How to Interpret the Malt Certificate of Analysis

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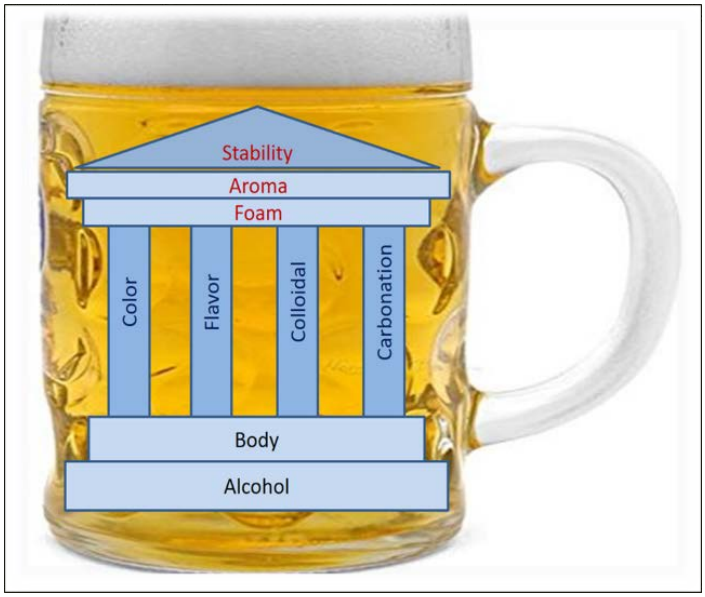
Introduction

Each beer has its own architecture designed by its architect, the brewer. Brewing raw materials such as malt supply the major building blocks necessary to produce a quality beer. The terms on a Malt Certificate of Analysis (COA) represent the common language used between brewer and maltster to communicate quality parameters for this, the most abundantly used raw material. Therefore, it is of particular importance for maltsters and brewers to equally understand the malt specifications required to produce both traditional and unique beer styles of the utmost quality.

A look at beer architecture highlights that malt provides the foundation for beer body as well as potential alcohol. However, malt also contributes to the essential pillars of quality beer: of color, flavor, aroma, foam, and of course stability (flavor and colloidal) (Figure 1).

Fig. 1. The key dimensions of beer architecture



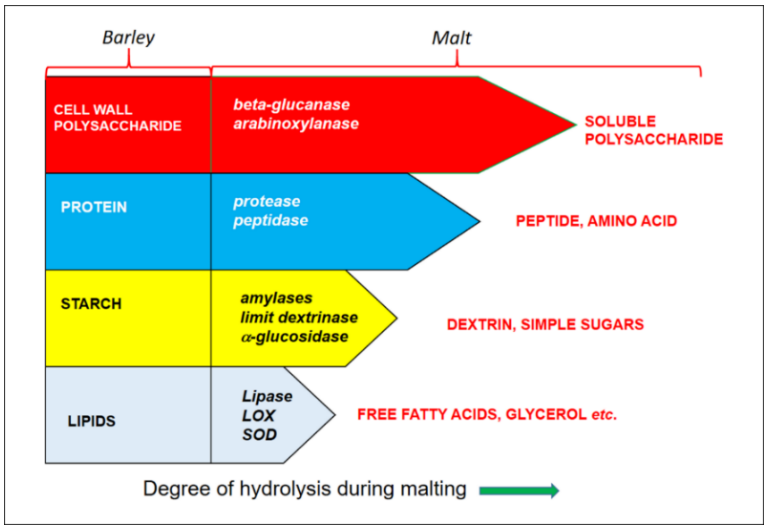
Biochemically, malt provides brewers with fermentable extract, enzymatic power, free amino nitrogen, color, and flavor potential. There are many parameters of malt analysis, all of which provide important information to brewers. Typically these analyses can be classified as either physical or chemical malt parameters. However, the COA also provides both congress wort and enzyme analyses. It's a challenge to choose which particular parameter is most critical as it really depends on what the brewer desires from the malt. However, if we look at the parameters in greater detail it becomes evident that some duplication exists; many of the chemical analyses measure the same potentials in one or more of the three major areas of malt modification: i.e., cytolysis, amylolysis, and proteolysis. Cytolysis is the degradation of cell wall materials like *β*-glucan and arabinoxylan. Amylolysis

