

Malt specifications & brewing performance

When buying malt, the brewery is looking for a product, which will yield the most economic extract (wort) and will operate satisfactorily under brewhouse conditions and throughout the brewing process. Malt, which is difficult to handle can cause quality and process problems involving additional costs. To ensure that an appropriate malt is supplied the brewer will set and agree a suitable specification with his supplier.

Brewhouse performance of the malt is affected by the interactions between malt quality and:

- The type of brewing process.
- The type of brewhouse equipment.
- Other materials that are used with the malt e.g. adjuncts.

The brewer has certain objectives when purchasing malt:

- To recover a high yield of sugar (extract) from the malt.
- That the malt will operate satisfactorily in the plant without additional processing or treatments.
- The malt will pass through the plant within the required cycle time (run off time).
- The wort produced from the malt provides all the necessary nutrients to ensure a satisfactory fermentation.
- The malt delivers the flavour and process requirements of the brewer and his customers.

All of these benefits are supplied on consistent and reliable basis.

Malt specifications

Barley, and the malt produced, is derived from natural living material, and hence subject to all the variations which can occur as a result of genetic and environmental conditions. It follows that no two batches of malt are alike.

Malt is analysed in accordance with standard industry tests such as the IoB, EBC and ASBC methods of analysis. However, standard malt specifications are not always a reliable indicator of how well the malt will perform in the brewery. Brewers and maltsters are continually looking for better predictions of brewing performance of a malt.

Barley variety

There is a list of approved barley varieties for malting. Each barley variety has its own

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Continuing this series of technical summaries for the Institute & Guild's AME candidates.

characteristics through its genetic make-up which will determine certain properties of important to brewing. Some varieties produce better malt than others.

Barley variety will influence malt quality in terms of variables such as:

- % nitrogen or protein in grain (see later)
- % beta-glucan after malting
- Size and homogeneity of grain – plumper grains yield better extracts and are easier to malt and mill. Most brewers specify that all grains should be ≥ 2.2 mm
- Not all barley varieties have similar abilities to produce enzymes, this can be important particularly when using high levels of adjunct.

The environment also influences these factors, e.g. weather, soil type and the use of fertiliser.

The barley variety used to make the malt is considered important not only because of its brewing properties, but because of special characters it gives to the finished beer. Today many traditional ale brewers still specify Maris Otter as they believe it makes better quality beer, even though this variety is no longer recommended because of its poor yield and agronomic performance.

Extract Yield

Extract is a measure of the amount of sugar recovered from the malt after mashing. The extract value is based on a laboratory mash. There are two basic laboratory procedures used for measuring extract.

- The IoB method, which involves mashing 10% malt with, distilled water and letting the mash stands for 60 minutes at 65°C. The extract is measured as the specific gravity of the filtered solution at 20°C. The results are expressed as litre degrees per kilogram.
- In the EBC (European Brewery Convention) method two mash stand temperatures of 45°C and 70°C are used. The Extract is expressed % sugar (sucrose) over total weight of malt

Extract value for typical malt made from standard 2-row barley.

Malt extract "dry"	IoB l°/kg	EBC°Plato
Standard ale malt	305 – 315	81 – 82
Standard Lager malt	300 – 310	80 – 81

Both methods give a prediction of brewhouse performance. However under laboratory conditions mashing are not optimised which explains how extract recoveries of greater than 100% can be achieved with more modern mashing and wort separation techniques such as the modern mash filter.

The factors which favour high extract recovery include:

1. Varietal effects – different barley varieties give different yields
2. The total nitrogen content – the higher the nitrogen the lower the extract.
3. Corn size – large even corns size give better malting and milling performance.
4. Modification – the malt should be adequately but not over-modified – see later.
5. Enzyme capacity – the malt should have sufficient enzymes to degrade the starch and convert it to simple sugars.
6. Low in gums – extract recovery can be reduced by the presence of gums – particularly beta-glucans in the malt. This problem is often resolved by the addition of exogenous beta glucanase.

Malt Nitrogen (usually expressed as % nitrogen)

The higher the level of nitrogen the lower the % extract. Therefore brewers specify the % nitrogen or protein in malt.

