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The Influence of Elevated Germination Temperatures on the Resulting Malt Quality and Malting Losses

The major goal for the malt industry is achieving a 'good' malt quality by means of high enzyme activities and a cytolytic modification to the greatest possible extent. For producing industrial scale malt batches of up to 300 tons, it also is greatly important to keep the energy costs and the malting losses as low as possible. Furthermore many possibilities have been investigated to reduce the production time to increase the capacity of the malting plants.

Published findings claim that relatively low temperatures during steeping and germination (12–17 °C) are required to produce high quality malt; however, these processes consequently take 5 to 7 days excluding the kilning. Applying higher temperatures were found to lead to raised malting losses and reduced extract yields. Most of these studies were carried out several decades ago and new barley varieties with improved malting properties are available now.

In this study, constant germination temperatures between 16 and 28 °C were used to obtain the influence of the temperature on the germination and thus the resulting malt quality and malting losses. Applying a germination temperature of up to 24 °C compared to 16 °C led to a faster start of germination, to an improved malt quality, and in particular to an enhanced cytolytic modification. Furthermore, an equal to improved homogeneity was achieved in a shorter germination time without markedly increasing the malting losses. The optimal germination temperature was detected to lie between 20 and 24 °C. An observed reduced FAN content can be advantageous for improved flavour stability of beer produced of the malt due to fewer precursors for the formation of aging-related off-flavour compounds such as Strecker aldehydes. Furthermore, no lautering problems for the malt samples germinated at higher temperatures than 16 °C could be detected. Outcomes from these trials benefit the malting industry in terms of potential energy and time savings without negatively affecting the malt quality. However, more barley varieties need to be tested and the results need to be verified.

Descriptors: germination temperature, malting losses, malt quality, cytolysis

1 Introduction

In order to accelerate the malting process, several investigations were done during the last decades. The germination performance is primarily influenced by the steeping regime, the temperatures and the rate of water uptake. Latter, in turn, is dependent on the cultivar, the crop year, the kernel size, the nitrogen content, the kernels' physiological status (dormancy, water sensitivity) [1, 3, 4] and a sufficient oxygen supply [5, 25, 29]. After steeping, the malt quality, by means of forming sufficient enzyme activities and achieving a proper cytolytic and proteolytic modification can mainly be influenced by increasing the three parameters germination time, steeping degree of the grain and the temperature in the grain bed [22].

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Published findings claim relatively low temperatures of 12–17 °C during germination [12, 16, 22, 26] for producing malt with a high quality, such as high extract yields and a good proteolytic and cytolytic modification. However, the production of malt is a time and energy consuming process and higher germination temperatures consequently lead to a sooner initialisation of the germination which, in turn, results in a possible advantageous reduction of the germination time [20]. Hence, many authors investigated the use of higher germination temperatures during the last decades.

In general, increasing malting losses, reduced enzyme activities and lower extract values in the malt germinated at higher germination temperatures up to 20 °C were reported [2, 13, 16, 22, 23, 26, 30]. However, *Narziß* [16] and *Sommer* [21] also found 1–1.7 % higher degrees of final attenuations due to a higher cytolytic modification when applying higher germination temperatures which could compensates the lower extract. *Weith* [27, 28] found a faster formation of enzymes at the beginning of germination, but at the end of the germination a colder germination led to higher activities in the final malt.

In many publications, markedly reduced proteolytic modification could be observed [12, 16, 21, 26, 30] resulting in insufficient contents of free amino nitrogen which are necessary for a proper yeast nutrition [16, 21]. Concerning the proteolytic modification when germinating at higher temperatures, Sommer [21] assumed a soluble nitrogen reduction of 10–50 mg/L per degree Celsius. In contrast to this, the soluble nitrogen is increased by 20–50 mg/L when increasing the steeping degree by 1 % independent from the germination time.

Regarding the cytolytic modification, several authors observed an improved cell wall degradation when applying higher germination temperatures [13, 16, 22, 23, 26, 30]. Nevertheless, *Baxter* [2] showed that the high germination temperature of 25 °C can lead to a reduced cytolytic modification again. Sommer [22] evaluated the results of *Schilfarth et al.* [19] and Weith [26] about the influence of increased germination temperature for accelerating the cytolytic modification with regard to the economic efficiency. It was stated, that increasing the temperature by 1 °C results in about 0.3 % higher malting losses and about 0.4 % lower extract yields, and thus, by reasons of economic efficiency, it was advised not to germinate at higher temperatures.

