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Brewing Techniques in Practice

W. Back, M. Gastl, M. Krottenthaler, L. Narziß, M. Zarnkow

FACHVERLAG HANS CARL

BREWING TECHNIQUES IN PRACTICE

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An In-depth Review of Beer Production with Problem Solving Strategies

Werner Back, Martina Gastl, Martin Krottenthaler, Ludwig Narziß, Martin Zarnkow

FACHVERLAG HANS CARL

IMPRINT

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FOREWORD

There has been a desire within the international brewing community for some time to make this technical text available in English, and with the present translation of 'Brewing Techniques in Practice' this has finally been realized. In doing so, information concerning beer styles and brewing methods commonplace outside of Germany has been incorporated into this volume. Craft beer has also been taken into consideration. The existing chapters were revised and updated to reflect the current state of scientific findings and technical knowledge. Like the original text, the English edition has been organized along thematic lines, which address routine day-to-day tasks faced by brewing technologists.

The complex explanations found in this book provide a well-reasoned, articulate and comprehensive overview of each topic for brewers working in the industry as well as for students of brewing. The respective concepts are clearly elucidated in their entirety in each chapter, both at a scientific and a technical level. Particular emphasis is placed on the fundamental aspects of biochemical processes as well as production techniques, so that the information can be readily applied in practice. The organization of the book, which includes a thorough summary at the end of each chapter, has proven to be an indispensable tool, especially as it allows problems, causes and solutions to be explored with ease. Those in the industry will find the tables with standard values for substances typically found in wort and beer to be quite useful. A table has been added providing conversions of international units along with key indicators for technical processes. An overview of the requirements necessary for a beer to be acknowledged as having been "brewed according to the German *Reinheitsgebot*" has likewise been appended to this English edition.

Additionally, a section of the book has been set aside for the purpose of distinguishing the *Reinheitsgebot* (referred only to lager beer), the medieval purity law of 1516, from the current provisional beer law (*Vorläufiges Biergesetz*), which comprises the current regulations governing beer production in Germany. The *Reinheitsgebot* still serves as the core of the *Vorläufiges Biergesetz*, in that the four ingredients stipulated for brewing beer in the law from 1516 still apply under the existing regulations. The *Vorläufiges Biergesetz* regulates all further aspects of modern beer production.

I am grateful to my co-authors for their contributions to the current English edition, as well as to my former colleagues at the *Technologie der Brauerei I* at the TUM-Weihenstephan, who laid the groundwork for this technical brewing text. I owe all of them a debt of gratitude for their diligent and competent teamwork.

My thanks also go to the Fachverlag Hans Carl for the willingness to publish this revised and updated English edition of the handbook.

Werner Back
Freising, August 2019

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MALT

1 INTRODUCTION

Malt quality is of great consequence in beer production and thus has a substantial impact on the quality of the finished beer. Individual production steps, e.g. lautering, fermentation and filtration, as well as attributes central to the character of beer, e.g. flavor, color, foam and stability, are heavily influenced by malt quality. The malt utilized in beer production is mainly produced from malting barley; however, for some specialty beers, e.g. Southern German-style wheat beer, malt is also produced from wheat or even other cereals, e.g. rye or oats (cf. Cereals and Pseudocereals). Barley is a natural product, making it subject to regional and seasonal fluctuations. The task of compensating for this variation, at least to the extent physically possible, falls to the maltster whose vocation it is to make homogeneous malt of a consistent quality available to breweries. However, biological and economic constraints limit the degree to which quality can be rectified in the malthouse. Maintaining high standards of quality for German malting barley and, in turn, for the malt created from the barley for the purpose of brewing beer, is the responsibility of the entire production chain, from the farmer to the brewer. Advancements in barley breeding and cultivation have resulted in malting barley of an extremely high quality, particularly spring barley varieties. Specifications define the quality of malt required for effortless processing and thus have become the standards used by malt producers and other processing companies.