Fig. 2. Malt analyses categorized by nature of enzymatic hydrolysis

Malt Modification or Cell Wall Degradation	Degree of Protein Degradation	Starch-Degrading Power
Extract	Kolbach Index	Diastatic Power
F-C difference	Soluble Nitrogen	α-Amylase
β-Glucan	Free Amino Nitrogen	β-Amylase
Viscosity	Hartong Value	Conversion Time
Acrospire growth	Color	Fermentability
Carlsberg staining		Attenuation Limit
Friability		
β-Glucanase		
Wort filtration time		

indicates the degradation of starch to dextrin and fermentable sugars. Proteolysis results from protein degradation to peptides and amino acids (Figure 2). It is therefore very important for all to understand the implication of those parameters.

Fig. 3. Biochemical changes of major barley components during malting



The types and desired degrees of biochemical changes are schematically summarized in Figure 3. Ideally, the following takes place in malting:

- Intensive degradation of cell walls
- Moderate breakdown of the protein matrix rendering adequate amount of soluble proteins
- Exposure of the starch granules for subsequent enzyme degradation in mashing
- Limited degradation of lipids to prevent formation of precursors for beer staling
- Development of the required enzyme package
- Mallard reaction between sugars and amino acids for color and flavor formation, particularly in specialty malt

What follows is an in-depth look at Malt COA Parameters:

Physical Analyses

Moisture

Moisture is actually an economic factor. When moisture is too high, brewers pay for the excess water. However, low moisture can lead to husk shattering that causes excessive dust production during malt handling. Moisture can also indicate kilning intensity, which relates to malt enzyme activity and other quality characteristics like malt color and flavor. Typical malt moisture ranges from 3.5% to 5.0%.

Assortment

Assortment is a kernel size distribution measurement, which can affect necessary mill setting adjustment at the brewery. Assortment also gives indication of the kernel plumpness, which can affect

malt extract potential. Grains that stay on top of the 7/64th-inch and 6/64th-inch sieves are considered "plump." Grains that remain on the 5/64th-inch sieve are "thin," and grains that pass through the 5/64th-inch screen are "thru." Ideal plumpness values should be above 80% with thins contributing to less than 3% of the overall sample. Specifications vary between barley types. Two-row varieties typically have higher plumpness than six-row varieties.

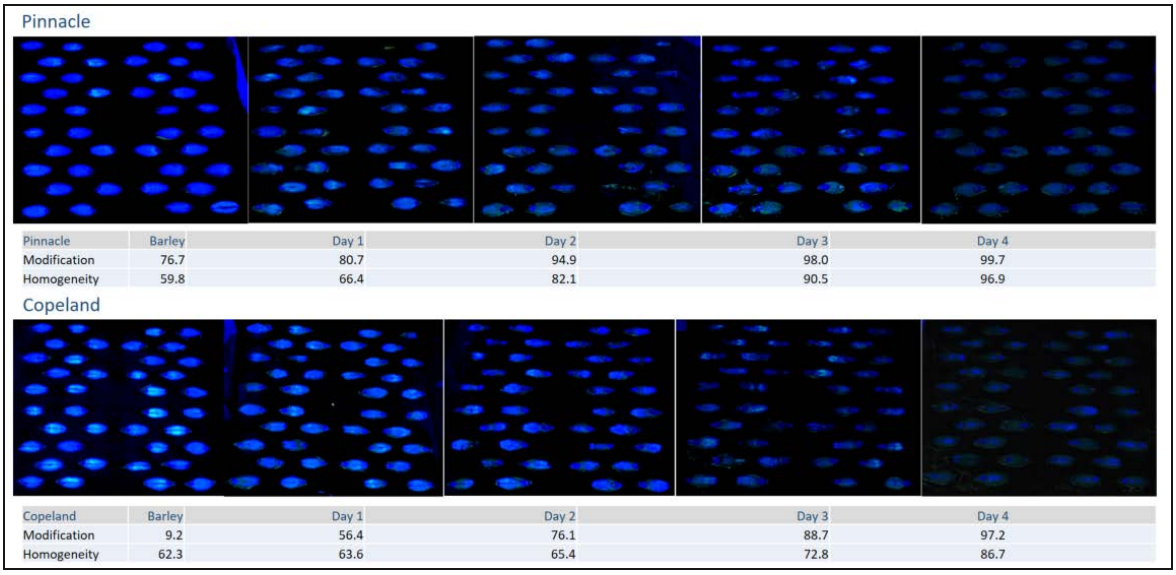
Acrospire Growth

This parameter measures the degree of growth of the acrospires, which corresponds to grain modification progression and uniformity among kernels. The result is influenced by barley vigor, malting process, and grain homogeneity. Ideally acrospires growth range should be between 3/4 to 1 of the kernel length. Because of the deculming process post-malting, a value higher than one is not readily measurable due to the loss of the overgrown acrospire during malt cleaning.

