developed with the aim of increasing the productivity of batch fermentations by shortening cycle times. For any commercial brewer the capital costs of fermenters and associated plant represent a major investment. This is particularly so in the case of the very-large-capacity vessels used by many of the major world brewers. In addition to capital
expenditure the revenue costs associated with running fermentations must also be taken into account.

Shortening total cycle times for individual batch fermentations is a useful method for increasing the productivity of fermenting vessels. The following example illustrates potential gains.

Assume a tank farm of $30 \times 2000$ hL fermenters with a total cycle time from fill to empty of 14 days:

Total annual productivity $= (365/14 \times 30 \times 2000) \text{ million hL per annum}.$

Assume a reduction in cycle time from 14 to 12 days:

Total annual productivity $= (365/12 \times 30 \times 2000) \text{ million hL per annum}.$

The change in productivity can be viewed in several different ways. The increase in productivity of the existing tank farm is equal to 15%. This would mean the current annual output could be achieved with five fewer fermenters representing a saving in revenue costs. Alternatively, if it were wished to increase volume output this could be achieved without needing to expend the capital costs of five new fermenters. Of course, the latter viewpoint assumes that the rest of the brewery could support the additional volume; however, it is commonly the case that fermentation is the rate-limiting step in the process.

Fermentations can be accelerated in several ways. The usual method is to increase the temperature of primary fermentation and, in so doing, to reduce the time taken to achieve attenuation gravity. All brewing yeast strains have optimum growth temperatures of at least 30°C and therefore considerably higher than the temperatures actually used for fermentation. However, this approach must be followed with care since higher fermentation temperatures can adversely perturb the concentrations of many important beer flavour components produced by yeast during fermentation. Nevertheless, many pilsner-type lagers that historically were fermented at low temperatures (5–10°C) are now produced at temperatures more associated with ales (15–20°C).

The use of relatively high fermentation temperatures for the production of pale lagers is somewhat controversial. Many brewers claim that the delicate nuances associated with traditional lager beers are lost when high-temperature rapid regimes are used. Indeed, the long fermentation times used in the brewing of such beers, which may extend to several weeks, are used as a mark of excellence. Appellations such as ‘slow brewed’ are used as marketing tools and adherents of this ideology would argue that many of the major brewers are willing to sacrifice quality for financial gain. The high quality of the traditional lagers cannot be gainsaid; on the other hand, the majority of scientific advances that have been made with regard to elucidating relationships between yeast metabolism and beer flavour have been carried out using model systems based on the high-temperature rapid method. These have shown that with knowledge of the appropriate metabolic triggers and responses it is possible to make beers with acceptable flavour profiles and in a predictable manner.

Predictability is another important consideration. The benefits obtained by shortening fermentation cycle times are much reduced in value if there is much variability. The latter is not uncommon in many breweries; thus, a nominal cycle time of, say, 14 days can quite easily in practice mean 12–16 days, or even worse. In this situation capacity planning is difficult. In order to obtain more constant cycle times it is necessary to regulate with the best achievable
accuracy and repeatability all those parameters that influence fermentation performance. In this regard, advances in control of basic parameters such as temperature, pitching rate and wort oxygenation have eliminated a great deal of variability. Undoubtedly variability in the composition of raw materials such as malts will always present some uncertainties. However, these can often be compensated for by adjusting parameters such as pitching rate and/or wort oxygenation. Further work remains to be done regarding the influences and causes of variability in pitching yeast physiology.

The whole of the cycle time must be considered when looking at ways of shortening it as only times for filling, emptying and cleaning in place (CIP) are generally immutable. Where practised reduction in the duration of VDK stand times is possible. The use of enzyme preparations, where permitted, containing α-acetolactate decarboxylase (see Maturex®) will eliminate the need for a warm rest as will removal of diacetyl via the use of immobilised yeast technology. A significant portion of the cycle time for many fermentations is taken up by crash cooling. With very large fermenters this can account for up to 24 hours. It is possible to reduce this by half by introducing a method of agitating the vessel contents during the cooling phase. Alternatively, vessels may be racked warm and beers chilled in-line during transfer to the next stage of brewing.

**Acetic acid bacteria**

Gram-negative beer spoilage bacteria that are able to oxidise ethanol to acetic acid. This ability is exploited for the industrial manufacture of vinegar. Two genera are recognised, *Acetobacter* and *Glucobacter*. Both are pleomorphic occurring as straight or curved rods or spheres or stages in between and may be motile or non-motile. They are tolerant of hop acids and ethanol but are obligate aerobes; therefore, spoilage occurs in finished beer where there is inadvertent ingress of air, such as may happen during dispense of cask ales. Spoilage is characterised by sour acid flavours as a result of the formation of acetic acid. Growth is evident in the form of ropes, slimes and surface pellicles.

**Acetobacter**

See acetic acid bacteria.

**α-Acetohydroxybutyric acid**

α-Acetohydroxybutyrate is an α-acetohydroxy acid which is an intermediate in the pathway that leads to the synthesis of the amino acid isoleucine by yeast. Its greater significance in brewing is that it is the immediate precursor of the important vicinal diketone 2,3-pentanedione.

The structure is CH₃·CO·COH·CH₂·CH₂·COOH.

See diacetyl cycle.

**α-Acetolactate decarboxylase**

α-Acetolactate decarboxylase (ALDC) (EC 4.1.1.5) is an enzyme that catalyses the decarboxylation of its substrate to yield acetoin and CO₂. It occurs in several bacteria including strains of *Bacillus* and *Lactobacillus*.

Commercial preparations of the enzyme are available and these are used, where permitted, as additives in fermentation (Maturex®, Novozymes, brewing@novozymes.com). The presence of the enzyme in fermenting worts converts the substrate directly to the relatively non-flavour
active compound acetoin and, in so doing, prevents or reduces the formation of the vicinal diketone diacetyl. The net effect of this is to shorten fermentation times.

Commercial preparations of the ALDC enzyme are obtained from a recombinant strain of *Bacillus subtilis* in which the responsible gene *AldB* was isolated from a strain of *Bacillus brevis* using a plasmid initially cloned into *E. coli*, B12.