Through selection of the barley variety and the level of malt quality and hence the standard values and thresholds for the quantifiable attributes described in the malt analysis, a brewer ultimately determines the quality of the raw materials required for a particular beer style. When deciding which attributes should receive the highest priority, the accuracy of the analyses as well as how these various attributes interact with one another should be taken into account. Meticulous attention must be exercised in obtaining analysis results. The procedures for conducting the brewing analyses established throughout Europe have been published in collections of brewing analysis methods by the *Mitteleuropäische Brautechnische Analysenkommission* (Central European Brewing Technology Commission or MEBAK) and by the European Brewery Convention (EBC) [1, 5].

The laboratory mashing method for the evaluation of malting barley varieties was changed prior to the 2012 harvest. The Congress mash method was replaced with an isothermal 65 °C mash (similar to hot water extract), allowing a more practically oriented assessment of new barley varieties to be carried out while also providing insights into processability [2]. However, when evaluating malt quality, the results obtained with the Congress mash method are not equivalent to those found with the isothermal 65 °C mash method. In this situation, comparative analysis is needed to find a common basis. Direct conversion factors will certainly never be generated for adapting the pool of data collected for the Congress mash method to the data for the isothermal 65 °C mash method [3]. Due to the considerably advanced proteolytic and cytolytic modification of grain accomplished in the malthouse, brewers can concentrate their efforts on degrading the starch in the mash vessel (cf. Mashing). Before discussing the individual attributes measured in malt analysis, one should understand that the quality of the assessment itself, as well as the quality of a particular lot of malt, largely depends on representative sampling. The importance of collections, along with the rules governing collection and the preparation of samples, have been described in numerous publications [1, 6, 4].

2 THE QUALITY ATTRIBUTES OF BARLEY MALT AND WHEAT MALT

2.1 QUALITY ATTRIBUTES OF BARLEY MALT

First and foremost, a barley malt analysis describes the three primary modification processes that have occurred in the kernel: cytolysis, proteolysis and amylolysis. The single most important task of the maltster, given the fact that modern brewhouse procedures often entail mashing in at temperatures above 60 °C, is to effect a homogenous and complete degradation of the cell walls and to attain a suitable level of protein modification. Thus, malt quality plays a key role in ensuring that the production process runs smoothly. In large breweries, where up to twelve batches of wort are brewed per day, modifying the temperatures and rests in the mash program to accommodate individual fluctuations in malt quality is not practicable if brewing operations are to remain on schedule. Thus, mashing is largely limited to amylolysis, that is, the degradation of amylose and amylopectin required for brewing (cf. Mashing).

2.1.1 CYTOLYSIS

Cytolysis describes the degradation of the substances providing structure and support to the cells that surround the starch in the endosperm. Structural proteins and polysaccharides in the cell wall, especially β-glucans, are subject to these degradation processes. If the processes are allowed to continue during malting until the support structures of the cells are largely broken down, the enzymatic degradation of the endosperm during mashing is much less arduous, resulting in higher brewhouse yields. Likewise, insufficient modification of these support structures not only brings about shortfalls in brewhouse yield but also causes large quantities of high molecular weight β-glucans to become soluble and enter the process of wort production.

Older sources attest to the favorable influence of high molecular weight β-glucans on foam and mouthfeel. As long as the β-glucans are not in gel form, quantities of up to approximately 350 mg/l do not pose a problem from a brewing standpoint (isothermal 65 °C mashing procedure)[7, 8, 9]. β-Glucan gel can lead to filtration issues even at concentrations as minute as 10–15 mg/l, a level only slightly above the reliable detection threshold (cf. Filterability – Issues with Turbidity). Wort produced using mash programs with mash-in temperatures above 60 °C are particularly susceptible to gel formation. At mash temperatures in the range from 60 to 65 °C, a substantial amount of β-glucans still bound to the cell walls is liberated by the enzyme β-glucan solubilase. However, degradation of this high molecular weight fraction can no longer take place, since the endo-β-glucanases – the enzymes responsible for breaking down these large β-glucans – are inactivated at temperatures as low as 52 °C. Thus, given a consistent malt quality, brewhouse procedures incorporating high mash-in temperatures will always lead to higher total β-glucan concentrations in wort and beer. For this reason, high mash-in temperatures require more extensive modification of the cell wall (cf. Mashing).