Friability

Friability is a relatively common, practical, and critical parameter found on a Malt COA. Friability gives an indication of how crumbly (friable) the malt kernels are as a result of malt modification. More intensive and even degradation of the barely kernel contents make the grain more friable. Friability is influenced by kernel texture (mealiness), enzyme activity, and malting process conditions. Usually friability should be at the level of 75% or more. The value is generally used for reference to determine mill settings—particularly when the brewer switches to a new variety, new lot, or new crop year. There is a relatively close correlation between friability and other modification parameters such as *β*-glucan level.

Fig. 4. Modification and homogeneity of malt samples germinated for 1, 2, 3, and 4 days



Pinnacle	Barley	Day 1	Day 2	Day 3	Day 4
Modification	76.7	80.7	94.9	98.0	99.7
Homogeneity	59.8	66.4	82.1	90.5	96.9

Copeland	Barley	Day 1	Day 2	Day 3	Day 4
Modification	9.2	56.4	76.1	88.7	97.2
Homogeneity	62.3	63.6	65.4	72.8	86.7

Malt modification and homogeneity by Calcofluor staining

High molecular weight *β*-glucans (MW>10,000) in cell walls are stainable with fluorochrome Calcofluor. Stained material emits florescence under UV light. Kernels are pressed and aligned on a Cernit block, followed by sanding and the staining process (first with Calcofluor and then Fast Green for contrast). Looking at stained kernels, one can observe the intensity of the florescence caused by the *β*-glucans in the malt. In areas where the endosperm is not modified, a bright blue fluorescence is shown while the well-modified areas lose such ability due to the lower *β*-glucan molecular weight.

Through instrumental reading and data processing, the degree of modification and homogeneity can thus be acquired and reported. Figure 4 demonstrates these readings from malt samples that were experimentally germinated for 1, 2, 3, and 4 days respectively. It is evident that even hydration from steeping and sufficient germination time are essential to obtain ideal modification and homogeneity.

Chemical and Wort Analyses

Extract

Extract represents the malt soluble content transferred to the wort under defined mashing conditions. Extract values can be obtained from either fine grind or coarse grind malt. The commonly used mashing procedure, called congress mash as described in the *ASBC Methods of Analysis*, has temperature ramps and holds at 45 ˚C (113 ˚F) and 70 ˚C (158 ˚F), respectively. Filtered congress wort is used to determine extract, color, soluble protein, FAN, viscosity, and β-glucan. Extract level is a very key economic value indicator of the malt quality. Extract level is influenced by kernel size, degree of malt modification, and enzyme levels. In theory it should positively correlate with starch content and negatively correlate with the protein content of the barley. **Fine grind extract** (dry basis) is usually reported and generally expected to be above 80% for two-row malt and 78% for six-row malt. It should be noted that the congress mashing regime is a worldwide reference procedure but it does not necessarily bear close resemblance to wort produced via all industry-used mashing programs such as infusion mashing.

Traditionally brewers take the **coarse grind extract**, as-is, as a reference to predict potential brewhouse yield. Therefore, extract analysis from a congress mash in conjunction with coarse grind is typically performed in the lab in addition to the usual fine grind. The smaller the difference between coarse and fine grinds (**F–C difference**), the better the modification of malt. Nowadays, however, F–C difference normally falls into a narrow range of 1.0% to 1.5%. Other measurements of modification, such as β-glucan and soluble to total protein ratio (S/T), present the brewer with more quantitative information.