Furthermore, *Baxter* and *O'Farrell* [2] observed extended lautering times of the laboratory mashes when germinating at 25 °C compared to a reference germination temperature of 16 °C. However, a more moderate germination temperature of 20 °C resulted in lower filtration times, but no other disadvantages could be found.

In contrast to these findings, *Pool's* [17] investigations about the variation of germination temperatures between 10 and 24 °C showed that an increase of malting losses applying higher germination temperatures up to 18.5 °C could be compensated by reducing the germination time. Comparing a germination of five days at 15.5 °C and four days at 18.5 °C, similar cytolytic modification and similar malting losses as well as extract yields were achieved in less time. Nevertheless, the protein degradation was markedly reduced. It has to be taken into consideration that the trials were done using gibberellic acid and a the grain was steeped eight hours at 40 °C in order to reduce the malting losses. This may also have influenced the resulting advantages when applying higher germination temperatures.

All found investigations were done 25 to 50 years ago thus the results may not be valid for the barley varieties cultivated nowadays because quality has changed a lot. Hence, the topic of the present study was to elaborate the effect of different germination temperatures (16, 20, 24, 28 °C) on the speed of germination, the final malt quality and the resulting malting losses in small scale malting trials using the still common spring barley variety Marthe, which has been processed during the last decade. Samples were taken and kilned 3, 4, 5 and 6 days after steeping in. The steeping program, a steeping degree of 45 % during germination and the kilning parameters were kept constant for all trials. Hence, the influence of the germination temperature on the malt quality could exclusively be observed by analysing the resulting malt quality. Additionally, laboratory lautering tests as well as the time of the congress wort separation were applied to get information about the processability.

2 Materials and methods

Small-scale malting

For investigating the impact of the germination temperature on the malt quality and malting losses at 16, 20, 24 and 28 °C, in total, four malting trials were conducted with the two-row spring barley Marthe (water content: 13.9 %, protein content: 10.5 %, germination energy: 98 %, water sensitivity: 35 %). Samples were kilned 3, 4, 5 and 6 days after steeping in. For obtaining the exclusive influence of the varied germination temperature, the steeping program (constant at 15 °C; 1st wet steep 5 h, air rest 19 h – aeration each 4 h –, 2nd wet steep 4 h), the steeping degree of 45 % and the kilning program (withering 15 h at 50 °C; curing 4.5 h at 80 °C) were kept constant for all trials.

The trials were done in duplicate in a small-scale malting plant (system model A1-2008, no. 176/1, Schmidt-Seeger, Beilngries, Germany). The automated plant consists of a combined steeping-/germination unit with a maximum load of 8 baskets á 800 g each and an accordingly adjusted kilning unit. The steeping-/germination unit is equipped with a box which contains the 8 baskets and is housed in an insulated floodable chamber. The box can be ventilated with tempered and humidified air and can be periodically rotated to avoid the formation of clusters. During germination (5 days), the water content of the samples was checked daily by weighing the germination baskets and calculating the steeping degree with reference to the dry matter. Afterwards, the amount of water for adjusting the steeping degree to 45 % was calculated by the actual steeping degree and initial barley weight. It was sprayed onto the baskets on the first and second germination day. Germination was controlled and germination performance and homogeneity were monitored by counting and evaluating the percentages of chitted and forked kernels 48 hours after steeping in.

The rootlets of the kilned malt were removed with an automated sample cleaner (model SLN, Pfeuffer, Kitzingen, Germany) and the removed rootlets were weighed for determining the losses.

Malt Analyses

The malt analyses extract, apparent final attenuation, Kolbach index, free amino nitrogen (FAN), viscosity, modification and homogeneity (Carlsberg method), ß-glucan content, friability, acrospire length and filtration time were performed according to MEBAK [9]. The activities of α- and ß-amylases were determined with commercial assay kits (Megazyme, Bray, Ireland). All analyses were done in duplicate.