Various key metrics are used to describe the level of cytolytic modification. The value for friability has proven useful in this regard. The procedure is simple, and the value can also be ascertained rapidly. Cell wall modification is evaluated with a friabilimeter to determine the overall friability of a specific lot of malted grain and the percentage of kernels that are classified as completely glassy. This information is then used to draw a conclusion regarding how uniform the process of malting the barley has been. High values for friability are not necessarily an indication of over-modification, as long as they only apply to cell wall modification and not to protein modification. Therefore, breeders involved in developing malting barley varieties face the challenge of striking the right balance among the individual traits used to define modification, especially with respect to proteolytic and cytolytic processes.

Other attributes providing information about the degree of cytolytic modification include the viscosity and the β-glucan content of both the Congress wort and of the 65 °C mash as well as the homogeneity and modification of the malt. The values obtained for the 65 °C mash are a better gauge of cytolytic modification than the values obtained with the Congress mash.

Owing to the 45 °C rest, the Congress mash method promotes more β-glucan degradation. However, with this method, once the temperature of the mash reaches 45 °C, it is immediately heated to 70 °C, which does not allow enough time for an adequate β-glucan solubilase rest. Thus, variation in cytolytic modification among different lots of malt cannot be sufficiently characterized by means of the Congress mash method. The isothermal 65 °C mash, on the other hand, more clearly distinguishes this variation with its high mash-in temperature and intensive β-glucan solubilase rest. From time to time, the difference in the results between the Congress mash and the isothermal 65 °C mash is also employed as an assessment criterion. One should be mindful of the fact that both MEBAK and the EBC no longer include the method for determining the difference in extract between fine and coarse grist in their analysis collections. Based on statistical evaluation in combination with practical tests, the following analysis results and limit values have been shown to be useful for mash programs utilizing high mash-in temperatures.

Table 1: Cytolytic malt analysis attributes for mash programs utilizing high mash-in temperatures (isothermal 65 °C mashing procedure)

friability	> 85 %
whole glassy kernels	< 2 %
viscosity, isothermal 65 °C mash (adj. to 8.6 %)	< 1.6 mPa·s
β-glucans, isothermal 65 °C mash (adj. to 8.6 %)	< 350 mg/l
homogeneity	> 75 %

Practical experience has shown that it is prudent to determine the viscosity of the isothermal 65 °C mash in addition to the friability (including the glassy kernels) and homogeneity as part of a routine analysis program. Only in cases of considerable uncertainty (results exceed or fall below the limit values) would it be worthwhile to perform the remaining analyses in table 1. Interpretation of the results is recommended as follows: If the results for at least two of the analyses fall outside of the range for the limit values given, then mashing in at a high temperature with the malt in question can lead to difficulties during lautering and filtration. If, on the other hand, the results remain within the limit values and filtration issues arise, these can most likely be traced back to errors in brewing techniques (cf. Filterability – Turbidity Problems). If only one of the values exceeds the limit, then the analysis should be repeated. In some instances, the analyses to determine the percentage of whole glassy kernels and the concentration of β-glucans exhibit very poor reproducibility. The corresponding statistical data analysis can be found in the collection of analysis methods published by MEBAK or EBC. Low values for homogeneity and a disproportionate rise in the viscosity and the concentration of β-glucans in the Congress wort compared to the values from the 65 °C mash indicate that highly modified malt has been mixed with slightly modified malt [10].