The enzyme has also been cloned directly into brewing yeast strains such that these have a reduced ability to produce diacetyl during fermentation. The utility of these transgenic strains has been demonstrated successfully, although owing to the perceived reluctance of the public to accept beers made in this way none of these yeast strains are currently used in commercial brewing.

See diacetyl cycle.

**α-Acetolactic acid**

α-Acetolactate is an acetohydroxy acid that is an intermediate in the pathway leading to the synthesis of the amino acid valine by yeast. Its greater significance in brewing is that it is the immediate precursor of the important vicinal diketone diacetyl.

The structure is CH$_3$·CO·COH·CH$_3$·COOH.

See diacetyl cycle.

**Achel**

One of the Trappist monasteries of Belgium producing Trappist beers.

See Trappist beers.

**Acidification power test (AP test)**

Name given to a test used to assess yeast vitality in which the ability of a suspension of brewing yeast to acidify the external medium is assessed and which produces results that can be used to predict subsequent fermentation performance. Acidification occurs as a result of the proton exclusion via the activity of the membrane-bound H$^+$ ATPase. The classical test has two components: firstly, the spontaneous acidification when yeast is initially suspended in the test medium (AP1), and secondly, acidification in response to added sugar, usually glucose or maltose (AP2). Typically each component is measured over 10 minutes at a defined temperature and with a known yeast concentration. Both parts of the test are related to membrane functionality. The magnitude of AP1 is related to the availability of endogenous glycogen stores (which is reflective of prior yeast handling); whereas AP2 provides a measure of glycolytic flux.

Several modifications to the basic test have been made. The cumulative acidification test measures the change in absolute proton concentration with respect to time, which allows consideration of both transient increases and decreases in pH, which has been observed for some yeast samples, and, in addition, it avoids the problems associated with detecting comparatively small changes and the logarithmic nature of the pH scale. In the titratable AP test the pH is held at a constant value and the amount of NaOH that is required to be added to accomplish this is measured. The vitaltitration yeast vitality test [acidification power test (AP test)] test uses a procedure in which the initial pH is adjusted to pH 10.0 and the time taken for a yeast sample to reduce this to pH 6.5 (the usual intracellular pH of yeast cells) is determined.

See yeast vitality.
**Acid malt**

Acid malts are those which are manufactured in such a way that they contain lactic acid. The acid component is used to control the pH of the wort. This may be necessary where the brewing liquor does not contain the appropriate balance of minerals to ensure that the pH is sufficiently acid to ensure good rates of saccharification and proteolysis. This can be the case where very soft brewing liquor is used as in traditional lager brewing. The advantage of controlling wort pH in this manner is that it does not impinge on the restrictions of the Reinheitsgebot.

Acid malts typically contain high nitrogen levels and have high cold water extracts. They are used at rates in the region of 3–10% of the grist. The malts contain in the region of 2.0–2.5% lactic acid. The malts do not break the rules of the Reinheitsgebot since the lactic acid is produced naturally via the action of lactic acid bacteria. Several processes may be used to encourage the growth of the bacteria. Grains may be macerated, which releases grain sugars, followed by an anaerobic rest during which the bacteria multiply and acid production ensues. Alternatively the natural bacterial flora may be enhanced by spraying cultures of lactic acid onto green malt suspended in water followed by incubation at 50°C for up to 36 hours and prior to kilning. In another procedure kilned malt is steeped in water during which lactic acid bacteria grow and acidify the medium. The mass is then kilned such that the lactic acid remains associated with the dried grains. Where the rules do not prohibit the practice lactic acid may be added directly to steep water.

**α-Acids**

α-Acids are the precursors of the principal hop-derived bittering components of beers. They are isomerised during the kettle boil to yield the bitter iso-α-acids.

See [hop isomerisation](#).

**β-Acids**

Beta (β-) acids, together with α-acids and the uncharacterised fraction, form the soft fraction of hop resins. Typically they comprise between 3 and 10% of the total dry weight of baled hops. Chemically the β-acids comprise mainly lupulone, colupulone and adlupulone (see diagram for structures).

![Structure of hop β-acids](#)

*Structure of hop β-acids, where R = CH₃CH(CH₃)₂, lupulone; R = CH(CH₃)₂, colupulone; R = CH(CH₃)₂CH₂CH₃, adlupulone*
β-Acids are of little value in brewing, although they can be modified chemically to produce bitter compounds; however, owing to the presence of the three isoprenyl groups they are potent antibacterial agents.

β-Acids are subject to oxidation during prolonged storage of hops, the principal products being hulupones. The latter are intensely bitter and may contribute to overall bitterness in some beers. A multitude of other products of auto-oxidation have been isolated, the effects of which on stored hops, and beers made from them, are probably negative.

See hop resins.

**Acid washing**

Treatment used for the disinfection of pitching yeast based on the relative acid tolerance of brewing yeast compared to many common bacterial contaminants (but by definition not wild yeast).

Best practice requires a treatment using a food-grade acidulant, usually phosphoric acid but occasionally sulphuric, in which the yeast slurry is held at pH 2.2 (±0.1) at 3°C (±1) for at least 1 hour but no longer than 2 hours. Care must be exercised to ensure that the acid is dosed in a manner that ensures that the pH of all of the slurry is gradually reduced without the formation of ‘hot spots’. Yeast with a viability less than 90% should not be acid washed. Commonly the process terminates when the slurry is pitched. If this is delayed the slurry pH must be increased to around pH 4.0 using sterile NaOH. Ammonium persulphate, a powerful oxidising agent, is sometimes incorporated into the acid at a concentration of around 0.75% w/v. This reportedly increases the potency of the treatment against bacteria such that a higher pH (up to pH 2.8) may be used, thereby reducing the risk to yeast viability.

**AC Metcalfe**

A two-row variety of malting barley which was placed on the US approved list in 2005 originally bred in Canada, hence, AC, Agriculture Canada, and registered in 1994. It was the most successful of a batch of new varieties that included CDC Kendall, CDC Stratus and CDC Copeland, which were viewed as replacements for the popular but fading Harrington variety.

**Acridine orange**

A fluorescent dye (Systematic name: 3-N, 3-N, 6-N,6-N-tetramethylacridine-3,6-diamine) that binds to nucleic acids. DNA and RNA can be distinguished based on the colour of fluorescence following excitation with light of an appropriate wavelength. It has been suggested, probably incorrectly, that it can be used as a viability dye based on the assumption that nucleic acids are rapidly degraded after death. More commonly it is used in a double staining technique with a dye such as propidium iodide, where the latter is used to stain viable cells.