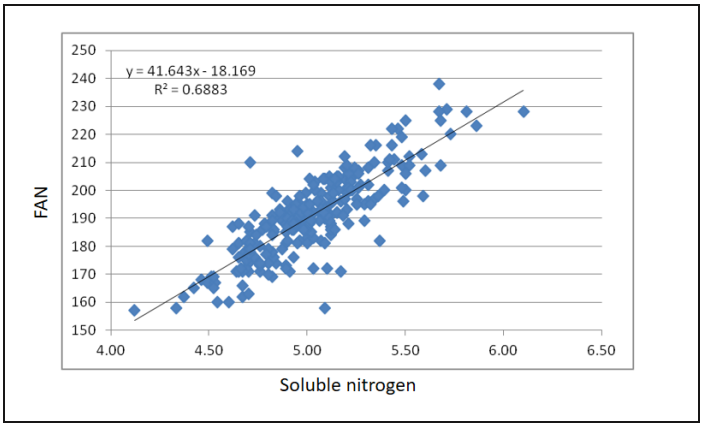
Protein

Malt protein is the building block that leads to the production of foam peptides, free amino nitrogen, and sometimes undesirable beer haze. It is the progenitor of many other important parameters such as color, enzyme activity, and flavor potentials. The determinant factor for malt protein is barley protein content that in turn is dependent on agronomics as well as varietal type. The specification range for protein is generally between 10.0% to 12.5% depending on the type of beer, with adjunct beers generally requiring up to 13%. For all-malt brews, low protein content is preferred as it reduces potential for residual beer amino acids that can lead to flavor instability. However minimum protein levels should be attained to ensure that fermentable extract formation from starch is kept relatively high.

Soluble Protein

Soluble protein, also expressed more accurately as soluble nitrogen (SN), is the portion of protein solubilized into wort; the insoluble portion of protein is left behind in the spent grain. Some soluble nitrogen exists in the form of free amino nitrogen available to yeast as nutrients and for color formation through the Maillard reaction. Other soluble nitrogen materials of certain molecular size contribute to foam formation and persistence. The level of wort soluble nitrogen depends largely on the degree of protein modification. Typical levels of soluble proteins range from 4.3% to 6.0% of the malt by weight. Within a certain variety, i.e., under a set enzyme package, there is a relatively linear positive correlation between free amino nitrogen (FAN) and measured soluble protein (Figure 5).

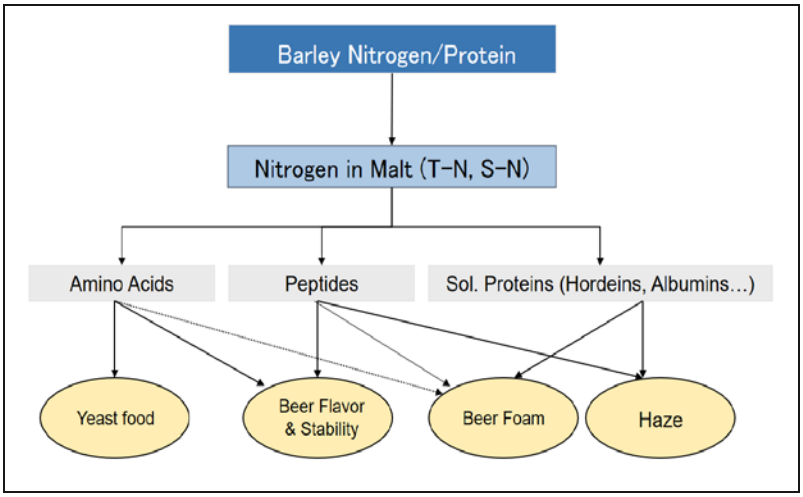
Fig. 5. Relationship between FAN and soluble nitrogen in malt productions from a North American two-row variety



Kolback Index or S/T Ratio

The Kolback Index (KI) is a calculated value of soluble protein divided by total protein and expressed as a percentage value. It gives an indication of degree of protein degradation or proteolysis. This parameter is a key reference for the balanced quality of malt. As malting progresses, total protein is broken down (modified) into smaller and more soluble proteins. Low KI could indicate limited solubilization but is also an indicator of the presence of high molecular weight (MW) protein fragments, which could negatively affect beer colloidal stability. On the contrary, excessive proteolysis could result in over degradation of the protein, which negatively alters foam-active peptides (Figure 6). The typical Kolback Index range is between 38% to 46% S/T.

Fig. 6. Effects of protein and protein degradation products in malt



Free Amino Nitrogen

Free amino nitrogen (FAN) is a measurement of the yeast available (yeast assimilable) amino nitrogen material and typically consists mostly of amino acids. FAN becomes particularly important when high carbohydrate adjuncts are used in the brewing process. In all malt brewing, however, sufficient FAN levels typically exist in the wort. A caution to the brewer: excessive residual FAN in finished beer can lead to beer staling. FAN is the substrate for Strecker degradation which results in Strecker aldehyde production and causes staling flavors in beer. Desired FAN ranges between 150 to 220 ppm depending on the grain bill and if any type of adjunct is used as well as how much.