2.1.2 PROTEOLYSIS

Proteolysis describes the degradation of the protein in the kernel and its resultant transformation into more soluble molecules, which can be of a low, medium or high molecular weight. While extensive cell wall modification does not impact beer quality in either a positive or negative manner, it does improve processability. Both excessive and negligible levels of protein modification are regarded as detrimental. Low protein modification carries the risk of depriving the yeast of assimilable nitrogen compounds. Negative outcomes include inadequate yeast reproduction and the formation of undesirable fermentation by-products (e.g. diacetyl). On the other hand, a high level of protein modification results in excessive degradation of high molecular weight proteins. A dearth of sufficient concentrations of high molecular weight proteins – but also a surplus of medium molecular weight proteins and certain amino acids (lysine, arginine and histidine) – has a negative effect on foam stability. Malt subjected to elevated levels of protein modification produces wort and beer that tends to be darker in color and contains an overabundance of certain amino acids. The presence of these amino acids leads to the production of uncharacteristic aromas in beer, along with reduced flavor stability (cf. Flavor Stability). Furthermore, beer containing higher concentrations of amino acids is more susceptible to beer spoilage microbes.
The Kolbach index (degree of protein modification), the soluble nitrogen content and free amino nitrogen (FAN) are key metrics for proteolysis. The Kolbach index is the most commonly used metric for assessing proteolysis in commercial breweries. It represents the percentage of the total protein converted into soluble form during malting and subsequently during the Congress mash (calculated value). The preferred range for pale, all-malt beers is between 38 and 42 % (Congress mash method). The degree of protein solubility limits the possibilities for theoretical combinations derived from the absolute values for the protein content of the malt (standard values: 9.5–11 %) and the soluble protein (standard values: 3.9–4.7 %). This is intended to ensure that the overall composition of soluble protein is balanced in the ranges of both the high molecular weight (foam stability) and the low molecular weight (yeast nutrition) proteins, independent of the total protein content of the malt. Soluble protein is calculated by determining the soluble nitrogen (conversion factor: 6.25) in most cases. Consequently, calculations based on the data above yield values of 650 to 750 mg of soluble nitrogen per 100 g of malt (dry matter) and 130 to 160 mg of FAN per 100 g malt (dry matter) which should account for approximately 21 % of the soluble nitrogen (Congress mash method). A curtailed mash program or the use of adjuncts, such as rice or corn, would mean that higher amounts are required (cf. Cereals and Pseudocereals).

2.1.3 AMYLOLYSIS

Of the metrics available for amylolytic activity, the following measurements are routinely performed: extract, limit of attenuation, β-amylase activity (expressed as diastatic power in WK units or β-amylase activity in BU) and α-amylase activity (ASBC or DU, using a Megazyme kit). The extract content indicates the percentage of finely milled malt (dry matter) that can be solubilized using the laboratory mash method and gives an indication of the expected yield during the brewing process. In the case of barley malt, the values are between 78.0 and 83.5 % (Congress mash method).

The limit of attenuation is a metric for evaluating the quality of wort in a laboratory and provides information on how well the extract can be metabolized by the yeast. The degree of final attenuation reached in the finished beer at a brewery should be compared to the laboratory results for the limit of attenuation. The final attenuation should be equal to or as close as possible to the limit of attenuation. The quantity of fermentable sugars and their relative proportion are the defining factors for the limit of attenuation; however, it is also affected by the gelatinization temperature of the starch (cf. Mashing). In addition, the role of trace elements and the nitrogen composition should also not be underestimated. As a measure of quality of the Congress wort, the following applies: the higher the limit of attenuation, the better (> 81 %). Final attenuation in the brewery is sometimes disproportionately high and can be difficult to control. Within this context, there is some discussion as to whether or not attempts should

be made to regulate the limit of attenuation in the malt (cf. Acidification with Natural Lactic Acid). The β-amylase activity of malt is primarily of interest outside of Germany, e.g. in countries where large quantities of adjuncts are used. These adjuncts usually contribute very little enzymatic activity of their own. For an all-malt beer, values for β-amylase activity greater than 200 WK or 750 BU, respectively, are considered adequate. If β-amylase activity is too low, this can cause a shift in the sugar spectrum and may result in abnormal fermentations in extreme cases (diauxie).

The pace-setting enzyme during starch degradation is α-amylase. It degrades starch into fragments consisting of amylopectin and amylose, providing substrate for β-amylase. An α-amylase activity of more than 60 ASBC units or DU is desirable. If the mash is acidified, α-amylase activity may be inhibited to some extent (pH optimum: 5.4–5.6). If the gelatinization temperature of a given lot of malt is high, it would be beneficial to avoid acidification during mashing, since this could result in increased iodine values. Furthermore, undesirable consequences may arise as well, such as higher values for turbidity in the filtered beer. Furthermore, a lack of available substrate for β-amylase can adversely impact the limit of attenuation (cf. Mashing).

2.1.4 ADDITIONAL MALT SPECIFICATIONS

2.1.4.1 DMS precursor

The DMS precursor (DMS-P), otherwise known as S-methylmethionine (SMM), is an amino acid not found in barley in its unbound form, but it is present in malt.