See yeast viability.

**Acrospire**

In brewing terminology the acrospire is the name given to the leaf sheath or coleoptile of barley. Together with the scutellum, rootlets and coleorhiza it forms the embryo. During germination of the grain the acrospire grows under the husk along the dorsal side of the grain. Assessment of the length of the acrospire is used to gauge the progress and uniformity of
modification during the malting process. Where acrospire lengths are not uniform this is indicative of uneven germination or possibly mixing of grains of differing quality. For the purpose of the assessment the length of the acrospire is judged relative to the length of the grain. In the system used in North America where the grain length is 1, the acrospire length is classified as being within the ranges 0.0–0.25, 0.25–0.5, 0.5–0.75, 0.75–1.0 and >1. This is also referred to as the acrospire profile. In good quality malts a high proportion, typically more than 85%, of the acrospires should fall within the 0.75–1.0 range. Some grains produce acrospires that are greater in length than the grain. These are referred to as being overgrown corns or huzzars, cockspurs or bolters. From a malting standpoint these are undesirable since they are usually rich in enzyme content but deficient in extract. When the acrospire length has reached 0.75–0.88 of the relative length of the grain the hot and cold water extract values and concentration of total soluble nitrogen substances cease to increase with further germination time.

**Acrospire profile**
An assessment of malt quality based on an assessment of the length of the acrospire relative to that of the grain.

*See acrospire.*

**Actidione**
Synonym for cycloheximide.

**Activated carbon**
Activated carbon, also known as activated charcoal (or active carbon, charcoal) is used as a filtration medium, particularly as one of usually many steps used in the purification of water destined for use in brewing. In particular, treatment with this material is used to remove organic impurities (see water for more details). The process is usually referred to as carbon filtration.

The material relies on surface adsorption for operation. The term activation refers to the treatments used in its preparation in which it is rendered into a form in which the ratio of surface area to mass is very large.

Activated carbons are prepared from a variety of starting materials including various coals or coal derivatives or plant materials such as woods or the kernels of seeds. The preparation involves pyrolysis of the raw material at high temperature under anaerobic conditions followed by activation in which the carbonised material is oxidised by heating in the presence of oxygen or another oxidising atmosphere. In addition, various chemical treatments may also be incorporated into the production process. A range of chemical additives can also be incorporated into the carbon to provide additional functionalities. For example, silver nanoparticles can be added to impart antiseptic properties.

The activated carbons are supplied as granules, powders or extruded forms. Each of these forms is tailored towards specific applications. For water treatments powdered types can be used in the form of columns where the process flow passes through a bed of carbon. In other applications the carbon may be supplied in the form of impregnated sheets through which the liquid to be treated is passed.

After use the carbon must be regenerated, typically via a heat treatment.
**Activated charcoal**
See activated carbon.

**Active dried yeast**
See dried brewing yeast.

**Adhulpone**
A product of the auto-oxidation of hop $\beta$-acids.
See hulupones.

**$\alpha$-Adhumulone**
$\alpha$-Adhumulone is one of the principal hop-derived $\alpha$-acids which are the precursors of the bittering components of beer.
See hop isomerisation.

**Adjunct mill**
Adjunct mills are those that are set up specifically to process certain types of solid adjunct. They are used where the solid adjuncts require a very different milling treatment to that which is applied to malts. Examples of these adjuncts are various whole grains of sorghum, wheat or oats, or derivatives of these. The mills may be hammer or roller types (see the relevant entries for details); however, they are set up to suit the nature of the particular adjunct being used. Of course, the same mills may be used for the production of all grists, but many brewers find that better overall process efficiencies can be obtained if separate mills, sometimes of different types, are used, for example, a hammer mill for the treatment of adjuncts and a roller mill for the treatment of malts.

**Adjuncts**
Adjuncts are defined simply as sources of extract other than malt. A wide variety of materials may be used. They may be employed purely on the basis of cost or because they impart desirable properties to the beer which may not be achieved by the use of malt alone. Commonly particular adjuncts may be used in certain geographical locations where they are plentiful and therefore by inference inexpensive, for example, the use of rice in many North American beers. In countries subject to the strictures of the Reinheitsgebot the use of adjuncts is prohibited. In some countries the use of adjuncts provides tax advantages, for example, the happoshu-type beverages of Japan.

Adjuncts are typically derived from various cereals. These may be relatively unprocessed raw cereals or semi-purified extracts. Adjuncts may be liquid or solid. In the case of liquid types they take the form of various sugar syrups. Typically these may be added to wort during the boiling stage, and for this reason these are often referred to as copper (kettle) adjuncts. The reason for addition at this stage is a convenience since it bypasses the solid handling wort preparation stages and the heat treatment ensures sterility. Addition of these materials to the copper does come at some financial cost owing to the proportion of energy used to heat it. Since this heat treatment serves no purpose other than sterilisation there is no reason why the syrup adjuncts cannot be added after wort cooling and pre-fermenter fill (providing that
the microbiological standard of the syrup is adequate). Liquid adjuncts are commonly used as a convenient method of producing highly concentrated worts required for high-gravity brewing. Liquid adjuncts may also be added post-fermentation, for example, as priming sugars, added to adjust the flavour and/or colour of finished beer or as a source of fermentable extract in those beers which are subjected to a secondary conditioning process.

Solid cereal adjuncts require some form of processing in order to release the starch and render it available and susceptible to the activity amylases. At their simplest they take the form of relatively pure solid sugars, which are dissolved in water prior to use. In the case of most solid adjuncts the pretreatment entails milling and mashing, either as an admixture to the malt grist or via a separate treatment in plants dedicated to this purpose. For this reason such materials are referred to as **mash tun adjuncts**. Some solid mash tun adjuncts such as flaked maize and torrefied wheat have been pre-cooked and do not require to be mashed, while others require to be cooked. The treatment that is required to release the sugars from solid adjuncts is dependent upon the gelatinisation temperature of the starch grains. If similar to malted barley the adjunct may be processed with the malt in the mash tun. If the gelatinisation temperature is higher than that of malt a separate dedicated cereal cooker is required (see [cereal cooker](#), [gelatinisation](#) for more details). Depending on the nature of the adjunct it may be entirely devoid of hydrolytic enzymes. In this case exogenous enzymes may be required to release the extract or those present in the malt must be used. The option chosen has an influence on the nature of the mashing regime and plant employed.