Laboratory lautering tests

To get further information about the processability of the produced malt, an in-house-method of a laboratory lautering test was used to determine the lautering properties of the mashes produced from the respective malt samples. The lautering test was performed in triplicate at 20 °C using a Filtercheck®-apparatus (Stabifix, Gräfelfing, Germany). 50 g malt were ground with a DLFÜ-mill (Bühler, Uzwil, Switzerland) at a disk gap of 0.8 mm and mashed in with 180 mL bi-distilled water of 45 °C. For mashing, the congress mashing apparatus (Bender & Holbein, Bruchsal, Germany) and regime according to MEBAK [9] were used. After cooling the mash to 20 °C, bi-distilled water was added to the mashes to adjust the beaker contents to 200 g. After filling the mash onto a steel mesh with a gap size of 0.25 mm placed on the bottom of the Filtercheck®-apparatus, followed by a lautering rest of 2 minutes, the filtrate was collected on a scale and the filtrate volume was recorded during the test and afterwards plotted against the lautering time. Comparing the curves and the filtrate volume after a certain time of 300 seconds provided information about the malt's lautering properties.

3 Results and Discussion

For evaluating the germination performance, the percentages of chitted and forked kernels were counted after 20 hours of germination, or 48 hours after steeping in (Fig. 1). Up to the germination temperature of 28 °C, the germination start was faster compared to the reference temperature of 16 °C which showed an about

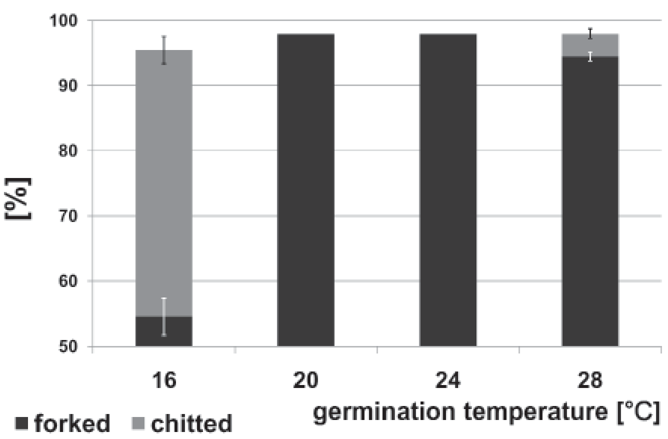

Fig. 1 Evaluation of the germination performance by counting the percentages of chitted kernels 48 hours after steeping in (mean of two germination boxes. duplicate standard deviation of forked and germinateted kernels included)

50 % reduced proportion of forked kernels. At the time point, no difference in the germination energy between 20 and 28 °C could be detected, but the proportion of forked was slightly lowered when applying 28 °C. From that, it can be assumed that using 28 °C as the highest applied temperature led to an inhibition of growth compared to 20 and 24 °C. Pool [17] reported an enhanced germination rate when increasing the germination temperature which is an important basis for a possible germination time reduction. *Axcell et al.* [1] and *Home et al.* [6] claimed that warm steeping improves the water distribution within the kernels which is important for a simultaneous germination start. This may also explain the improved germination performance from the present study applying higher germination temperatures than 16 °C if the water, sprayed at the first and second germination day for adjusting the steeping degree, was more evenly distributed and faster taken up.

In figure 2, the malting losses of the malt samples germinated at the different temperatures and kilned after 2 to 5 germination days are shown. As expected, the malting losses increased with higher germination temperatures and with proceeded germination. An aim of these trials was to figure out the necessary germination time reduction for applying higher germination temperatures in order to achieve similar or lower malting losses compared to the reference sample germinated for 5 days at 16 °C. This was lower or similar about one day earlier at 20 °C, two days earlier at 24 °C and three days earlier at 28 °C. In the following, the results of several malt analyses, carried out on the malt samples taken on the different germination days, were shown with a focus on the important samples which did not exceed the reference's malting losses (bigger symbols and standard deviation of the parameters given by the MEBAK [9] included).