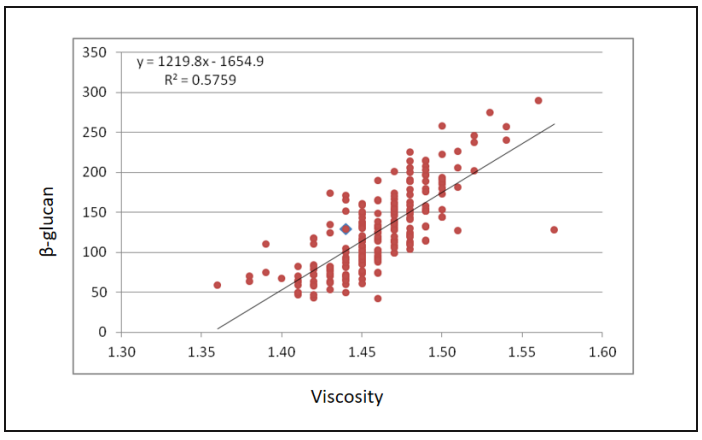
Viscosity

Wort viscosity generally correlates to malt *β*-glucan content. Other polysaccharides like arabinoxylans found in barley cell walls also contribute to wort viscosity. High viscosity leads to filtration and thus brewhouse throughput issues. Reported COA viscosity can indicate potential issues in brewhouse performance and extract yield and likely lauter and beer filtration rates. COA viscosity reported for wort is usually dynamic viscosity (or absolute viscosity, expressed in centipoise) instead of the kinetic viscosity (in centistoke). General desired viscosity on COA specifications ranges from 1.45 cP to 1.55 cP for barley malt, while notably higher for wheat malt due to the arabinoxylan content.

***β*-Glucan**

β-glucan is the predominant barley endosperm cell wall polysaccharide. Worts with large molecular weight *β*-glucans exhibit high viscosity. During malting, *β*-glucanases hydrolyze *β*-glucans to smaller fragments. A highly modified malt has relatively low *β*-glucan content due to intensive cytolysis. High levels of *β*-glucan may negatively impact extract yield, lautering efficiency, beer filtration, and beer colloidal stability. Sometimes *β*-glucans can also contribute to haze formation in packaged beers in colder climates; however, *β*-glucans can also be beneficial for the mouthfeel of beer. Similar to the modification measurement, when *β*-glucan molecular weight is greater than 10,000 in the wort, the staining power with Calcofluor is relatively high, giving strong fluorescence that is measurable with instrumentation. Because the *β*-glucan analysis does not necessarily reveal or correlate to polysaccharide molecular weight distribution, a key parameter impacting wort viscosity, some laboratories use high-performance liquid chromatography (HPLC) to investigate molecular size distribution. The *β*-glucan content in the wort depends on the *β*-glucan content in the malt in combination with malt enzyme activity that can be leveraged during mashing. Usual *β*-glucan levels on a COA specification are required to be below 180 mg per liter. *β*-glucan is thus an indication of malt modification and is highly correlated with several other COA parameters: wort viscosity (Figure 7), modification level, friability, and F–C difference of extract.

Fig. 7. Relationship between *β*-glucan and viscosity of malt productions from a North American six-row variety



Color
Wort color potential is largely developed in the malt during the kilning stage of malting. Components responsible for color are the nonenzymatic caramelization and Maillard reaction products that lead to oxidation of sugars via pyrolysis (caramelization) and pigment production via reducing sugar and amino acid interaction (Maillard reaction). Color is a key specification for both pale and specialty malts. Congress wort color can closely predict the color of production wort and hence also of final beer. A typical range for wort color is 1.5 to 2.5 ASBC units for base pale malt. Stewing and roasting are two processes that promote high color formation in specialty malt types. However, a main drawback to consider is that more intensive curing usually lowers enzyme potential.