Dimethyl sulfide (DMS) splits off of the larger DMS-P molecule at above approximately 70° C, essentially at every stage of malt and wort production in which thermal processes exceed that temperature.

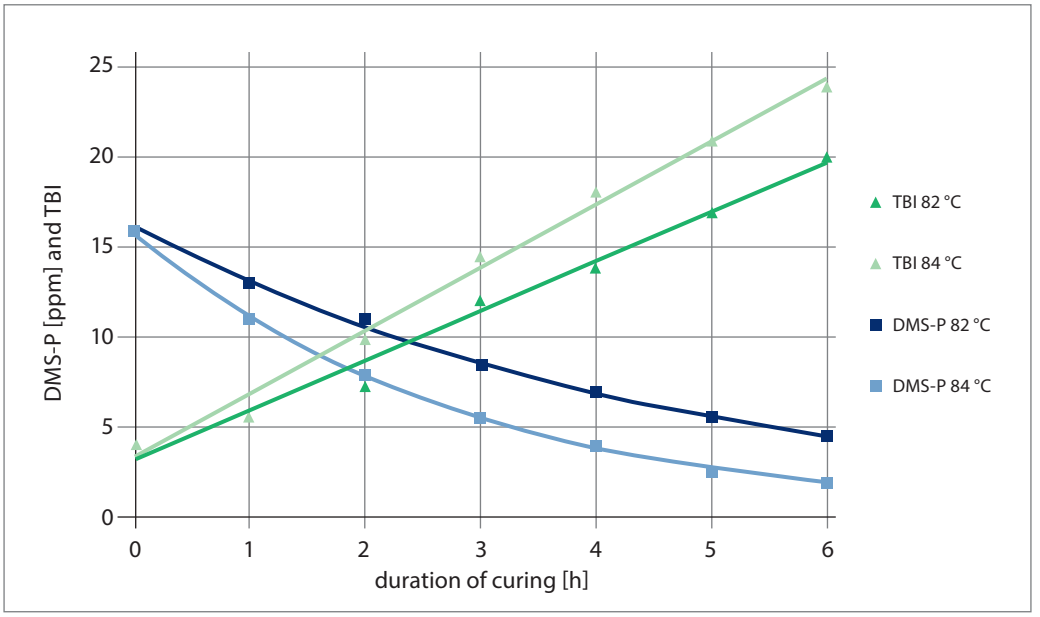
The vast majority of DMS should be cleaved from the DMS-P molecules and eliminated during malt kilning and wort boiling. One should be cognizant of the fact that DMS will continue to be formed in the whirlpool (cf. Wort Boiling, Wort Boiling Systems). The temperature and duration of curing during kilning are the most effective means for influencing the level of DMS-P in the malt. In principle, the following applies: the higher the temperature or the longer the duration of curing, the lower the level of DMS-P in the malt. However, economic considerations and excessive thermal stress (see TBI) can be detrimental to pale malt and thus serve as arguments against curing longer at higher temperatures.

DMS can create flavor and aroma impressions in the finished beer that are reminiscent of boiled cabbage or cooked vegetables. The sensory threshold for free DMS in beer is approximately 50–100 µg/l. Therefore, depending on the intensity of the wort boiling process, the DMS-P content of malt should not exceed 5–7 ppm (cf. Wort Boiling, Wort Boiling Systems).

2.1.4.2 TBI (thiobarbituric acid index)

The TBI is a metric representing the sum of the thermal stress to which the malt has been subjected during the kilning process. Maillard products deepen the color of the malt and the finished beer and may, in part, have a negative impact on the beer's flavor stability. These compounds are formed in reactions brought about by thermal stress. For pale malt, the TBI measured in the Congress wort should not exceed 18, and the values for DMS-P must be reduced to below the recognized upper limit. As already stated above and is often the case in malting and brewing technology, a compromise must be reached between the lowest possible thermal stress on the malt and the cleavage of DMS-P along with the elimination of DMS when determining the intensity of the kilning process (fig. 1).

