Good Malt – Good Beer?

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Introduction

Good beer is characterized by a few quality traits, which are easy to agree upon. They are: (i) flavour (combination of taste, aroma and mouthfeel); (ii) appearance (colour, clarity, foam, and beading); (iii) wholesomeness (absence of hazardous compounds, presence of useful compounds). Given the choice (which isn't always the case) brewers throughout the world prefer good quality malt. They believe that this will increase their chances of both professional and commercial success. Significantly, they know that with the right malt, the job of making good beer will be easier. But, despite (or perhaps *because of*) a voluminous literature on the topic, they encounter more difficulty in defining good malt than they do in defining good beer. It is my purpose in this paper to address this issue.

What is malt?

Barley malt grains are partially-germinated seeds which have been heated and dried. Contrary to expectation, they are not necessarily dead. Many can re-germinate, given the opportunity (water, air, time), though they are seldom capable of forming a healthy plant.

Malts fall into two broad types: standard malts and speciality malts. Standard malts, which include those used for the bulk of the grist of both lagers and ales, provide extract, flavour, colour, and nutrients for yeast. Speciality malts are used primarily to supply colour and flavour, while sacrificing extract yield.

One very important aspect of malt is that it is substantially inhomogeneous. There are considerable differences between individual corns. This has a major impact on processing, and on prediction of the performance of a single batch. It is all too easy after looking at an analysis sheet of a single batch of malt to make the mistake of thinking that we are dealing with a homogenous product. This is never so.

Why malt?

Barley is difficult to process into wort. It does not mill easily, it lacks appropriate levels of enzymes for starch and protein conversion, and the starch is not easily accessible. And it lacks *malty* flavour. Germination corrects for most of these deficiencies, and kilning takes care of flavour. Some beers are produced from barley alone, using exogenous enzymes. The attraction of such beers lies in their favourable tax treatment, not usually in their quality or ease of production.

Historically, kilning was introduced both as a preservation method, and as a means of introducing flavours. Pale malts are a modern invention – historically, most malts have been dark. Significantly, kilning takes place in a stream of air, rather than in inert gas, allowing ample opportunity for reaction of malt components with oxygen. Such reactions can be both enzymic and non-enzymic. They can be beneficial (*eg* oxidation of flavoursome dimethyl sulphide to flavourless dimethyl sulphoxide), or deleterious (*eg* oxidation of malt unsaturated fatty acids *via* the action of lipoxygenase 1).

Kilning reduces the levels of live microorganisms, minimizing their impact in the mashing process. But, enzymes associated with dead organisms may still be significant to beer quality.

What does malt contain?

Like most commodities, malt is taken for granted. However, the myriad of components it provides us with is remarkable. Were we to obtain them from separate sources we would find ourselves faced with many problems, including:

(i) difficulties in storing the individual materials;
(ii) the need to separate them from one another;
(iii) the need to keep them dry, and;
(iv) the need to stabilize some of them with special molecules or mixtures of molecules.

Important chemicals contributed to the brewing process by pale malt include starch, protein, amino acids and peptides, phosphate, polyphenols, melanoidins, *O*- and *N*-heterocylic compounds, lipids and sterols, beta-glucan, vitamins, metal ions, and enzymes. In addition, malt husk material provides the filter medium for mash tun and lauter tun separation systems.

What positive attributes does malt contribute to beer?

In addition to providing nutrients for yeast growth, malt contributes a variety of positive characters to beer, which are summarized in Table 1.

Table 1. Positive characters contributed to beer by malt.

Character	Compounds responsible
Malty flavour character	*O*- and *N*- heterocycles
Sweetcorn flavour character	Dimethyl sulphide (*syn* methyl sulphide)
Flavours due to esters and higher alcohols	Malt provides the precursors for these materials (amino acids and sugars)
Colour	Melanoidins and polyphenols
Foam	Polypeptides, some of which are glycosylated.

What negative attributes can malt contribute to beer?

Negative characters contributed to beer by malt are summarized in Table 2. In addition to these effects on beer, malt components can also influence the brewing process itself. For example, excessive levels of beta-glucan can give rise to poor wort filtration and beer filtration performance. Malt components can bring about premature flocculation of bottom-fermenting yeast during fermentation, or changes in the skimming behaviour of ale yeast strains. And malt may be implicated in fobbing during fermentation.

Table 2. Negative characters contributed to beer by malt.