<table>
<thead>
<tr>
<th>Liquid adjuncts</th>
<th>Comments</th>
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<tbody>
<tr>
<td>Cane sugar syrup</td>
<td>Sucrose syrup obtained from cane or beet</td>
</tr>
<tr>
<td>Invert sugar</td>
<td>Syrup obtained via inversion of sucrose and containing equal mixtures of glucose and fructose</td>
</tr>
<tr>
<td>Starch-based syrups</td>
<td>Generic name for a variety of syrups produced by acid or enzyme hydrolysis of cereal starches. The precise composition can be controlled to produce syrups with desired properties such as fermentability. For example, high-dextrin syrups are of limited fermentability and are used to impart body to beer; conversely, high-maltose syrups are highly fermentable and are used purely as sources of extract. Depending on the purity some starch-based syrups also contain significant concentrations of nitrogenous compounds as well as other components.</td>
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<tr>
<td>Dextrose syrup</td>
<td>Glucose syrup, also known as corn sugar, prepared via the hydrolysis of corn starch.</td>
</tr>
<tr>
<td>High-fructose corn syrup</td>
<td>Also known as HFCS, isoglucose, or glucose–fructose syrup. It is prepared from corn starch glucose via treatment with glucose isomerase to produce a mixture primarily of glucose and fructose. The product of the enzymic treatment is blended with glucose in varying proportions to produce a syrup with desired properties. Different grades of the syrup are denoted by the acronym HFCS followed by a number that indicates the relative proportions of fructose and glucose; for example, HFCS-55 contains 55% fructose, 45% glucose. HFCS is used as a priming sugar since it is sweeter than pure glucose syrup, it is liquid, and in some markets less expensive than sucrose syrup.</td>
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**ADJUNCTS**

<table>
<thead>
<tr>
<th>Liquid adjuncts</th>
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<tbody>
<tr>
<td>Malt extract</td>
<td>A liquid syrup made via the hydrolysis of cereal grains, clarified and concentrated by vacuum evaporation. The composition of the extract is complex and uncharacterised. Various sugars are present together with nitrogenous and other compounds derived from the cereal grains. The precise composition depends upon the gist and the mashing conditions; thus, the activities of hydrolytic enzymes may be retained or destroyed. The use of exogenous enzymes may be used to manipulate the sugar content and spectrum. Malt extracts are widely used by micro- and home brewers.</td>
</tr>
<tr>
<td>Liquid malt</td>
<td>Sometimes used as a synonym for malt extract (see above). Also, a product used in German brewing made by mashing unskilled green barley followed by concentration and removal of undesirable flavour components. Although the material is used as an adjunct its use for the production of beers subject to the restrictions of the Reinheitsgebot is permitted. As such it can be used as an additional source of enzymes.</td>
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<tr>
<td>Caramels</td>
<td>Usually electropositive type III caramels prepared via heating pure sugar syrups with ammonia to give a range of highly coloured and flavoured liquid products used for adjusting colour and/or taste. Used as copper (kettle) adjuncts or added to finished beer.</td>
</tr>
<tr>
<td>Miscellaneous syrups</td>
<td>Syrups prepared from hydrolysed potato starch are used by some brewers; in addition syrups made from honey or maple are used in certain beers.</td>
</tr>
<tr>
<td>Solid adjuncts</td>
<td></td>
</tr>
<tr>
<td>Coloured malts</td>
<td>Speciality malts that have been produced under conditions which impart changes in colour and flavour are used widely as adjuncts to adjust colour and flavor, in particular, where the use of other process aids is subject to regulation.</td>
</tr>
<tr>
<td>Malted cereals</td>
<td>Several cereals may be malted to produce a product analogous to malted barley grains. These include true cereals such as wheat, oats, rye and sorghum; in addition, pseudo-cereals such as buckwheat and quinoa.</td>
</tr>
<tr>
<td>Raw cereal grains</td>
<td>Raw barley grains may be used as adjuncts. The grains are hard and require hammer milling; however, the starch granules have the same gelatinisation temperature of malted barley grains and no separate cooker is required. The hard husks assist with wort clarification in lauter tuns. Low endogenous enzyme levels usually require the use of exogenous enzymes and worts may be viscous owing to the presence of high ß-glucan levels. Problems with beer hazes may also arise from overuse. The germs of maize grains contain appreciable lipid, and in order to avoid deleterious effects on beer foams degerming is required before use as adjuncts. For this reason maize grains require some processing before use (see grits, flaked cereals). Rice adjuncts are supplied in the form of milled products that comprise almost pure endosperm made from short-grain varieties and have a low nitrogen content. The starch gelatinisation temperature is high and a separate dedicated cereal cooker is required. In addition, fine pre-milling is needed. Varieties must be low lipid types in order to prevent problems with flavour stability and depression of ester formation during fermentation. Sorghum starch granules have high gelatinisation temperatures (71–80°C) and, as with rice, require a dedicated mill and cereal cooler. When used at too high a proportion problems with low pH, high viscosity (poor run-off) and low free amino nitrogen (FAN) can occur. The use of exogenous hydrolytic enzymes is also required.</td>
</tr>
<tr>
<td>Liquid adjuncts</td>
<td>Comments</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Raw cereal grains</td>
<td>Unmalted wheat, blended with malted barley is used in the production of many traditional white beers. Used at high proportions it causes problems with wort viscosity and wort fermentability but it does have the advantage of conferring excellent beer head properties. For the latter reason small amounts are commonly incorporated into the grists of lager beers. Raw grains of <em>Triticale</em> are attracting interest as a source of adjunct. They contain high endogenous levels of amylases; the starch granules have low gelatinisation temperatures and contribute significant FAN.</td>
</tr>
<tr>
<td>Grits</td>
<td>Grits are derived from cereal grains from which the hull and germ have been removed and thus they comprise more or less pure starch. As such they require to be cooked. Grits of maize, rice, sorghum and barley are used as adjuncts.</td>
</tr>
<tr>
<td>Flaked cereal grains</td>
<td>Flaked cereal grains of maize, rice, pearl barley and oats may be incorporated into grists as solid adjuncts. They are pre-cooked as part of their preparation and thus do not require to be gelatinised.</td>
</tr>
<tr>
<td>Torrefied grains</td>
<td>Torrefied whole unmalted grains, usually of wheat or barley, are prepared by heating such that the kernels split and they increase in volume. The heating process gelatinises the starch grains. Torrefied grains may be used as a source of extract, but they are also a good source of head retaining proteins.</td>
</tr>
<tr>
<td>Micronised grains</td>
<td>Micronised grains (maize, barley or wheat) are similar to torrefied types. They are produced by applying heat to ceramic tiles such that they emit radiant heat. The grains are arranged in thin layers and allowed to pass below the heated tiles such that they achieve a temperature of approximately 140°C. The heating process dries the grains and causes them to swell and rupture. During the heat treatment the starch grains gelatinise.</td>
</tr>
<tr>
<td>Extruded grains</td>
<td>Raw sorghum grains can be extruded in a treatment in which they are subjected to a heat treatment of 150–200°C (optimum 175°C for the most efficient filtration). This causes the starch granules to gelatinise.</td>
</tr>
<tr>
<td>Flours and refined starches</td>
<td>Refined starches are purified from a variety of plant sources including wheat, barley, corn, cassava or potato. They represent the purest form of mash tun adjunct. They may be sold as flours or used to make syrups. Where they have low gelatinisation temperatures they may be incorporated directly into mashes; otherwise they require pre-cooking. The purer forms cause no problems with run-off and do not contribute significant flavour; however, they are generally low in nitrogen. Flours, especially wheat, may be used as adjuncts. Wheat flour is essentially pure endosperm. It is produced by a process of milling and sieving, which separates the endosperm material from other contaminating materials. Most often, for brewing, the flour is further purified to produce a product that is low in nitrogen. For brewing, flours are combined with a binding material that increases the average particle size and reduces dust formation. The product has the same advantage and disadvantages of raw wheat, that is, good head formation but high wort viscosity.</td>
</tr>
</tbody>
</table>