Figure 1: Relationship between the temperature/duration of kilning and the TBI/DMS-P content in malt according to FORSTER [8].
For example: a concentration of 5 ppm DMS-P is obtained under the following conditions 3.2 h/84 °C/TBI=14.5 or 5.5 h/82 °C/TBI=18.



2.1.4.3 Malt color and boiled wort color

Obviously, the color of the malt significantly influences the color of the finished beer. Both are determined photometrically or visually from Congress wort samples (unboiled or boiled). In comparing analytical results, one should note which methods were used to determine the color. Pale malts used to produce Central European lager beers should possess a color between 2.5 and 3.5 EBC. The color itself is indicative of the malt and how it was produced. In principle, the color of the boiled wort can be used to predict the color of the finished beer if information is known about the brewing techniques employed. The thermal stress brought about by the brewing process, any potential oxidation processes (especially during mashing) and the extent of the pH drop during fermentation all have a considerable influence on the beer color, independent of the malt color. The application of less intense wort boiling methods and low thermal stress on both the malt and the wort can result in finished beer that is too light in color. In such cases, the desired color can be adjusted by adding of any number of specialty malt products [10, 12].

2.1.4.4 pH

The pH of the malt is determined by measuring the pH of the Congress wort. For pale barley malt, the pH should range from 5.80 to 5.95. Darker malts possess a larger quantity of Maillard products and thus a lower pH, which varies between 5.50 and 5.80. If the pH of pale malt is too low, this can be an indication that it has been overly modified or too intensely sulfured. One can expect that the mash produced using malt of a low pH will also exhibit a low pH.

2.2 QUALITY CRITERIA FOR WHEAT MALT

The criteria for assessing the quality of wheat malt were appropriated directly from those for judging barley malt. Since the technological requirements are different for the production of Southern German wheat beers, a critical view of these quality criteria is therefore necessary. The differences in barley and wheat as well as in clear, bottom-fermented beer and cloudy, top-fermented beer require a fundamentally different approach to the raw materials. The quality of wheat, the capacity to convert wheat to malt and the influence of the malt quality on that of the wheat beer, are not nearly as well researched as the same characteristics in barley and barley malt. Nevertheless, in each respective section of the discussion below, the properties of wheat malt are compared to the properties of barley malt and, where relevant, their similarities and differences are also examined [4].

2.2.1 CYTOLYSIS

The polysaccharide β-glucan, which is present in the cell walls of barley malt, is the primary focus of the analyses for characterizing the cytolytic processes involved in malt modification, and it also largely determines the viscosity of wort produced from barley malt. Staining β-glucans with calcofluor provides the analytical foundation for evaluating the homogeneity of malt or for directly determining the concentration of β-glucans in wort and beer. Wort brewed with wheat malt generally exhibits a higher viscosity (1.6–1.8 mPa·s in Congress wort) than wort brewed with barley malt. However, the viscosity is not attributable to β-glucans, but rather to other polysaccharides called pentosans. Little is known concerning their behavior during the processes of malting and brewing. It has been reported that if they are exposed to hot side aeration during mashing, the pentosans in rye malt can increase the viscosity of the wort quite dramatically, leading to difficulties in the lautering process [13]. Nevertheless, although gel formation has been documented with β-glucans, its formation in beer containing pentosans has yet to be demonstrated. With regard to the aforementioned analysis of barley malt and the evaluation of its cytolytic modification, one should keep in mind that not all of the tests based on β-glucans are applicable to wheat malt. In essence, the analyses used to assess the homogeneity of barley malt as well as the direct determination of β-glucans in wort and beer are not relevant for judging the quality of wheat malt. Moreover, the friabilimeter test is of little value in determining how friable the structure of the endosperm is in wheat malt. For this reason, only the viscosity remains as a means for assessing the level of cytolytic modification. Unfortunately, the results for the viscosity of Congress wort produced with wheat malt cannot be adequately correlated with lautering behavior or filterability in the production of *Kristallweizen* (filtered Southern German wheat beer) (cf. Filterability – Issues with Turbidity). However, given the fact that no other parameters exist for evaluating the processability of wheat malt, viscosity is currently the only reliable indicator for the degree of cytolytic modification in wheat malt.