Character	Compounds responsible
Off-flavours (grainy, astringent, stale *etc*)	Various small molecules (including *O*- and *N*-heterocyles, carbonyls *etc*) and enzymes (including lipoxygenases, lipases *etc*)
Safety concerns (toxin, mutagen, carcinogen or teratogen)	*N*-Nitrosodimethylamine, chloropropanols, aflatoxins, mycotoxins
Appearance problems (haze)	Proteins, polyphenols
Foam problems (gushing)	Polypeptide derived from fungal contaminants on grain

How does malt influence beer flavour?

Taste

Malt has a direct influence on two tastes; *sweet* and *sour*. Sweet tastes derive from sugars, which mostly have their origin in malt starch. Sour tastes derive from organic acids produced by the germinating grain and from those produced by yeast from malt carbohydrate, but acids produced by grain microflora are also significant. In addition, sour taste has its origin in the phosphoric acid released from malt-derived phytic acid by the enzyme phytase.

Aroma

Malt provides us with a huge variety of aroma-active compounds. Depending on the malting and beer production styles we adopt, we can generate a range of cereal-like characters including *malty*, *cereal*, *chaffy* and *powdery*. In the case of dark malts, we can generate *toffee, burnt*, *chocolate* and *roasted* characters. These are generally imparted by *O*- and *N*-heterocyclic compounds. Yeast can modify some heterocylics during fermentation to give *sweet* aromas. Pale malts contain *S*-methyl methionine, a precursor of dimethyl sulphide (DMS) which imparts *sweetcorn* character to beer. Darker malts can contribute dimethyl sulphoxide, which can be transformed by yeast, and by contaminant bacteria, to give DMS. Amino acids give rise to a wide range of flavour compounds *via* yeast metabolism, including higher alcohols and esters. Metal ions from malt have an important, though indirect, influence on beer flavour. For example, zinc ions affect formation of higher alcohols, and consequently esters, in addition to playing a major role in yeast fermentative activity.

Mouthfeel

Malt influences the mouthfeel of beer in various ways. Starch degradation products, including dextrins, help impart *body* to beer, as may beta-glucans. Polyphenols can influence *astringency*. And, indirectly, malt starch is the source of at least some of the CO_2 in beer.

How does malt influence beer appearance?

Colour

Malt contributes two classes of compounds to beer that impart colour: these are *polyphenols* and *melanoidins*. In addition, malt contributes an enzyme called *polyphenol oxidase* which modifies the colour of the polyphenolic material during mashing and run-off.

Speciality malts such as chocolate, amber, and Cara pils malts can be used to impart distinctive colours to beer and to provide more control over beer colour.

Clarity

Haze material contains two major components – *protein* and *polyphenol*. Malt and hops are the two sources of polyphenols in beer: proteins are generally contributed by malt. During the beer production process these two groups of components are encouraged to react to produce insoluble complexes. In this way they are gradually eliminated from the process stream.

Foam

In most beer styles, malt is the primary source of beer foam proteins and polypeptides. In beer, these materials are cross-linked by hop-derived iso-alpha-acids, which are in turn bound to divalent metal ions, to give a stable three-dimensional structure around bubbles of CO_2 gas. The identity of these malt-derived foam proteins has been much debated, especially the point of whether they differ from those involved in haze production. As yet there is no definite agreement. However, the consensus appears to be: (i) Foam proteins have a range of sizes, though protein fractions with molecular masses of 40,000, and 8,000 – 18,000 play an important role; (ii) They are amphipathic: that is, they have both hydrophilic and hydrophobic properties. The hydrophobic properties of the foam proteins are particularly important; (iii) Substituent groups on the foam proteins (*eg* sugar residues) may be important.

To make up for deficiencies in malt quality, process performance, or trade dispense practices, some breweries use foam stabilizers. The most common of these is propylene glycol alginate (PGA). PGA protects foams against lipid damage. Malt contains a natural foam stabilizer, though its importance in commercial brewing operations has yet to be clarified. Lipid transfer protein (LPT1) can bind lipids, that might otherwise destabilize beer foam.

How does malt influence the wholesomeness of beer?

Most research on relationships between wholesomeness of beer and malt quality has laboured on the negative side. For example, undesirable materials identified in malt or the barley from which it was made have included: *N*-nitrosodimethylamine, fungal toxins (including mycotoxin B, aflatoxin A, and vomitoxin), barley storage pesticides, and chloropropanols.

Fewer studies have focused on positive contributions that malt makes to the wholesomeness of beer. These could include trace metals, vitamins, proteins, dietary fibre and antioxidants.

How does malt influence the storage properties of beer?