Typical % nitrogen is in the range of :

Ale Malt	1.4 – 1.6%
Lager Malt	1.6 – 1.8%

(Nitrogen is sometimes expressed as % protein which is % nitrogen x 6.25)

However nitrogen plays an essential role in the quality of the beer:

- Nitrogen, in the form of amino acids, is required for yeast growth with typical values of 160 to 240 mg/l depending on yeast strain and wort gravity.
- Hydrophobic nitrogen from the malt provide the beer foam and head retention in beer.
- Some long chain polypeptides cause colloidal instability (chill and permanent haze) in beer and have to be reduced in the brewing process.
- Proteins and polypeptides contribute to the texture and mouthfeel of the beer. Excessive removal leads to a thin tasting beer with poor foam.

It is important to ensure a avoid excess nitrogen in the barley, but ensure sufficient of the nitrogen available is broken down to soluble nitrogen. The ratio of total to soluble nitrogen is an important indicator or brewing performance. Most of the nitrogen breakdown occurs during malting.

Moisture (usually expressed as % moisture)

The lower the % moisture, the higher the extract in the malt. Malt specifications express the extract as “extract dry” or “extract as is” – which includes the moisture content.

The darker the malt colour, the higher or longer the kilning time. This results in lower % moisture. Because of their darker colour ale malts tend to have a lower % moisture than lager malt.

Kilning uses a large amount of energy. The next process stage after kilning is mashing when the malt is re-hydrated, There is no benefit in excessive moisture reduction and the trend is to move to higher lager malt moistures to reduce energy costs. For safe storage and good milling performance malt moisture should not exceed 6%.

The higher the moisture, the lower the extract yield per tonne of delivered malt. This has to be adjusted in the price since the brewer wants to pay for malt not water.

Typical % moisture values for standard malts:

Standard ale malt = 2 – 3% moisture
Standard lager malt = 4 – 6% moisture

Colour

During kilning chemical reactions take place between the malt components to produce colour compounds. There are a number of colour and flavour reactions. The principal reaction is between amino acids and sugars called the “Maillard reaction” which produces both colour and flavour active compounds.

The higher the kilning temperature, the greater the amount of colour compounds produced. As well as producing colour, these compounds also contribute to flavour.

The colour of the malt is based on the colour obtained from the IoB or EBC mash using a 10% solution. This colour value provides an approximate indicator of final beer because it is based on a dilute laboratory mash with an original gravity of 1030° (8°Plato). Further colour develops during wort boiling.

Modification

Before the brewer can break down the starch in malt to sugars during mashing, the maltster has to break down the cell structure in the endosperm to make the starch granules accessible. This process is called modification and is the most important measurement when predicting brewing performance and extract yield from malt.

Modification gives a measurement of how evenly the cell structure in the endosperm has been broken down during the malting process. Enzyme activity starts from the embryo and the aleurone layer surrounding the endosperm to break down the protein and beta-glucan cell walls surrounding the starch granules (see Figure 1).

The process of modification has the effect of stripping away the cell wall structure and is shown in the two electron micrographs (Figures 2 and 3).

The degree of modification can be measured



Figure 1 – Process of modification of a barley corn.



Figure 2. Before – showing the beta glucan cell walls surrounding the starch granules in the endosperm before in barley before malting.



Figure 3. After – showing how the cell structure has been stripped away exposing the starch granules, which can now be degraded by enzymes during mashing.

Thanks to Professor G. Palmer, Heriot Watt University, for permission to use the electron-micrographs.

in a number of ways:

Direct observation

The electron micrographs clearly show the degradation of the cell walls. This is a complicated and expensive technique for routine analysis.

However, the presence of cell wall material can be detected using a calcofluor stain. The calcofluor dye binds with beta-glucans (cell wall material) and fluoresces under UV light.

Thus if sectioned grains are exposed to this dye those parts of the corn rich in beta-glucan will fluoresce. This technique can be used to determine both the proportion of corns that have modified as well as the extent of modification within individual corns.