2.2.2 PROTEOLYSIS

The analyses used to assess the proteolytic modification of barley malt are also used for wheat malt: total protein (conversion factor: 6.25), soluble protein, the Kolbach index (the quotient derived from these two values) and FAN. Protein modification in wheat malt has a significant impact on the aroma of weissbier [14]. Research results indicate that more extensive proteolytic modification results in the formation of fewer esters, thus leading to more neutral beers.

Furthermore, proteins play a central role in the consistent and permanent haze present in weissbier. Researchers are currently investigating the properties of these haze-forming compounds as haze is an important attribute of weissbier and other cloudy beer styles. Weikl has already shown that yeast cells are generally too large and sink too quickly to generate lasting turbidity [15]. Particles capable of doing so are between 0.1 and 1.0 µm in size. These particles have been identified as proteins and also, in part, as α-glucans. However, exactly how the variety of wheat and the malting technology influence the occurrence of these particles in beer remains largely unknown and is the subject of current research on weissbier.

Compared with bottom-fermented beers, the presence of proteinaceous particles appears to exercise a much greater influence on the filterability of *Kristallweizen* [16]. The desire for stable turbidity levels on the one hand and good filterability on the other suggests that two types of wheat malt with different specifications with respect to protein modification are required for weissbier and for *Kristallweizen*. Generally speaking, the key metrics for proteolytic modification of barley malt can be applied directly to wheat malt, although the overall protein content of wheat will be slightly higher, which in fact is desirable. Sacher has shown that a protein content of around 12 % for wheat malt and a moderate level of protein solubility are beneficial for the aroma of weissbier [14].

2.2.3 AMYLOLYSIS

Even with a significantly higher protein content, due to its lack of husks, wheat malt yields a higher amount of extract than barley malt, but in the end, weissbier exhibits a lower final degree of attenuation. This may also be due to a considerably lower level of α-amylase activity in wheat malt. As a rule, iodine tests show that saccharification turns out to be less extensive in a weissbier mash. For the most part, the α-glucans responsible for higher iodine values are considered favorable for achieving a stable turbidity, although a reliable confirmation is still lacking. In *Kristallweizen*, α-glucans are the primary cause of elevated values for turbidity, according to the 90° scattered light measurement. In any case, they are deemed undesirable in *Kristallweizen*. Measuring the α-amylase activity of wheat malt does not provide any valid insight into its processability. However, it has been shown that in the absence of any suitable alternatives, enzymatic activity can be helpful in estimating the quality of wheat malt. In this regard, the highest amount of enzymatic activity possible is preferable.

2.3 FOOD SAFETY

In light of a number of recent scandals and due to the globalization of the food industry, many consumers, merchants and legislators have focused their attention on the safety of food. Beer is largely protected against pathogenic microbes, due to many positive attributes, which include a low pH and compounds from hops (cf. Microbiology). Even the raw materials barley and wheat, and the malt produced from them, are foods that exhibit a low and manageable risk for consumers. Nevertheless, in recent years, a large number of safeguards have been created, strengthened by new legal regulations and the establishment of upper limits across the EU. The upper limits and analysis methods are the subject of a never-ending, highly politicized discussion. It is imperative to avoid any negative publicity arising from product safety issues which were initially reported as factual, only to be revealed later as untrue. For this reason, performing analyses for the detection of residues and toxins require the greatest care and expertise, and as noted previously, competent sample preparation is indispensable.
The risks inherent to the production chain – from farmers to merchants onto maltsters and finally to the delivery of malt to the brewer – can be impartially assessed. Risk analysis and risk assessment must be carried out independently by each company. Sources for additional information on current developments relevant to this topic are provided in the overview in table 2.

3 SUMMARY

Because malting barley is an agricultural product, the quality of barley is subject to varietal and seasonal fluctuations as well as disparities in cultivation practices. Maltsters endeavor to minimize this variation to an extent that it is both technologically feasible and economically reasonable, in order to best fulfill the quality criteria specified by brewers. A quality assessment of the malt attributes is generally carried out according to the methods developed by MEBAK or the EBC. These analyses describe, above all, the scope of the three main processes involved in modification, that is, proteolysis, cytolysis and amylolysis. They each profoundly influence the quality of finished beer. It is the task of brewers to determine upper and lower limits for the quality of the malt based on the type of brewhouse equipment and the brewing techniques at their disposal. In doing so, the various parameters should not be considered in isolation but rather as a whole. One must also be aware that individual attributes or sets of attributes can influence numerous production steps and thus the quality characteristics of the beer, sometimes in opposition to one another. Malt specifications, therefore, always represent a compromise and can be adjusted to adapt to the quality of a particular year's harvest and to the characteristics of a given variety of malting barley.

