Module 3  |  Malt Quality and Brewhouse Performance
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Objectives of the Module | At the end of this module, you will be able to:
1. List and explain the principle methods of measuring malt quality and how the analyses are conducted.
2. Understand why it is necessary to analyse malt.
3. Explain the main issues of malt quality with respect to brewhouse performance.
Module Contents | This module covers the following:
1. Malt Analysis and Specifications
IBD Notes References | The following sections in the IBD notes are applicable:
Unit 1.3 – Malt Quality and Brewhouse Performance
1.3.1 The requirements of good quality malt
1.3.2 Typical specification ranges for ale and lager malts
1. MALT ANALYSIS AND SPECIFICATIONS

Malt analysis is conducted for the following reasons:

- As an estimate of the **brewing value** of the malt
- The brewer aims at smooth running of all processes – the analysis tells them of any potential difficulties
- Focus on prediction of the extract potential of malted grains
- Basis for **commercial transaction**, i.e. for purchase from the maltster

**What Does a Brewer Really Want From Malt?**

- A good source of fermentable sugars – the main purpose for the wort produced from malt is for yeast to ferment it to alcohol.
- A source of enzymes – these are critical in the brewhouse to break down the larger macromolecules to nutrients that the yeast may utilize in fermentation.
- Macro- and micronutrients for fermentation – many are already present in the malted barley and merely need dissolving in the brewhouse.
- No processing problems – as we shall see, poorly manufactured malt may give the brewer many processing problems.
- Contribute right flavour profile for final beer – each beer has its own profile so the malt must be able to give to the wort the correct characteristics that will allow the yeast to ferment to give the right beer profile.
- Stable beer with good shelf-life – as well as processing problems poor quality malt may also lead to a beer with negative properties such as haze and poor foam.

**Malt Analysis Systems**

Many are the official analysis methods of organizations; EBC, ASBC, IOB, MEBAK etc.

There are different analysis methods used dependent on country, barley varieties and malting procedures, requirements and specifications of breweries

- **Institute of Brewing (IOB)**
  - Used by UK Brewers and Distillers since 1906
- **European Brewing Convention (EBC)**
  - Analysis committee set up in 1948
  - Used extensively by continental lager breweries
- **American Society of Brewing Chemists (ASBC)**
  - Similar results to EBC

**Methods of Malt Analysis**

There are generally considered to be three different sets of analysis that can provide vital information for the brewer:

- Visual evaluation
- Physical and physiological examinations
- Chemical and physicochemical
However, before analysis can begin a representative sample must be taken. The brewer has to be careful because there is a small chance that an unscrupulous supplier has sent a ‘mixed’ batch of malt that is not uniform throughout! There are three main sampling methods for malt delivered to site usually by rail or truck:

1. Use a sampling spear. This device takes small samples from various heights within the grain bed of the rail or road truck. Samples are taken from various points within the truck and these may then be mixed to provide a homogenous sample.

2. Take a sample on intake. It is possible to have a ‘trickle sample’ device on one of the intake conveyors that takes a sample over the whole intake which should therefore be very representative. The main problem with this method is that it cannot be used as a basis to decide whether to accept the batch or not.

3. Do no sampling or analysis! This is actually what many brewers do as the have a Quality Assurance policy where the supplier sends a Certificate of Analysis as the basis of assurance that the batch of malt is within specification. Even if I were running a system like this I would still insist on a sample being taken for visually analysis to check that there had been no mishaps to the batch during transportation.

**Physical Analysis**

A physical examination can tell the brewer much about the quality of the malt.

- **Breakage** – this indicates how well the malt has been treated during transportation, storage and mechanical handling.
- **Dust** – excessive dust can lead to high losses and processing problems in the brewhouse.
- **Foreign seeds** – it is amazing what can be found in batches of malt either to poor control procedures or using transport (road, rail or ship) for different types of grains and cereals.
- **Insects and fungus** – obviously neither are wanted as they will lead to reduced extract yield as well as potential food safety issues such as mycotoxins and gushing.
- **Visible mould.**
- **Varietal purity** – as discussed previously this is quite difficult to do (particularly on malt rather than barley) but the expert eye can tell morphological differences in the grain.
- **Off odours** – can be caused either by infections, disease or infestations or damp storage.
- **Uneven appearance** – brewing is a batch process where the main focus is process control. The key skill of the brewer is to produce a consistent product and the basis of the starting point for this is a consistent raw material. Therefore the malt corns should all be of the same size, colour and shape with no admixtures.
- **Plumpness** – as discussed previously the kernels should preferably be of a uniform plump size. This will increase extract potential and lead to more consistent milling in the brewhouse where thin grains may be inadequately crushed.