Enzyme Analyses

Diastatic Power
Diastatic power (DP) is a measurement of all enzymatic activities toward the degradation of starch. It reflects the combined effect of four key diastatic enzymes, chiefly α-amylase, β-amylase, limit dextrinase and α-glucosidase. These enzymes work in concert to degrade starch into dextrins, oligosaccharides, and glucose. Limit dextrinase is a debranching enzyme that cleaves α-1,6 linkages of amylopectin molecules. α-Glucosidase works from the nonreducing end of both amylose and amylopectin molecules to release single glucose molecules. β-Amylase works from the nonreducing end to produce a single molecule of maltose. Other than α-amylase, other enzymes are relatively thermal labile, so their levels in malt are very much affected by kilning intensity.

The DP parameter therefore potentially predicts the degree of wort fermentability and potential. DP is particularly important to consider when starchy adjunct is to be used in the brewing process. Desired levels of DP depend on targeted beer style and potential inclusion of adjunct. Typical DP ranges vary from 60 to 160 deg. ASBC (EBC: 180–520 WK). The current AMBA reference information for Diastatic Power (°ASBC) is six-row > 150 (487 EBC), adjunct two-row > 120 (387 EBC), all malt 110–150 (353–487 EBC), and distillers >200 (650 EBC).

α-Amylase
α-Amylase is a vital diastatic enzyme. α-Amylase attacks molecules of amylose and amylopectin in random fashion to produce dextrins that vary in molecule size. This enzyme is relatively heat stable under malting and mashing conditions. When starch gelatinization temperature is too high, e.g., 67 ˚C, where the malt β-amylase, limit dextrinase, and α-glucosidase are likely to be denatured quickly, the starch conversion is heavily reliant on the α-amylase. Therefore α-amylase is considered a major contributor for starch liquidation and conversion.

Typical ranges for brewing malt vary between 40 to 60 international units. In some cases, when gibberellic acid is applied during the malting process α-amylase values can be elevated, e.g., for production of distiller’s malt.

Lipoxygenase
Lipoxygenase (LOX) catalyzes lipid oxidation, which leads to an increase in nonenal potential. LOX promotes enzymatic oxidation of polyunsaturated fatty acids, e.g., linoleic acid, to precursors of trans-2-Nonenal (T2N), which contributes to papery or cardboard off-flavors in aged beers. There are multiple LOX isoenzymes in malt and their levels depend on barley variety and rate of LOX development in germination. The curing conditions in malt kilning affect residual LOX activity, as

most of the LOX isoenzymes are relatively heat labile. However, intensive curing can detrimentally lead to higher color and thermal load in the malt so a balance must be achieved

The ASBC has recently published a new LOX test procedure resultant from a multi-laboratory collaborative effort. Brewers of pale lagers and adjunct lagers prefer that LOX activity in malt to be below 20 units in order to control the formation of cardboard off-flavor in the products in the trade.

Other Malt Analyses

Dimethyl Sulfide Precursor
Dimethyl sulfide precursor (DMSP) is the precursor of dimethyl sulfide (DMS), which is a flavor component of beer resembling creamed corn that originates from malt and is released during wort production. DMS is volatile and can be reduced by intensive kilning in malting. Proper kettle boiling also therefore assists in the reduction of wort DMS/DMSP. During fermentation DMSP is metabolized by brewers' yeast to DMS. Typical levels in malt are less than five ppm.

N-Nitrosodimethylamine
N-Nitrosodimethylamine (NDMA), also known as dimethylnitrosamine, is a semivolatile organic compound that results from a reaction between oxides of nitrogen (NOx) in air and malt dimethylamine (DMA). DMA originates from malt amines hordenine and gramine, all of which are produced in germinating barley. These donors of DMA are present in sufficient amounts, with hordenine accumulating in rootlets, and are not readily controllable during the malting process. The important source of the nitroso group is the various oxides of nitrogen (NOx). Therefore, the key is to control the content of NOx, the nitroso group, in the kiln air. That is why indirect heating through use of heat exchangers in kilns is now more commonly employed. NDMA should be strictly controlled in finished malt as it is a suspected carcinogen. Permitted NDMA levels are normally below 5 ppb in the specifications.

Deoxynivalenol
Deoxynivalenol (DON) is a mycotoxin secreted by field fungi of the *Fusarium* species. DON is water soluble and can be reduced from barley during the malt steeping process. However, viable *Fusarium* that remain on/in the barley kernels can continue to grow and produce DON during the germination stages and detrimentally affect malt quality. The typical specification for DON is below 1.0 ppm on the malt, which adheres to the FDA mycotoxin regulatory guidance for grain commodities intended for human consumption.