Table 2: Sources for information on food safety

German and European authorities, legal principles, limit values and regulations	Sources
Lebensmittel- und Bedarfsgegenständegesetz (LMBG) Regulation (EC) no. 178/2002 of the European Parliament and of the Council of 28 January 2002 Lebensmittelhygieneverordnung (LMHV) Neuartige Lebensmittel- und Lebensmittelzutatenverordnung (NLV) Trinkwasserverordnung (TrinkwV) Gesetz zur Regelung der Gentechnik (GenTG)	The *Bayerische Staatsministerium für Umwelt, Gesundheit und Verbraucherschutz (StMUGV)* is the government agency responsible for the consumer protection system VIS (Verbraucherschutzinformationssystem- http://www.visernaehrung.bayern.de/de/left/recht/recht-ix.htm). The website above is in German and provides detailed information concerning the applicable laws and regulations, including a link to the federal bureau for food safety.
European Food Safety Agency (EFSA). The EFSA offers independent, scientific guidance to all questions within the framework of food safety, including the well-being and protection of animals in addition to the health of crops as community legal regulations apply to them. They also address questions concerning nutrition. Brewers of Europe	http://www.efsa.europa.eu/ https://brewersofeurope.org
Information about upper and lower limit values specific to malt and beer	Deutscher Brauerbund e.V. http://www.brauer-bund.de/ Bayerischer Brauerbund e.V. http://www.bayrisch-bier.de/ Deutscher Mälzerbund https://www.deutscher-maelzerbund.de/

4 OVERVIEW

		Barley malt		Wheat malt*
Laboratory analysis	Unit	Various mashing methods	*"Hoch-kurz"* mashing procedure	
Amylolysis				
extract	%, d.m.	> 81	> 81	> 83
extract, isothermal 65 °C mash			> 81	
α-amylase	ASBC, moisture-free/ DU, moisture-free	> 60	> 60	> 28
diastatic power	WK	> 200	> 200	
β-amylase	BU, moisture-free	> 750	> 750	
limit of attenuation	%, apparent	> 80	> 80	
limit of attenuation, isothermal 65 °C mash	%, apparent		> 84	
Proteolysis				
raw protein	%, moisture-free	9.5–11	9.5–11	11–12.5
soluble nitrogen	mg/100 g malt, d.m	550–700	650–750	650–780
soluble nitrogen, isothermal 65 °C mash	mg/100 g malt, d.m		570–670	
Kolbach index	%	38–40	39–42	37–40
Kolbach index, isothermal 65 °C mash	%		34–38	
free amino nitrogen	mg/100 g malt, d.m	120–150	130–160	
free amino nitrogen, isothermal 65 °C mash	mg/100 g malt, d.m		> 140	

***Congress mash method**

		Barley malt		Wheat malt*
Laboratory analysis	Unit	Various mashing methods	*"Hoch-kurz"* mashing procedure	
Cytolysis				
friability	%	> 82	> 85	
whole glassy kernels	%	< 2	< 2	
viscosity	mPa·s (adj. to 8.6 % w/w)	< 1.58	< 1.56	< 1.8
viscosity, isothermal 65 °C mash	mPa·s (adj. to 8.6 % w/w)	< 1.65	< 1.60	
β-glucans	mg/l	< 300	< 200	
β-glucans, isothermal 65 °C mash	mg/l	< 350	< 350	
modification	%	> 85	> 90	
homogeneity	%	> 75	> 75	
Further Analyses:				
DMS-P	ppm, a.d.	< 7	< 7	
DON	µg/kg	500	500	500
NDMA	µg/kg	< 2.5	< 2.5	< 2.5

***Congress mash method**

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