**Malt Breakage & Dust**

Increased dust will mean there are more losses within the brewhouse due to aspiration systems and malt cleaning. Particularly where a lauter tun is used (as opposed to a mash filter) excessive dust may also lead to filtration problems due to decreased bed permeability. Dust is also dangerous in terms of health risks through inhalation, and it is an explosion risk. Damaged corns may mean less husk for the filter bed in the brewhouse and broken corns can take up moisture and encourage mould and insects.

The amount of dust and small or broken corns is usually measured using a simple sieve test.
Malt Moisture

The Brewer wants malt not water and moisture content is one of the key contractual agreements between the brewer and the maltster. Additionally if the moisture is too high it makes the grain susceptible to mould growth and infestation on storage. However, if the grain is too dry then it can easily be damaged during transportation and storage which may have the adverse effects detailed above.

It is measured by placing dry ground malt in calibrated oven at 103 °C for 3 hours and measuring the % difference.

Typical lager malt value = 3-4%.

This figure is also used as the basis for dry extract calculations.

Friability Test

This is a relatively new method of analysis that tries to give an indication of the degree of modification of the grain. The friability will depend on variety, moisture, conditions during growing, level of modification, nitrogen and moisture content. It uses a special machine called a friabilimeter which crushes a set amount of malt in a uniform manner using a fixed amount of energy and then the fractions can be analysed. The analysis is rapid, reliable and cheap and has therefore gained wide acceptance as a standard method.

Various different measurements are recorded: friability, Partly Unmodified Grains (PUGs), Wholly Unmodified Grains, (WUGs), and homogeneity

Method:
- Take 50g malt and place in fribilimeter for a fixed period of time
- Friable bits crushed through mesh drum
- Weigh non-friable part remaining in drum (x g)
- Friability expressed as 100-2x
- Sieve unmodified portion over 2.2mm sieve for 60 seconds
- Partly Unmodified Grains (PUG) remain on sieve and expressed as %
- Homogeneity expressed as 100-PUG(%)=
- Wholly Unmodified Grains (WUGs) are all grains >¾ in length.

In this way the brewer gets a good idea of homogeneity of the malt batch, its degree of modification, and how many of the grains were either never malted or were dead at the onset of the malting process.

Laboratory Mash Extracts

Many of the analysis performed of malt have the first part of their analysis as production of wort from the malt using a small scale laboratory method. These methods literally mimic a brewhouse operation on a small scale in the laboratory and the resulting wort may be analysed for many different parameters. There are predominantly two types of mash that will now be discussed.
Brewhouse – Malt Quality and Brewhouse Performance

IOB Laboratory Mash

This mimics a typical isothermal infusion mash so is nicely representative if using well-modified malt. The basic method is as follows:
• Mill (setting 2 = fine, 7 = coarse)
• Weigh out 50g
• Mash in at 65 °C for 60 minutes (360ml pre-heated distilled water, magnetic stirring)
• Cool to 20 °C
• After 20 minutes make up to 450g
• Within 30 minutes filter through coarse filter paper (return first 50ml)
• Determine SG at 20 °C and then use formulae to express results as l°/kg or % extract

EBC Laboratory Congress Mash

This is the more widely used method that is good for all types of malt and more closely mimics the typical brewery parameters.
• Mill (settings 2 = fine, 10 = coarse)
• Mash 50g with 200ml distilled water
• Mash in at 45 °C for 30m with stirring then raise to 70 °C at 1°/min (25m)
• Add 100ml water at 70 °C and hold at 70 °C for 60m
• Cool to 20 °C in 10-15m
• Make up to 450g
• Filter (return first 100ml)
• Measure SG at 20°C
• Use sugar tables to express results as %extract

Problems with Laboratory Extracts

There are many reasons why the laboratory extracts do not actually mimic those found within the brewery. These include:
• Different milling to breweries – use quite fine disc mill in the laboratory
• Breweries do not use distilled water. They use treated liquor with different ionic contents which will affect enzyme activity.
• Lab mashes are much thinner again affecting enzyme activity.
• Breweries use a range of temperature programmes, not one standard one and rarely an isothermal one.
• No sparging of spent grains in lab mashes which effects both extract and what is contained in the extract.
• Little control of filtration in the laboratory.

Having said that over many years of correlation they still provide very useful information.