Haze stability

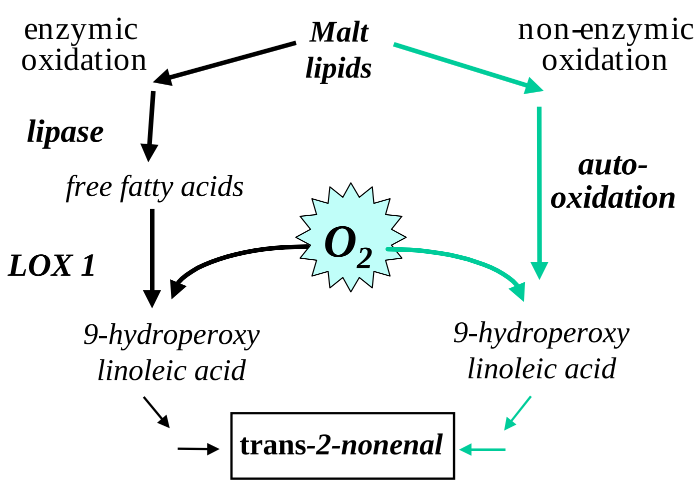
Beer has a tendency to develop chill hazes and permanent hazes during storage. Although malt quality plays an important role in this process, brewing technology has evolved to minimize its impact. Additions of cross-linking agents (such as formaldehyde) to mashes are still made in some developing countries, but such practices are outlawed in many parts of the world. More commonly, adsorbents are used at the beer filtration stage to remove haze precursors. For example, polyvinyl polypyrrolidone (PVPP) is used to remove polyphenols from beer. Silica hydrogels are used to remove proteins. Appropriate use of such materials can minimize the impact that ‘problem’ malts have on final beer quality. In some parts of the world, proteolytic enzymes such as papain are still used to modify the proteins that lead to chill haze formation, thereby extending beer shelf life.

Ideally, we would have no need for such processing aids and additives; the quality of our raw materials and process would suffice to assure beer quality. Some beers are produced in this way. In such circumstances it is essential to focus on the soluble nitrogen content and profile of the malt, and on the polyphenol content and profile of both malt and hops.

Oxidative flavour stability
Recently, malt has taken much of the blame for the instability of beer flavour during storage. Is this warranted? At least some of the instability of the flavour of pale lager beers is due to unsaturated carbonyl compounds, the most infamous being *trans*-2-nonenal. One theory, which is widely subscribed to, suggests that this compound has its origins in oxidation of barley lipids. This may be catalysed by a specific enzyme (lipoxygenase 1) during the malting or mashing processes. Oxidation of unsaturated fatty acids (in particular linoleic acid) leads to formation of hydroperoxides which then undergo further reactions, ultimately leading to volatile, highly flavour-active aldehydes, such as nonenal (Figure 1).

But the flavour stability story is not as simple as it first seems. Numerous studies have shown a relationship between many malt-associated parameters and beer flavour life. These include total nitrogen and free amino nitrogen. Heterocylic compounds from malt are also involved in beer staling, either directly *via* the Maillard reaction, or *via* yeast metabolism. And recently it has been shown that *trans*-2-nonenal can itself bind to beer proteins during production to be released during storage.

Figure 1. Formation of *trans*-2-nonenal in beer.



Sensitivity to light

When exposed to light, beer develops a characteristic flavour, variously termed *lightstruck*, *sunstruck* or *skunky*. The main determinant of whether this character develops is exposure to blue-violet light. Next in importance is the type and amount of hop product used to manufacture the beer. Today, beers can be brewed which do not develop a skunky character. These beers are bittered with chemically-modified hop extracts, rather than with iso-alpha acids. The role of malt in light sensitivity is secondary, but nonetheless important. Significant malt quality traits in this regard include protein content, especially the content of sulphur-containing amino acids, proteolytic activity, and flavin content.

Stability of beer foam quality
Some beers suffer a progressive loss in foam quality during storage. This is usually due to the activity of proteases in the packaged beer. These are yeast-derived, while their substrates (the

foam-active polypeptides) are malt-derived. There is, as yet, no evidence to suggest a role for malt quality in the variations noted between different beers in this character.

How does malt influence the cost of beer production?