By taking a series of transverse sections through the grain it is possible to make direct

observation of the endosperm and evaluate the degree of modification. It is found that these observations correlate well with brewing performance.

Indirect measurements

Another way of measuring modification is assessing factors influenced by the breakdown of the endosperm structure in the grain:

1. During malting the protein matrix, which surrounds the starch granules inside each storage cell is broken down. The greater the value of soluble nitrogen, the higher the modification. The IoB analysis it is usually expressed as the “Soluble Nitrogen Ratio” (SNR), which is the soluble nitrogen/total nitrogen expressed as a %. The EBC method uses a similar ratio based the EBC mash where it is called the Kolbach Index.

2. Unless the malt is fully modified a number of cells within the endosperm will not be degraded and will remain intact with coarser milling. When the malt is mashed the enzymes will not be able to penetrate the cells and gain access to the starch. These cells are ruptured with fine milling and the extract can be recovered. Another measurement of modification is the course/fine difference, which measures the difference in extract yield between finely and coarsely ground malt. The smaller the difference the better the modification.

3. During malting the cell walls in the endosperm are dissolved away making the grain softer and easier to mill. It is possible to use this property to measure the degree of modification, by measuring the amount of energy required to grind the malt (Friability). The method takes 50 grams of malt which is milled with a constant pressure over a mesh screen. The well modified grain will fall through the screen leaving the chunks of under-modified malt. The weight of ground malt indicates the degree of modification. It also measures the homogeneity or evenness of modification.

4. Cold water extract measures the amount of sugars broken down and released during the malting process. – higher cold water extracts indicate higher modification (see Table 1).

It is important to use malt that has been correctly modified:

In under-modified malt all the cell walls have

Table 1: Typical specification for modification in pale ale and well modified lager malt.

	Pale Ale Malt	Lager Malt
Index of modification		
Kolbach % (Sol N/Total N)	38 – 39	40 – 43
Course/Fine difference (l°/kg)	3 – 6	2 – 3
Friability %	≥ 95	≥ 95
Homogeneity %	≥ 88	≥ 82
Cold water extract %	1.8 – 2.0	2.0 – 2.2

not been broken down, it usually has a lower soluble protein content (SNR is lower) and there may still be small starch granules present which can give starch conversion and haze problems. Under-modified malt will give brewhouse problems and give poor extract recovery.

In over-modified malts the cell structure is fully broken down, the soluble protein is higher (high SNR), and most of the small starch granules have been broken down. It is much easier to recover but extract from over modified malt, but some extract may have been used up during the malting process. Excessive nitrogen breakdown may lead to loss of foam positive proteins and poorer beer foam performance.

Enzyme Activity.

The principal activity of malting is to encourage the barley to produce its own enzymes. Some of the enzymes are required during malting to modify the corn structure. The other enzymes, principally the Diastase enzymes (which break down starch) are required to work during mash conversion in the brewhouse.

There are two principle diastatic enzymes:

- Alpha amylase which randomly hydrolyses

the starch to produce shorter chains and reduces the viscosity. The activity of the enzyme is measured by the length of time required to break down a standard starch solution to a specific colour standard using an iodine indicator. The activity is expressed as dextrinizing units (DU).

- The other enzyme, beta amylase attacks the non reducing end of the starch chain to produce maltose sugar. The enzymic power is measured as DP (Diastatic Power in °Lintner) in the IoB methods of analysis.

The DP is around 35 – 40 for standard Ale Malts, but can be as high as 100 to 125 for lager malts and over 160 for some high protein six row North American malts. The latter malts have far more enzymic power than they require just to convert the starch from the malt itself and enable the brewer to use high levels of unmalted starch adjuncts (see a later series.)

In EBC analysis the diastatic power is measured as °WK (Windisch-Kolbach units). The value of °WK can be converted to °Lintner by the formula:

$$DP \text{ °Lintner} = (°WK + 16) / 3.5$$

The contribution of malt to flavour

Malt is the principal ingredient in beer supplying sugar to the yeast which produces alcohol. In addition to sugar, yeast requires a variety of essential nutrients which are necessary for satisfactory yeast growth and nutrition. The typical components required include:

- Simple sugars (glucose, maltose and maltotriose) for fermentation
- Amino acids (free amino nitrogen > 150 mg/l) for yeast growth
- Mineral ions for enzymes – typically zinc, copper etc
- Vitamins for healthy growth
- Some lipid material for cell wall production – although yeast manufactures most of these compounds using available oxygen in the wort.