The use of adjuncts is very common, and indeed very few brewers produce beers from all-malt grists. Much dedicated plant is required for the use of individual adjuncts. Apart from storage and handling facilities many solid adjuncts require dedicated adjunct mills and cereal cookers. Most concentrated liquid syrups do not require microbiological precautions.
to be taken since the low water activity prevents growth. However, many of these syrups are highly viscous, making them difficult to pump; in addition many have a tendency to set when cooled, and consequently holding tanks and transfer mains must be heated (usually 45–55°C).

All adjuncts must be used with great care. Many impart desirable properties such as good head retention in beers (wheat flour) or neutral clean flavours (rice). Conversely, some may be associated with haze problems or poor run-off owing to high β-glucans (raw barley). Relatively pure sources of starch or refined sugars are good sources of fermentable extract but tend to have low nitrogen contents such that injudicious use may lead to low-FAN worts with concomitant effects on yeast growth and the formation of yeast-derived flavour compounds.

**Adlupulone**

Adlupulone is one of the principal components of the β-acid fraction of the soft fractions of hop resins.

See β-acids, hop resins.

**Admiral**

A UK-bred hop variety. It is wilt-tolerant, contains 13–16% α-acids, and is generally used for bittering in UK-style ales.

**Ageing**

The term ageing as applied to the brewing process is principally of US usage and is used to describe the period of storage of green beer during which secondary fermentation and other changes occur which are associated with the maturation of green beer. It is a synonym for beer maturation, conditioning or lagering.

In another sense the term may also be encountered with respect to the changes in beer quality which occur after packaging. In this case the ageing processes are undesirable and associated with degenerative staling changes which define beer flavour stability.

See secondary fermentation.

**Agnus**

Agnus is a relatively new high alpha Czech hop variety registered in 2000. Its family tree contains Northern Brewer, Saaz hop, Fuggles and Sladek varieties. It contains 11.9–16.1% total α-acids (29.4–36.3% cohumulone), 3–6% β-acids. Total oils are 1.99–2.84% (10.2–11.6% caryophyllene, 0.05–0.1% farnesene, 16.2–20.0% humulene, 45.6–50.51% myrcene).

**Ahil**

Ahil is a hop variety, one of the four original Super Styrian high alpha varieties, together with Atlas, Apolon and Aurora, bred in the 1970s at the Hop Research Institute at Zalec, Slovenia. It derives from Brewer’s Gold and a Slovenian male. It contains 10–12% total α-acids of which 25% is cohumulone. Total β-acids and oils are 4–5% and 1.8–2.2%, respectively. Storage properties are fair.
**Ahtanum**  
US-bred aroma hop variety containing 5.7–6.3% α-acids.

**Air-dried malt**  
See wind malts.

**Air rest**  
An air rest is a stage in the steeping process of malting in which the bed of grains is drained of water and replaced by a stream of air. This removes oxygen-depleted steep water and exhausts CO$_2$ whilst replenishing the supply of oxygen. Usually one or two air rests are performed during a typical steeping process. The aim is to ensure that the grains are not deprived of oxygen, which would prevent rapid and even germination. The process is necessary since aeration of steep water alone is insufficient to ensure continuous aerobiosis.  
See steeping.

**Ajon**  
A beer native to Uganda made from malted millet.  
See native African beers.

**Akcent**  
See Valtický.

**Albumin**  
Albumin is the collective term for a group of proteins. They occur in all living cells. They are distinguished from globulins, the other major class of soluble protein, based on the fact that they are soluble in salt solutions but not in pure water. They are coagulable by heat.  
In beers they derive from malts and other sources of extract with significant nitrogen content. Along with globulins they are major contributors to beer foams.