Fine-Coarse Extract Difference

This test is done by measuring the laboratory extract on a coarse and a fine grind. If the difference is small it means that the malt is well-modified. Under-modified malts show significant differences as with a coarse grind the malt is not easily broken open to expose the starch granules during mashing. Therefore the test is generally used to predict level of modification although it has been superseded by the friabilimeter.
**Wort Carbohydrate Profile**

This is not done by most breweries as it is quite an expensive bit of kit but it really is the only way to not just tell you how fermentable your wort is but also what exactly are the sugars in that fermentable extract. Most brewers rely on measuring the attenuation limit as discussed below. Therefore generally:

- High Performance Liquid Chromatography (HPLC) can determine the carbohydrate spectra of the lab and brewery worts
- It is very useful when dealing with problem fermentations
- It is expensive to purchase and run and require sophisticated technicians
- Far more useful than Limit Extract (LE)

**Typical Wort Extract Composition (g/l) by HPLC**

<table>
<thead>
<tr>
<th>Carbohydrate</th>
<th>Value (g/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fructose</td>
<td>2.1</td>
</tr>
<tr>
<td>Heptasaccharides</td>
<td></td>
</tr>
<tr>
<td>Glucose</td>
<td>9.1</td>
</tr>
<tr>
<td>Heptasaccharides</td>
<td>2</td>
</tr>
<tr>
<td>Sucrose</td>
<td>2.8</td>
</tr>
<tr>
<td>Pentosan</td>
<td>0.4</td>
</tr>
<tr>
<td>Maltose</td>
<td>52.4</td>
</tr>
<tr>
<td>Beta Glucan</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Maltotriose</td>
<td>12.8</td>
</tr>
<tr>
<td>Soluble Protein</td>
<td>2.8</td>
</tr>
<tr>
<td>Tetrasaccharides</td>
<td>3</td>
</tr>
<tr>
<td>FAN</td>
<td>1.7</td>
</tr>
<tr>
<td>Pentasaccharides</td>
<td>1</td>
</tr>
<tr>
<td>Phenols</td>
<td>0.3</td>
</tr>
<tr>
<td>Hexasaccharides</td>
<td>2</td>
</tr>
<tr>
<td>Lipids</td>
<td></td>
</tr>
</tbody>
</table>

**Laboratory Attenuation Tests**

This is the more commonly used test and uses the following methodology:

- Determine Original Gravity (OG) of clear, coarse IOB extract
- Boil 250ml wort for 15 minutes and cool
- Make back to weight with distilled water
- Determine Specific Gravity (SG)
- Add yeast and ferment at 25 °C for 48 hours
- Filter and determine Present Gravity
- \( \text{Apparent Attenuation Limit (AAL)} = 100 \times \frac{(OG - PG)}{OG} \)
- \( \text{Real Attenuation} = \text{AAL} \times 0.819 \) - this figure compensates for the artificial lowering of the gravity due to the presence of alcohol which has a SG less than water.

The main problem with this analysis is that it uses yeast from the plant which may not be at its best in terms of viability and vitality.
**EBC Tall Tube Fermenters**

This test can be used to actually get a feel for how the fermentation will proceed and what type of beer will be produced from the malt.

- Coarse mill 320g malt
- Mash with 1.9l water
- Cloth filtration and add hops
- Boil and remove hot break
- Adjust to 11.3°P
- Add to tall tube fermenters (1.8m x 45mm ID)
- Pitch viable brewery yeast at 20 million cells/ml
- Aerate wort by inversion

**Carlsberg Sanded Slab Assay**

This is a reasonably rare test that can be used to assess modification.

- Embed 50 corns in clay block
- Sand down
- Stain with calcofluor
- Counter stain with fast green
- View under UV
- Calcofluor stains β-glucan in endosperm cell walls
- Measure area of endosperm modified by eye or computerised optics

**β-glucan Measurement**

This is an important measurement for the brewer. β-glucan comes from the cell wall of the barley. Some barley varieties have inherently high levels of β-glucan and high levels found in wort are indicative of a poor or under-modified malt. This is not good news for the brewer as it indicates that extract recovery may be difficult and there may be processing problems as the β-glucan significantly increases the viscosity of the wort leading to slow and poor run-off during mash separation.

- Can be measured in barley, malt or wort in two ways:
  - Enzymatic - very labour intensive
  - Fluorimetric - expensive but good for many samples as automated

Both methods believed by some to give suspect results so brewers often rely on wort viscosity measurement as an indicator.
Nitrogen in Malt and Wort

Measurement of the nitrogen components in wort is very important for the brewer as they basically give an indication of proteins and their constituents (amino acids, peptides and polypeptides). Protein is required to assist in foam formation and amino acids for yeast metabolism whereas excessive protein can lead to colloidal instability. There are various different measurements that can be done:

**Soluble Nitrogen Ratio (SNR) or Kolbach Index (KI):**

This is expressed as Soluble Nitrogen/Total Nitrogen x 100

- SNR on IOB coarse grind, KI on EBC fine grind
- Is an index of protein modification as it indicates how much of the original protein in the barley has been broken down
- Is often considered too simplistic a measurement to give a real assessment of modification:
  - e.g. low Nitrogen barleys modify faster and give high KI more easily
  - Barley germination is a dynamic situation and hence is not always a good assessment

**Amino Acids**

This measurement is critical in terms of assessing potential for yeast growth.