During fermentation yeast will produce a number of flavour compounds as a direct consequence of metabolising brewing wort. Changes in wort composition will influence this metabolism and hence the flavour of the beer produced.

Malt also contributes directly to the appearance final character and taste of the beer:

Murphy Half page ad

- Most of the colour of beer comes from the crushed malt or is developed during the brewing process from reactions between malt components.
- The colour compounds also give beer a characteristic flavour from light biscuity for the lager malt to a strong burnt acrid taste for black malt and roasted barley.
- The mouthfeel and texture of the beer comes mainly from the residual unfermentable sugars (dextrins) derived from the malt.
- The pH of wort and beer is regulated through the precipitation of malt components with mineral ions from the water.
- Beer foam is made up from hydrophobic proteins, which have their origins in the malt.
- Other protein fractions are involved in beer haze and have to be removed to achieve long term colloid stability in small pack beers.
- Malt also has an effect on beer flavour through certain flavour active compounds.

Most of these factors other than colour, are not included in the malt specification. However there is one flavour active compound formed during malting which has to be controlled in the finished beer.

DMS or Dimethyl Sulphide is a malt derived flavour compound with the flavour of "cooked sweetcorn" often associated with lagers. It has a flavour threshold of around 35 ppb. It is only noticeable in lightly kilned malts (lager) and is derived from a precursor, S-methyl methionine (SMM) produced during germination which is

Typical Specification for a Lager Malt.		
Specification	IGB (Institute & Guild of Brewing) methods:	EBC (European Brewery Convention)
Moisture	4.5 – 5.5 %	4.5 – 5.5 %
Extract yield (dry wt)	> 305 l/kg	> 80.5 %
Corn size > 2.5 mm	95%	95%
Colour	2-4 EBC	2-4 EBC
Total Nitrogen	1.6 – 1.8%	1.6 – 1.8 %
Total Soluble Nitrogen	0.57 – 0.66%	0.65 – 0.75%
FAN	> 160 mg/l	> 160 mg/l
SNR Soluble nitrogen ratio	34 – 40 %	38 – 44 %
Coarse/Fine difference	3 – 7 l/kg	1 – 2%
Friability meter reading	> 85%	> 85%
Homogeneity	> 96%	> 96 %
Diastatic Power	> 65° loB	> 220 Windisch-Kolbach
Wort viscosity mPas @ 20°C	1.55 -1.65	1.55 – 1.65
DMS precursor	2 – 8 mg/kg	2 – 8 mg/kg
Beta glucan mg/l	< 200	< 250
Alpha Amylase du (dextrin units)	> 30	> 30

converted to DMS by heating. The levels of DMS precursor can be reduced during malting by:

- Reduced proteolysis and rootlet growth during germination
- Poorly modified malts have lower SMM
- Higher kilning temperatures reduce SMM.

The brewer will often set a maximum specification for SMM to reduce the beer DMS. However in some beer brands DMS is seen as a positive flavour and high SMM levels are encouraged by short, low temperature kilning conditions.

Nitrosamines are chemical compounds containing the grouping N-NO and may be found in malt. They do not have a flavour

contribution but are thought to be carcinogenic.

Volatile nitrosamine in malt is produced as oxides of nitrogen (NOx) react with naturally occurring malt amines during kilning to produce N-nitrosodimethylamine, usually abbreviated to NDMA. NOx may be present either in the hot gases from combusted fuel where direct drying is used or even from general air pollution in indirectly fired kilns.

The most active forms of NOx are N₂O₃ and N₂O₄. To avoid the formation of these compounds most maltsters use indirect heat to fire the kilns, low NOx burners or burn sulphur. Although there is no legal limit for NDMA in the UK there is an industry agreed standard of < 5 ppb. ■



The Institute & Guild of Brewing

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