**Alcohol**  
Alcohol is a term used within the brewing and beverage industries and colloquially for ethyl alcohol. The term is used incorrectly in that alcohol is, of course, a generic name for organic compounds in which aliphatic types have the general formula C$_n$H$_{2n+1}$OH. Alcohols may be defined as organic compounds in which one, or more, hydroxyl groups are substituted for a hydrogen atom that was attached to a carbon atom. Ethyl alcohol (CH$_3$CH$_2$OH), the component of beers which has mind-altering properties, has several synonyms; ethanol, ethyl hydrate, fermentation alcohol, grain alcohol, grain spirit, pure grain alcohol, grain neutral spirit, neutral spirit. It may be noted that some of these terms refer to the source from which the alcohol was obtained. For example, grain spirit refers to the bland, colourless preparation of virtually pure ethyl alcohol which is obtained from the distillation of fermented preparations of grains.  
The etymology of the word is unknown. The prefix *al*, the definite article in Arabic suggests a Middle Eastern source. Indeed, the process of distillation was obtained by the early European
alchemists from Islamic scientists. It has been suggested that the second part of the word derives from Arabic al-
kuhl, pertaining to the preparations of antimony sulphide used for cosmetic purposes. In this case the term derives from the Arabic name for stibnite, the mineral from which the cosmetic was produced. This seems unlikely other than the fact that the cosmetic was produced by a process of sublimation, and by inference this might have had usage as a general term for distillation. Further weight is added to the unlikely link between alcohol and antimony by virtue of the fact that the modern Arabic term for alcohol is alkhwl. This appears to derive from al-ghawl, meaning a spirit. This would appear to be a more satisfactory route for the modern English word.

**Alcohol chill haze test**
The alcohol chill haze test, also known as a Chapon test, is used to assess the colloidal shelf life of beer. It is intended to be applied to bright beer and can be used to predict shelf life or as an indicative method of the effectiveness of stabilisation treatments.

A 200 mL sample of degassed beer is attemperated to 20°C and the haze is measured using a nephelometric haze meter. Pure absolute ethanol (6 mL) is added, and after mixing, the beer is attemperated to −5°C. After exactly 40 minutes the haze is again measured. The increase in haze provides a measure of chill haze. The magnitude is inversely related to the expected shelf life of the beer.

**Alcoholic proof**
Alcoholic proof is an archaic system used to define the alcoholic concentration present in beverages. It was usually applied to distilled spirits. Different scales of alcoholic proof are used in the United Kingdom and in the United States, respectively. In the United States alcoholic proof is twice the concentration of alcohol measured as ABV (% abv). In the United Kingdom the alcohol proof value is obtained by multiplying the value in % abv by 1.75. In the majority of countries alcoholic strength is now expressed as ABV (% abv).

The system of alcoholic proof arose in the United Kingdom at a time when precise analyses were not possible. In order to gauge alcoholic strength in concentrated form, such as distilled beverages, a test was performed in which gun powder was placed in the liquid. If the mixture was capable of sustaining combustion, it was declared to be ‘proof’. The scales derived from the fact that it was subsequently shown that this required the liquid to have an alcoholic content of at least 57.15% abv. An alcoholic solution containing this proportion of ethanol was therefore defined as being 100° proof.

**Alcolyzer**
Alcolyzers are devices designed for the rapid and automatic analysis of the concentration of ethanol in beers and other alcoholic beverages. The instruments use near infrared spectroscopy as the basis of analysis. Commonly the instrument may also incorporate a digital density meter of the oscillating U-tube variety (see density meter for more details). The combined instrument is capable of determining ethanol concentration and specific gravity and, by calculation, original extract (original gravity). More complex combinations of these instruments are also available which are capable of even more multiple analyses, for example, pH, colour and dissolved oxygen.
ALDC
Acronym for the enzyme with significance for diacetyl management, α-acetolacate decarboxylase.

See α-acetolacate decarboxylase.

Ale
Ale is the term used to describe a specific class of beer. The word apparently derives from Scandinavia as in the Norse, oel or aul. In current usage the term ale refers to beers that are produced by a fermentation that is characterised by the use of a yeast strain that during the growth phase separates from the green beer by rising to the surface. Hence, such ale strains are referred to as being top fermenting; the beers are described as being produced via top fermentation, and the fermentation vessels are designed to accommodate the formation and collection of a top crop.

In general, ale fermentations are performed at a relatively high temperature, typically 18–22°C, using worts that are made by infusion mashing and employing a mash tun. There is an enormous variety of ales. As a group they tend to be moderately to strongly hopped and they are often classified on the basis of colour. Thus, pale ales are golden in colour and are usually quite bitter in taste (hence ‘bitter’ as a descriptor for this category). Mild ale and brown ale are darker in colour and are usually sweeter than pale types. Very dark types include stouts and porters.

The combination of specific ale yeast strains and comparatively high fermentation temperatures favours the formation of higher alcohols, and in consequence ales tend to have more robust flavours and aromas in comparison with paler lager beers.

Ales predate pale lager-type beers and in this regard the latter tend to have a more traditional image. Thus, many traditional UK-style ales, also termed real ales, are made using a process in which the fermentation stage is completed in the cask (or bottle) from which the beer is dispensed.

The long provenance of ales explains the use of the high fermentation temperature. These products were originally produced in parts of the world where, prior to the introduction of refrigeration, it was not possible to control the fermentation and storage stages at the low temperatures generally considered to be essential for lager production. This explains the schism between UK-style ales and mainland European lagers in that only in brewing of the former was the climate lent amenable to low-temperature beer production. This suggestion is further evidenced by the altbier beers of Germany, literally ‘old’ beers that are clearly of the ale type. Similarly, majority of early US beers were produced by the first waves of UK immigrants and were of the ale variety. It was only later when European immigrants in the Milwaukee area realised that, during the winter months, access to ice from the nearby Great Lakes would allow low-temperature fermentation and lagering to be performed.

In more historical times in the United Kingdom the term ale was used for an un-hopped product and therefore could be distinguished from a hopped ‘beer’. Since the introduction of hops into the United Kingdom was a comparatively late development in brewing, probably in the fifteenth century, the term ale later acquired a sense of being older and more traditional. For example, the products derived from early commercial breweries were often referred to as
beers, whereas those from contemporary domestic breweries were called ales. Similarly, beer acquired an urban dimension, whilst ale had more rural connotations.

Several qualifying terms may be used in conjunction with the word ale, which add other layers of meaning. Frequently these are now of historical interest only; nevertheless some are mentioned here for the sake of interest. An ale-wife was a female brewer (or sometimes just a beer retailer). The product was sold in an alehouse.