- Spectra can be measured using ninhydrin, but different amino acids give different colour yields and hence potentially inaccurate results
- Laboratory mashes may give amino acid levels different to the brewery, for example, with no protease stand in the IOB mash
- HPLC analysis may be done which is accurate and useful for troubleshooting
- A lot of analysis has recently been done into foam producing proteins

**Laboratory Wort Colour**

Obviously this is a critical measure that gives insight into one of the key sensory facets of the final product, beer. It can be measured usually in tow ways, either spectrophotometrically or by a visual comparator.

- Use haze-free worts and measure quickly as colour fades
- Broadly correlates to brewery colour
- Boiled wort colour is a better indicator of brewery colour

**Amylolytic Enzymes**

A measure of enzymes in the malt is important for the brewer to understand how to develop mash profiles and hence produce the correct sugar composition and limit extract (LE) in the wort and hence the right profile for the final beer.

- Main enzymes measured are α- and β-amylase
- Measurement of α-amylase done in Dextrinising Units
- Measurement of β –amylase called Diastatic Power and is measured in Windisch-Kolbach Units
**Other Possible Measurements**

There are several other measurements that some brewers ask for from their maltsters.

- **S-methyl methionine (SMM).** This is the precursor of Dimethyl Sulphide (DMS) that is a significant flavour compound in beer.

- **Mesityl Oxide.** This is a taint that may be picked up from drying paint and leads to blackcurrant/ribes flavours in the final product.

- **Polyphenols and tannoids (condensed polyphenols)** can be measured in malt as an indicator of haze potential.

- **Filtration predictions.** These have been proposed for many years now to try and see what sort of the performance the malt will have during mash separation. They have never found wide applicability but two proposed systems are:
  - IOB/EBC use run-off rates
  - Terpal mashing system

- **Food safety issues.** e.g:
  - Pesticides – which could come from additions to growing barley.
  - Mycotoxins – which can be found due to fungal contamination of barley during growth, harvesting or storage.
  - Nitrosamines – these are potential carcinogens (such as n-Nitroso Dimethylamine NDMA) that can be formed in malt during kilning.
  - Microbiological spectra.
  - Gushing potential – again from fungal contamination by *Fusarium.*
## Typical Pale (Lager) Malt Specification

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>IDEAL SPEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley Varieties</td>
<td>Only Approved Varieties</td>
</tr>
<tr>
<td>Nitrogen In Malt (% On Dry Basis)</td>
<td>1.76 ± 0.06 (11.0 ± 0.4 % Protein)</td>
</tr>
<tr>
<td>TSN (% On Dry Basis)</td>
<td>0.65 – 0.77</td>
</tr>
<tr>
<td>Assimilable – N (Ninhydrin) (Mg/Litre)</td>
<td>170 - 200</td>
</tr>
<tr>
<td>Fine Grind Extract (% On Dry Basis)</td>
<td>&gt; 80.0</td>
</tr>
<tr>
<td>Apparent Attenuation Limit (%)</td>
<td>&gt; 80.0</td>
</tr>
<tr>
<td>Friability (%)</td>
<td>&gt; 80</td>
</tr>
<tr>
<td>Viscosity on Congress Wort (Cp)</td>
<td>&lt; 1.60</td>
</tr>
<tr>
<td>Wort β-Glucan (mg/litre)</td>
<td>&lt; 200</td>
</tr>
<tr>
<td>Diastatic Power (WK Units)</td>
<td>&gt; 230</td>
</tr>
<tr>
<td>Alpha-Amylase (DU)</td>
<td>&gt; 30</td>
</tr>
<tr>
<td>Moisture Content (%)</td>
<td>&gt; 3.5% Ex Kiln</td>
</tr>
<tr>
<td></td>
<td>&lt; 5.0% On Receipt</td>
</tr>
<tr>
<td>Wort pH</td>
<td>&gt; 5.60</td>
</tr>
<tr>
<td>Wort Colour (EBC Units)</td>
<td>4.0 ± 0.5</td>
</tr>
<tr>
<td>Clarity / Turbidity (On Congress Wort)</td>
<td>Clear</td>
</tr>
<tr>
<td>DMSP (µg/g)</td>
<td>&lt; 4.0</td>
</tr>
<tr>
<td>NDMA (µg/kg)</td>
<td>&lt; 2.5</td>
</tr>
<tr>
<td>Residual SO2 (mg/kg)</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>Aroma And Taste Of Malt And Wort</td>
<td>Clean And Free From Mouldy, Earthy Odours, Or Any Other Off-Flavours.</td>
</tr>
<tr>
<td>Contamination</td>
<td>Malt To Be Declared Free From Contamination By Chemicals, Ergot Antibiotics Or Any Substance Deleterious To Quality.</td>
</tr>
<tr>
<td>Malt Breakage</td>
<td>&lt; 1.5%</td>
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</table>