Conclusion

Cell wall polysaccharides, protein, and starch go through differing degrees of enzymatic hydrolysis during malting. The impact of enzymatic degradation on brewing processes and beer quality traits are represented in summary in Figure 8. Information found on a malt COA thus not only highlights malt modification but also its potential to impact beer quality. The malt COA can thus be thought of as a bridge that closes the gap between maltster and brewer, paving a straighter path to higher quality beer.

Fig. 8. Degree of impact by the degradation of malt components on brewing processes and beer quality traits

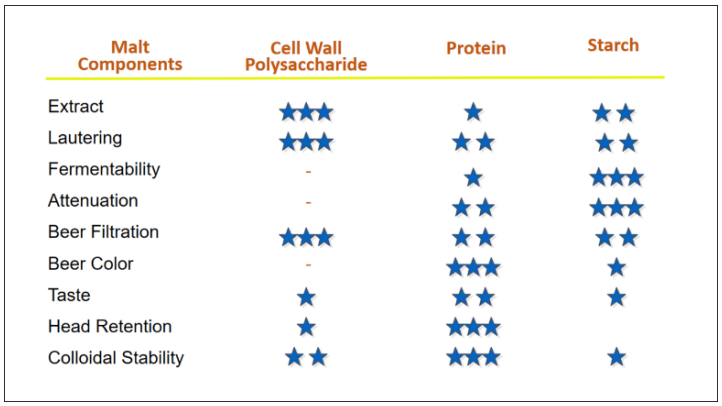
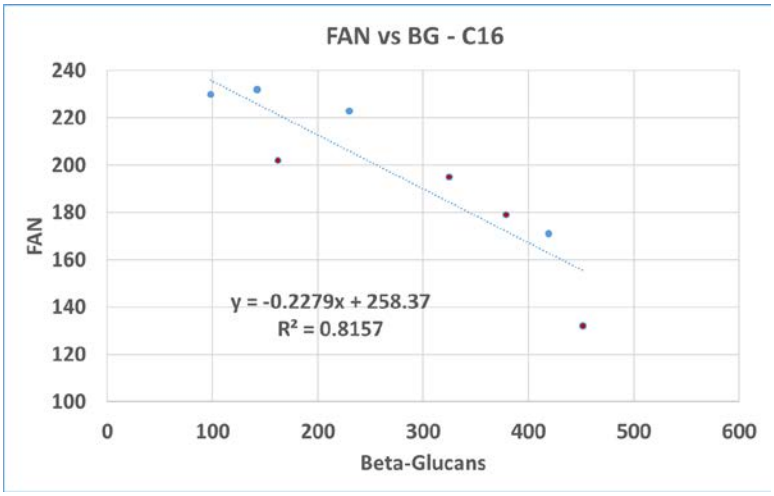


Fig. 9 Relationship of FAN and b-glucan in malt samples from two NA barley varieties of crop 2016



The interconnection of many malt parameters, e.g., viscosity and β-glucan, is evident, and many parameters possess interdependent dynamics—as one goes up or down it affects another parameter either up or down. Figure 9 demonstrates such dynamics where the lowering of malt β-glucan is accompanied by increasing FAN (Figure 9). In such an instance illustrated with the two North American varieties, at a FAN level of 160 ppm, the wort β-glucan could be as high or even beyond 400 ppm. Furthermore, from the example in Figure 5, one can see for a malt type with FAN of 160 ppm, the corresponding soluble nitrogen is about 4.3%. If the malt protein content is as low as 11.5%, the S/T value would be 4.3/11.5 = 37% which is generally too low for adequate protein modification. To improve the S/T up to the typical 43% point, the total protein in malt should be ~10% (4.3% soluble protein/ 43% KI) to literally align these parameters to the desired ranges. Because of these complex interdependencies of malt COA parameters, brewers and maltsters need to align to set reasonable and mutually attainable specifications in accordance with what mother nature presents. In this manner the maltsters can ensure that the brewers attain the proper building blocks to better suit production of architecturally sound (high quality) beers.

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Note: This article is intended as a preview of a chapter of an upcoming ASBC short book on MALT. This is only a brief and non-exhaustive review of malt analyses. Some other analyses are occasionally used by certain brewers of concern, such as the tendencies of gushing and premature yeast flocculation (PYF).