In the medieval period ale was the principal beverage that was consumed on celebratory occasions. For this reason the word ale was often appended to a term that indicated when, where or to whom the celebration was to be dedicated. There are many examples; to whit, leet-ales (appertaining to the days during which manorial courts sat), lamb-ale (a celebration of the spring sheep shearing), bid-ale (the name given to feasts at which the invitees were expected to raise funds, or 'bids', for specific causes). Church-ales were ecclesiastical events at which the sale of beer by church wardens raised funds for the upkeep of the church and provide alms for the poor. Commonly these ecclesiastical feats were held at specific times of the year and the name might be associated with this, for example, Whitsun-ales. Clerk's-ale was a feast associated with Easter and, as the name suggests, was aimed at fundraising for parish clerks. Cuckoos-ale was simply a period of celebration associated with rural areas of England and was held after hearing the first cuckoo of spring. College-ales were festivals held at specific times at universities which had their own on-site breweries. Bridal-ales refer to the practice of a bride selling beer to the guests at her own wedding with the intention of raising funds to pay for the celebration and the future life of the married couple.

**Ale-conner**

An ale-conner was an official in the United Kingdom who was charged with assessing the quality of beer. In medieval England, supposedly, the ale-conner had a uniform that included a pair of leather trousers. The assessment was carried out by pouring a small puddle of the beer under test onto a wooden seat. The ale-conner would sit in the beer for a defined period of time after which he would attempt to stand up. If the leather breeches had stuck to the by now dried residue of beer, it was considered to be 'strong' and of good quality. The veracity of this version of the ale-conner's craft seems rather far-fetched since presumably, if the beer was sticky and by inference high in sugar, it might not be strong in the alcoholic sense. Whilst it is true that brewers of this era, or the consumers of their products, would have few, if any, methods of measuring beer strength, it seems far more likely that rather than adopt this time-consuming approach they would simply taste the beer and, in so doing, use the more accepted and reliable method of quality assessment. By way of interest it may be noted that the father of William Shakespeare was recorded as being made an ale-conner for Stratford-on-Avon in 1557.

Irrespective of the methods used for testing beers these officials had much power as this extract dated 1464 taken from the records of the Ancient Trade Guilds and Companies of Salisbury

Touching the quality and price of ale and beer brewed within the said city. First, every brewer is to make a good wholesome brew of sufficient strength, and every flagon of the better ale is to be sold for one penny, and of the second ale three flagons shall sell for one penny, until a new Assize be
ordained by the officers, and thirteen flagons of the better ale shall sell as a dozen, and six flagons of
the said ale with a pottle shall sell as a half dozen, and likewise of the second ale according to its
price. Item, there are to be four tasters, to wit one to each ward, to taste and assay the ale brewed
from time to time in their several wards within the house of every inn-keeper when the ale shall be
in a certain vessel called the Kyse, as well in respect of its soundness as of its strength and flavour;
and if by them, or any of them, it shall be found defective in point of brew, to wit, in soundness or
strength or flavour, forthwith within twenty-four hours they shall be bound to bestir themselves and
present the defect or defects found by them to the Mayor, Seneschal and bailiff, or two of them, to
the effect that the tavern in which the said ale was found be forfeited to the Lord Bishop without
fine and redemption. And every inn-keeper aforesaid shall carry or cause to be carried his ale to his
customers and other men without taking any portage therefor (sic), provided the ale exceed not four
flagons, and in case any inn-keeper being so required by the Mayor or his deputy, shall refuse to do
his office, he shall be excluded ipso facto from brewing, and be compelled by the Mayor, Seneschal
or bailiff (sic) to make oath not to brew within the City for a certain time to be by them or one of
them limited. And furthermore it is ordained and agreed that every inn-keeper who shall be found
culpable and in default in respect of his brewing, and by the Mayor, Seneschal or bailiff (sic) or one
of them shall be so convict, shall for the first offence be in grave mercy, for the second offence in
greater mercy, and for the third offence shall be punished with imprisonment of the body at the
discretion of the Lord Bishop, if he be present, and if he be absent, at the discretion of the Mayor,
Seneschal or bailiff if they be present, and otherwise at the discretion of the Mayor; and for the fourth
offence, he shall suffer the penalty of the tumbril on the first or second Market-day next after the
defect was discovered.

**Ale extractor**
See vertical stillage.

**Ale founder**
Archaic term for an official appointed to inspect beer to ensure standards of quality and
quantity; an alternative to ale-conner.

**Alehouse**
A place where ale is served for consumption on the premises. In the original UK sense by
implication the alehouse was also the site of the brewery.

**Ale kenner**
Alternative name for an ale-conner.

**Ale mead**
See braggot.

**Aleurone body**
Cellular components of barley grains which function as storage bodies and which contain
proteins, polysaccharides and phytic acid. Also known as aleurone grains or aleurone
granules.
See barley grain, aleurone layer.

**Aleurone granules**
See aleurone layer.
The aleurone layer (from the Greek, *aleuron*, or flour) is a cellular component of the cereal grains lying beneath the *testa* and forming the outer layer of the endosperm tissue (see barley grain entry for diagrammatic view of localisation of aleurone layer). The bulk of scientific literature regarding this tissue refers to the aleurone layer of barley grains, and for this reason, as well as its relevance to brewing, the following discussion is restricted to this plant. The aleurone layer is distinguished from the rest of the endosperm in that it consists of living cells. During germination the cells of the barley grain aleurone layer produce hydrolytic enzymes such as α-amylase, β-glucanase and proteases. These enzymes are transported into the endosperm proper where they are responsible for the degradation of storage polymers such as starch and proteins to form relatively simple molecules that are used to provide carbon and energy for the growth of the embryonic plant.

On a dry weight basis the aleurone layer accounts for approximately 5% of the total dry weight of a barley grain. It comprises a layer of relatively thick-walled cuboid cells that surround the starchy endosperm. Plasmodesmata are also prominent. On average the aleurone layer of barley grains is three cells thick except for the portion that partly covers the embryo where it is reduced to a single layer of flattened cells. Unlike the endosperm proper the cells in the aleurone layer do not contain starch granules; however, they do have functional sub-cellular organelles and deposits of reserve materials including lipids and protein. Some of these storage reserves are located in membrane-bound sub-cellular structures termed aleurone granules (or grains).