Germinating at 16 °C led to a constant increase of the extract values with processed germination and to the highest extract value of 81.7 % after five germination days. With increasing temperatures, the extract decreased. This can be explained by the slow growth and reduced respiration at the lowest temperature of 16 °C. Hence, an advantage of the reference temperature of 16 °C is observable

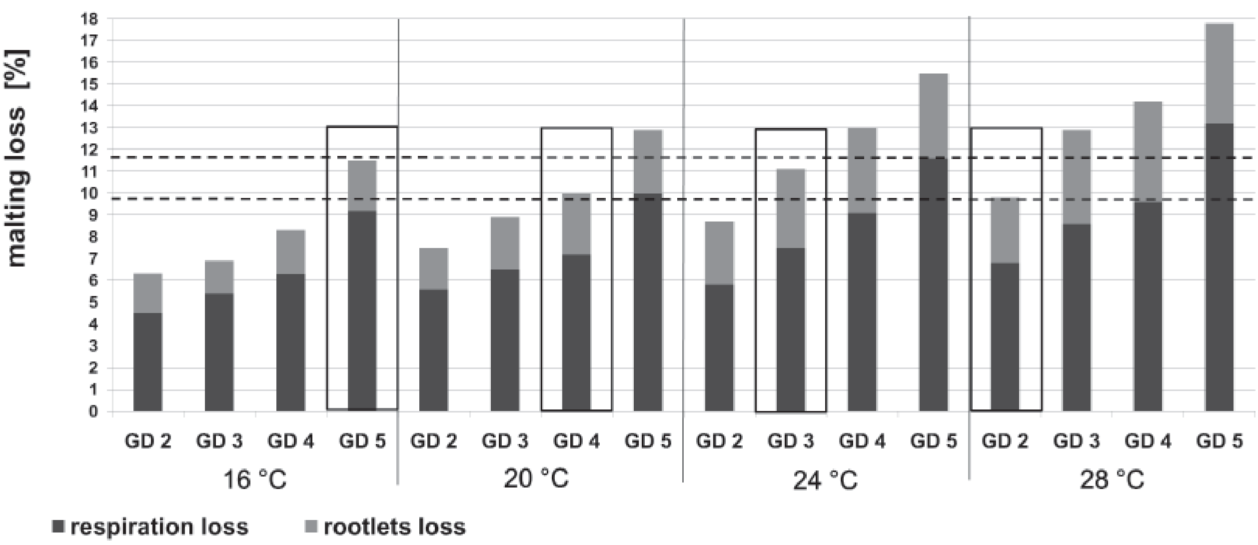

Fig. 2 Malting losses of the malt samples taken on the 1st to 4th germination day