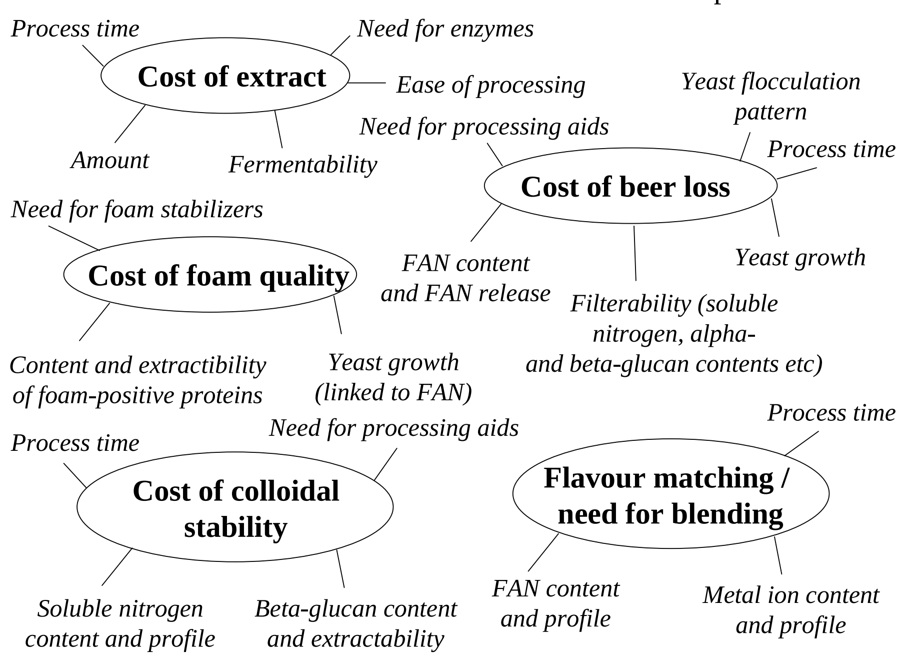
Important considerations in selecting malts for use in brewing (from the perspective of both maltster and brewer) are:

1. Purchase cost of the raw material (barley). This is driven by yield (which in turn is closely linked to disease resistance, need for pesticides, need for fertilizer *etc*), climatic and agronomic considerations, and marketplace conditions.
2. Cost of malting. Attributes which impact on malting cost include dormancy, germinative capacity and vigour, need for growth modifiers such as gibberellic acid or bromate *etc*.
3. Losses in handling. Malt damage impacts on cost, and results from an interaction between malt quality and handling. The key control parameter is grain moisture content.
4. Brewhouse yield – the amount of extract that can be derived from the malt in the brewery.

Total cost of ownership

The factors listed above may sometimes lead us in the wrong direction, since we may select a malt supply based on an apparently favourable price/performance ratio, while paying insufficient attention to the added value that malt brings to the process. The cost of corrective action in terms of labour, plant downtime, and processing aids may exceed the initial saving. Total cost of ownership is a phrase more commonly applied to computer systems and vehicle fleets, but the concept can be equally well applied to malt purchase. The benefit of taking this unconventional approach to malt quality evaluation is that it forces us to take a realistic view of the true cost of malt (see Figure 2).

Figure 2. Some of the factors to consider in the total cost of ownership of malt**.**



To illustrate the point, consider two possible malt purchases. The first meets most of our specifications (potential extract, colour, *etc*) and has been offered to us at $375 per tonne. Its only, and apparently minor, defect is that its starch deposits are laid down in a slightly atypical pattern, with an atypical proportion of small starch granules. The 'defect' is minor and the malt meets our standard specifications quite comfortably.

The second supply meets our specification exactly, but is more expensive, at $400 per tonne. Assume that we will be contracting for 10,000 tonnes of malt, making a potential price difference of $250,000. Which supply is best? Which will be more cost effective? From a purely financial point of view, the cheaper supply of malt looks like the best buy, but the small difference in specification could have significant financial consequences. For example, the differences in how the starch deposits are laid down will affect brewhouse extract release. Initially, this will lead to low extract yields in comparison with theoretical. Plant optimization will allow this to be progressively increased, through alterations in mashing and run-off practices. This has a hidden cost in terms of brewer time, and lost production time. And this optimization process has further consequences, as each trial brew will produce a slightly different product in terms of flavour, filterability, foam quality and so forth. Blending of trial beers is needed to maintain brand integrity – this process costs money. In some cases, a judgement has to be made. Is the trial product acceptable? Usually the answer is 'yes'. However, might it affect consumer behaviour in the medium to long term, through an influence on perception of consistency? – the answer to that question is 'possibly'. And changes in brewhouse practice may lead to changes in beer filterability – slower filter runs, shorter filter runs. A important problem in their own right, but magnified several-fold when they upset the brewery's production planning schedule, and the ability to meet demand for beer in the trade. Trade lost to competitors, disgruntled retailers, and tired employees fighting an uphill battle against a difficult (and self-inflicted) process problem.

So the cheaper malt supply may not be so cheap after all. This example is rather unsophisticated, simplistic and, of course, exaggerated. But it is reasonable to suppose that formal application of this type of thinking could help brewers select malts for the right reasons, rather than for the wrong ones. After all, it is no different from how brewers historically selected malts, in the days before 'sophisticated' malt analyses, and how many craft brewers still select their raw materials today.