In malting growth of the embryo is arrested during the kilning stage, thereby preserving the hydrolytic enzymes, together with the barley reserve materials so that they are available for used during the mashing stage of wort production to generate the spectrum of sugars and amino nitrogen required for growth of yeast during fermentation.

The production of hydrolytic enzymes by cells of the aleurone layer is regulated by the intermediary of the plant hormone gibberellins (see gibberellic acid). The latter promotes the expression of the genes within aleurone cells which encode the hydrolytic enzymes. Gibberellin is produced naturally by the barley grain embryo in which role it serves to break the dormancy of the grain. This action has been recognised by maltsters and commercial preparations of the hormone may be added to steep waters to improve the efficiency and consistency of germination.

The mechanism by which gibberellin exerts its effect on cells of the aleurone layer is complex and is still not entirely characterised. However, the evidence suggests that it serves as an initiator of two distinct signal transduction pathways. The first of these is a calcium-independent pathway that involves several components including cyclic guanosine monophosphate (cGMP). In this pathway, activation occurs, of an F-box protein that forms part of an Skp, Cullin, F-box containing (SCF)-ubiquitin ligase complex. The F-box protein binds to a repressor that is blocking the transcription of a gene whose product is required for expression of the genes encoding the hydrolytic enzymes. After degradation of the repressor via the SCF ubiquitin ligase transcription of the hydrolytic enzyme genes can proceed. The second signal transduction involves the calcium-binding protein calmodulin and one or more protein kinases. Activation of this pathway by gibberellin results in the up-regulation of a golgi body
secretory system in which the newly synthesised hydrolytic enzymes are transported from the aleurone layer cells into the endoplasm.

**Ale-wife**
In the United Kingdom in the medieval period brewing was commonly performed by women. These were termed ale-wives. In addition, the terms *brewess* and *brewster* were used to describe female brewers. Generally ale-wives were also responsible for selling the beer at the same location as its manufacture. The domination of the brewing trade at this time also extended to retailers who sold beer that they had purchased from ale-wives. These latter were also predominantly women and were called **huksters**.

This female dominance of brewing, which was also common in Ireland, persisted in the United Kingdom until the seventeenth century after which the business gradually passed into male hands.

**Alexis**
A spring malting barley variety.

**Ale yeast**
Name used to describe those yeast strains that are used to produce those beers defined as *ales*. Taxonomically ale yeasts are classified as members of the species, *Saccharomyces cerevisiae*. They are associated with fermentations in which the yeast crop separates from the green beer by rising to the surface and forming a surface pellicle. For this reason these strains are also referred to as **top-cropping** types, although this is an imprecise descriptor since many ale strains can be made to form bottom crops in an appropriate fermenter.

See *yeast*.

**Algoroba**
A native beer produced in South America and made via the fermentation of extracts of the fruits of various leguminous plants, in particular, various species of *Prosopis* such as *Prosopis juliflora*, the mesquite plant.

**Alkaline steeping**
Alkaline steeping describes one of a raft of methods that have been applied during the production of malts with the aim of improving the colloidal stability of beers made from them. The effect is made possible via the increased solubility of the testinic acid fraction of the husk, in other words, that which contains some of the phenolic haze precursors. Beers made from malts treated in this way may also be perceived to be less astringent, presumably also as a result of the removal of phenolic material. In addition, making the steep liquor alkaline has been used as a method of reducing the microbial flora present on the surface of grains and of removing mouldy or musty taints.

Typically the steep water may be made alkaline by the addition of lime (0.05–0.1% w/v) or by the use of NaOH. Since the alkali will eventually lead to severe damage to the grains the treatments must be limited to a few hours of exposure after which time the steep liquor must
be removed and replaced with fresh non-alkaline water. Alternatively, milder treatments can be accomplished by the use of sodium carbonate.

Alkaline steeping is not favoured by UK maltsters but has been used on continental Europe. It has found some favour in sorghum malting. Leyyedi & Taylor (Journal of the Institute of Brewing, 112, 108–116, 2006) reported that steeping sorghum grains in water supplemented with 0.2% w/v NaOH was not cytotoxic but was effective at reducing levels of coliforms and moulds. The diastatic power of a red tannin-free sorghum cultivar was increased from 16.2 to 26.9 sorghum diastatic units (SDU)/g.

**Alpha**

A shorthand term used as an abbreviation of alpha (α-) acids, the components of hops from which the bitter character of beers are derived.

See α-acids.

**Alsterwasser**

*Alsterwasser* is the name of a pre-mixed canned shandy-type product made in northern Germany.

See Radlermass.

**Altbier**

*Altbier* is a German style of beer that originated in the Westphalia region of Germany. They are particularly associated with the German city of Düsseldorf and for this reason they were often referred to as Düssel. The *Alt* part of the name translates as ‘old’. This is a reference to the fact that the beer is a top-fermented type made at a comparatively warm temperature. In this regard the beers are similar in nature to UK-style ales, and from a German perspective they predate the now more common lager beers. Hence, these beers, frequently simply referred to by the diminutive *alt*, are classed as old style types.

*Altbiers* arose in Düsseldorf in the nineteenth century and in effect, by a process of new product development, became hybrids between ales and lagers. Thus, the fermentation stage is carried out at a comparatively warm temperature using a top-fermenting ale yeast. This is followed by a period of low-temperature lagering. The resultant beers are pale to dark golden in colour with a moderately dry flavour. The latter is imparted by the period of lagering; however, this is offset by fruity warming notes introduced by the comparatively high concentrations of higher alcohols produced by the ale yeast.

*Altbiers* are now produced in several countries; however, although there is some variability, they all share the characteristics described earlier. The beers are produced throughout the year and indeed the Westphalia region of Germany escaped the Bavarian legislation which limited brewing to the winter months. There are some seasonal specialities. The *Sticke alts*, which translates as ‘secret’, is a stronger seasonal variant produced by some of the Düsseldorf brewers.

**Amadori rearrangement**

The Amadori rearrangement describes chemical reactions in which an N-glycoside undergoes an isomerisation reaction to yield the corresponding 1-amino, 1-deoxy-ketose, also termed a ketosamine.