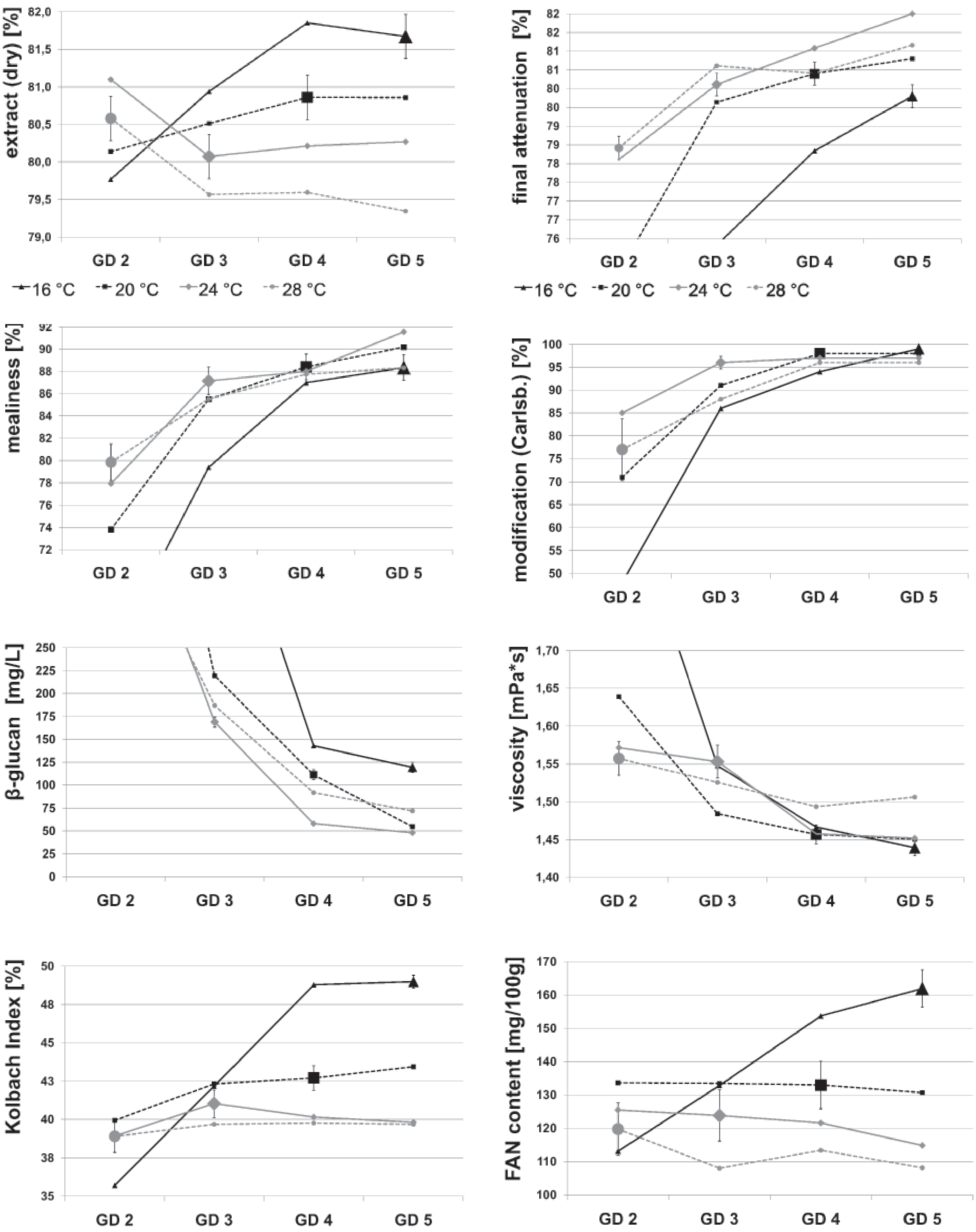

Fig. 3 Comparison of the extract, final degree of attenuation, mealiness, modification, β-glucan content, viscosity, Kolbach Index and FAN content of the malt samples taken on the 1st to 4th germination day (standard deviation according to MEBAK analyses for the important malt samples achieving comparable malting losses included)

because of the highest extract yields reached. On the other hand, in consideration of the results from the final degree of attenuation, it seems that this advantage was partly relativised because a lower value was reached when germinating at 16 °C compared to the 20 and 24 °C-samples. At this juncture, Narziß [16] and Sommer [21] found improved final degrees of attenuations when increasing the germination temperature and explained that by an enhanced cytolytic modification. Furthermore, lower malting losses were observed compared to the reference sample which was germinated for 5 days at 16 °C (see Fig. 2). Germinating at 28 °C for 2 days was not sufficient to compensate the lower extract yield by the resulting degree of final attenuation.

In general, the cytolytic modification, as indicated by the mealiness, the modification according to Carlsberg, the β-glucan content and the viscosity, was achieved faster with increasing germination temperatures. This trend was observed by several authors [13, 16, 22, 23, 26, 30]. The β-glucan content and the mealiness values, observed after 5 germination days at 16 °C, were improved or similar one day in advance when applying temperatures of 20 to 28 °C. Acceptable values were already reached at germination day 3. Considering the important samples, which reached lower or similar malting losses, the mealiness and the modification of the reference sample were reached one and two days earlier when applying 20 and 24 °C, respectively. The viscosity and the β-glucan content of the 24 °C-sample germinated for 2 days showed a reduced cytolytic modification but the values were still in the range of the MEBAK recommendations [9]. Germinating at 28 °C for two germination days did not lead to a sufficient cytolytic modification of the malt which explains the reduced extract yield indicated by the extract and the final degree of attenuation for this sample.

For evaluating the proteolytic modification, the results of the free amino nitrogen content or FAN and the Kolbach-Indices are shown (see Fig. 3). According to MEBAK, the barley malt's FAN content should lie between 120 and 160 mg/100 g malt. Too low values, that could be observed for the 28 °C-samples, can lead to fermentation problems due to an insufficient yeast nutrition. On the other hand, high FAN values, which were found in the reference sample, can negatively influence the flavour stability of the beers produced thereof. According to the MEBAK specifications, the result of the 28 °C-sample was too low, and the 20 and 24 °C-samples were sufficient and in a lower range.