Malt specifications – fact or folly?

Given the huge variety of influences which malt has both on the brewing process and on the beer itself, it is clear why no single set of specifications (such as those in Table 3) can satisfy everyone. And, absurdly, the standard error of some methods can be higher than the range of specifications demanded by some brewers. The specification list has changed little from 100 years ago, when typical analyses would have included: moisture content; hot water extract; fine/coarse difference; diastatic power; grain density (a check for sinkers in a glass of water); and arsenic content (as most malts were dried by direct kilning using anthracite).

What should we *really* be trying to measure?

My aim in reviewing, at a somewhat basic level, the properties of malt that contribute to beer quality, has been to highlight their diversity. The ideal malt should have all these properties and components at exactly the right level. However, this is seldom possible since:

(i) Some traits are incompatible – for example, as extract yields have increased over the last few decades, nitrogen contents have reduced correspondingly; however, the tolerance on specifications has not moved in line with this change in many cases;

(ii) Malt is the product of agriculture, and as such varies from batch to batch and within batches.

Variability is at the heart of the problem. Variable malts themselves are not particularly difficult to handle, except in extreme circumstances. What causes more problems is blending of different malts by maltsters or brewers to give a single batch that is ‘in specification’. While superficially the practice makes sense, it can cause more problems than it solves. What is needed is more understanding between maltsters and brewers, and more trust. It is a brave maltster who dares to convince a brewer that they should accept an out of specification malt, on the basis that it will outperform an in-specification, but nevertheless ‘rogue’, batch. Some companies have moved toward this co-operative ideal, but there is some way to go.

Table 3. Typical malt specifications**.**

Specification	Justification	Useful?
Moisture	Key parameter. Breakage of malt at low moisture. Risk of spoilage at high moisture. Financial implications too as malt sold on weight basis.	Yes
Extract (fine grind)	Key parameter. Aim is to predict extract yield from the brewhouse.	Yes
Extract (coarse grind)	Important parameter. Gives information relating to malt modification.	Yes
Fine-coarse difference	Important parameter. Gives information relating to malt modification.	Yes
Cold water extract	Gives information relating to malt modification.	Sometimes
Total nitrogen (TN)	Key parameter. Malts with high total nitrogens are unsuited to beer production, giving problems with microbiological stability, colloidal stability, beer flavour, and beer flavour stability.	Yes
Total soluble nitrogen	Key parameter. Malts with high total soluble nitrogens are unsuited to beer production, giving problems with microbiological stability, colloidal stability, beer flavour, and beer flavour stability.	Yes
Kolbach index	Key (and often maligned) parameter which relates to malt modfication, particularly with respect to protein modification.	Yes
Free amino nitrogen	Relates to protein modification.	Sometimes
Dextrinizing power (DP)	Relates to enzyme potential of malt.	Yes
DP/TN ratio	Corrects apparent enzymes level for amount of protein present.	Sometimes
Amylase activities	Relates to levels of saccharifiying enzymes.	Sometimes
Friability	Key parameter. Relates to modification and milling potential.	Yes
Attenuation limit	Crude indication of brewery fermentation performance.	Sometimes
Wort viscocity	Useful predictor of wort run-off.	Yes
Beta-glucan content	Useful predictor of wort run-off and, when done by staining of grain, gives information on pattern of modification.	Yes
S-Methyl-methionine	Indicator of DMS potential.	Yes
Acrospire length	Indication of grain growth and modification. Can be difficult to assess.	Sometimes
Wort pH	Screen for defects.	Sometimes
Wort taste	Screen for defects.	Yes
Colour	Key parameter. Aim is to predict wort colour.	Yes
Homogeneity	Key parameter. Methodology is a problem.	Yes
Chloropropanols	Screen for harmful substances in coloured malts.	Yes
N-Nitrosodimethylamine	Screen for harmful substance.	Yes
Appearance	Key parameter. Absence of infestation; level of stones *etc*.	Yes
Pesticide residues	Screen for defects.	Yes

Conclusion

In looking at malt purchase, brewers and their buyers have to consider not just the 'headline' specification, but also the implications of the softer aspects of malt quality. Rather than add more analyses to the list, perhaps we should focus on fewer, looking for information, rather than data. Ultimately, it seems, a brewer's judgement on malt quality, using malt analyses as an aid rather than a straightjacket, is likely to be the best path.

Further reading

ASBC (1997) Transcript of an ASBC discussion session on "Malt specifications – What do brewers need". www.scissoc.orga/asbc/MALT_Specs

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