Regarding the Kolbach-Indices, germinating at 16 °C led to too a high proteolytic modification after four and five germination days. All samples applying 20, 24 and 28 °C were lower and in the range of the MEBAK specifications due to the balance between an enhanced growth and protein degradation. A reduced proteolytic modification was also demonstrated in previous investigations [12, 16, 21, 26, 30] whereas Narziß [16] stated that applying higher temperatures is a possibility to reduce the protein degradation.

Comparing the enzyme activities of α- and β-amylase in figure 4, a faster enzyme formation with increasing germination temper-ature was observable. This was also described by Weith [26]. In contrast to other findings [2, 12, 16, 21, 23, 26, 30], in this investigation, the formation of enzyme activities were not dramatically reduced when applying higher germination temperatures. It was stated that the enzyme α-amylase is not formed before the second day after steeping in [7, 8, 14]. The results of this investigation imply a faster formation when applying higher temperatures as recommend by authors of previous investigations which recommend a germination temperature between 12 and 17 °C [12, 16, 22, 26].

Compared to the reference sample, the α-amylase activity of the 20 °C-sample germinated for four days was similar and of the 24 °C-sample germinated for 2 days was acceptable. Germinating at 28 °C did not lead to a sufficient α-amylase activity. Compared to the reference sample, the activity of the β-amylase was improved and similar when applying germination temperatures of 20 and 24 °C or 28 °C, respectively.

The standard methods Calcofluor according to Carlsberg and development of the acrospires in the final malt [9] were used to evaluate the homogeneities of the produced malt. For clarification of the trends, their results are depicted in figure 5.

By means of both methods, higher homogeneities could be observed when applying 20 °C compared to the reference sample.

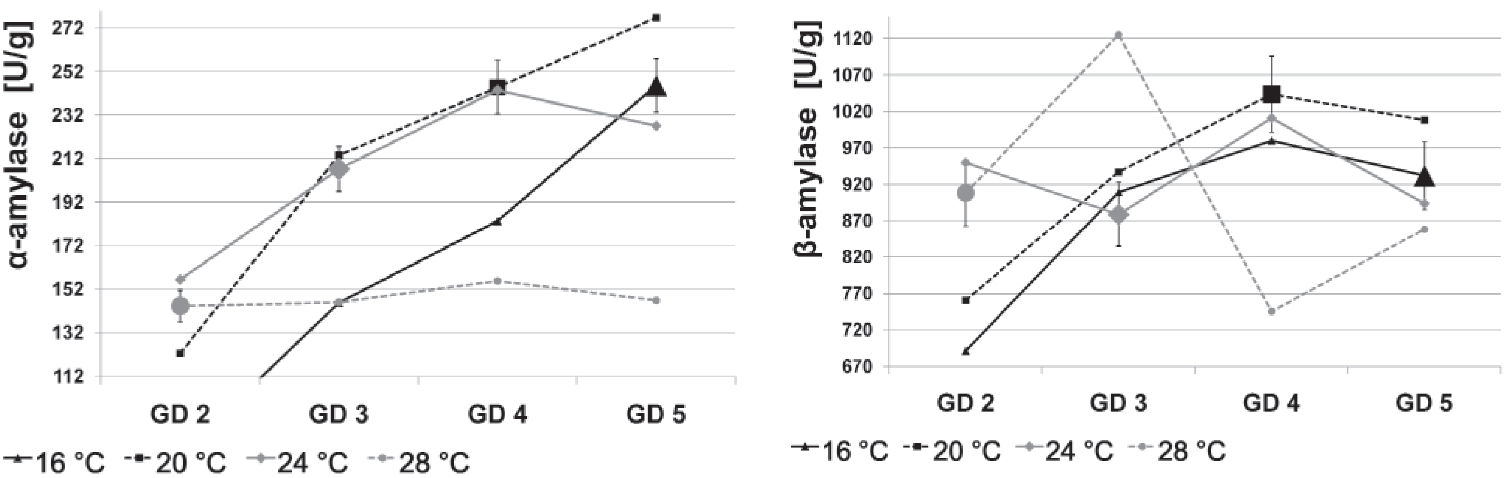

Fig. 4 **Comparison of the enzyme activities of α- and β-amylase of the malt samples taken on the 1st to 4th germination day (standard deviation according to Megazymes analyses for the important malt samples achieving comparable malting losses included)**

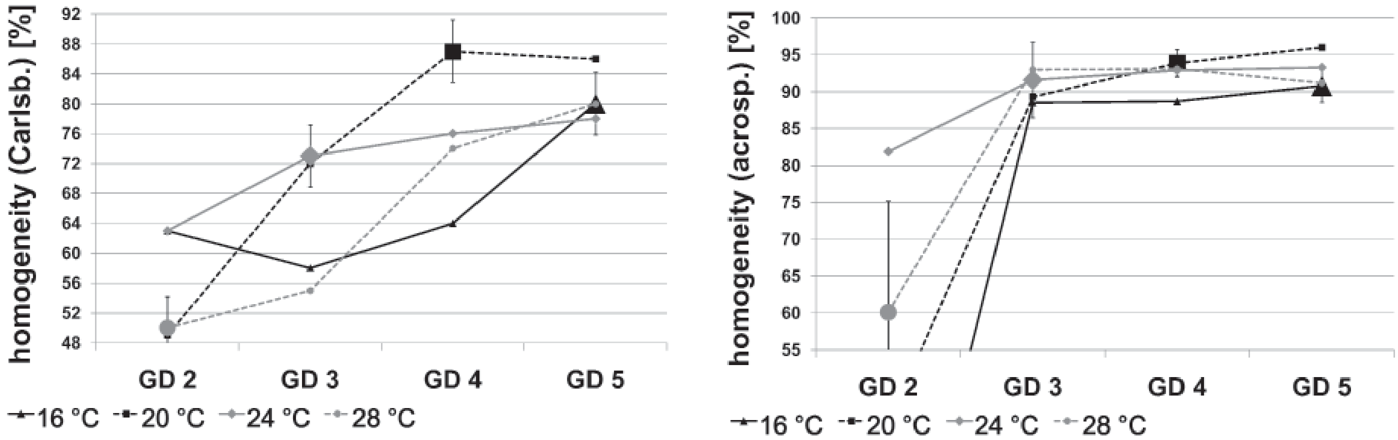

Fig.5 Comparison of the homogeneity according to Carlsberg and the homogeneity of the acrospires length (Carlsberg-standard deviation according to MEBAK analyses; acrospire standard deviation of duplicate determination)

Nevertheless, no significant differences could be shown for the 24 °C-sample and the reference sample. Germinating at 28 °C led to significantly decreased homogeneities which imply an inhomogeneous growth due to the high germination temperature of 28 °C.

In contrast to the findings of Baxter and O'Farrell [2] who found extended lautering times of the laboratory mashes when germinating at 25 °C compared to a reference germination temperature of 16 °C, no significant differences could be observed for the samples germinated at the different temperatures and taken at the germination days two to five (see Fig. 6). This was explained by the high standard deviation of the method. Nevertheless, all samples were filtered in an adequate time between 24 and 42 minutes.

'Good' malt qualities as suggested by analytical data do not necessarily imply an adequate lautering time in the breweries [18, 24, 31]. The lautering performance is influenced by many factors and published literature claims are ambiguous. For further examination of the germination temperature's influence on the lautering performance of the produced malt samples in the present study, an in-house method was developed (see materials and methods section) and used to check the produced malt samples. The obtained curves of the tests are displayed in figures 7. The trials were done in triplicate.

The malt's lautering properties are evaluated by comparing the curve shapes as received when plotting collected wort volume against filtration time and by analysing the total volume after 300 seconds filtration time. In correlation to the results of the filtration time (see Fig. 6), no significant lautering properties between the important malt samples, which showed an acceptable malting loss compared to the reference sample, could be detected. Merely, the run off at the beginning of the measurement was slightly slower for the malt samples germinated at higher temperatures but after 300 seconds the same amount of lautered wort were measured. Nevertheless, the data seemed to be valid because the developed laboratory lauter test had successfully been used in other investigations [10, 11] by means of detected significantly varying lautering performances between different processed malt samples produced from one barley cultivar. Hence, the result of these trials imply that there was no negative influence of higher germination temperatures on the lautering performance which was supported by the lack of differences found with the analysis of the filtration time of the congress mashes.

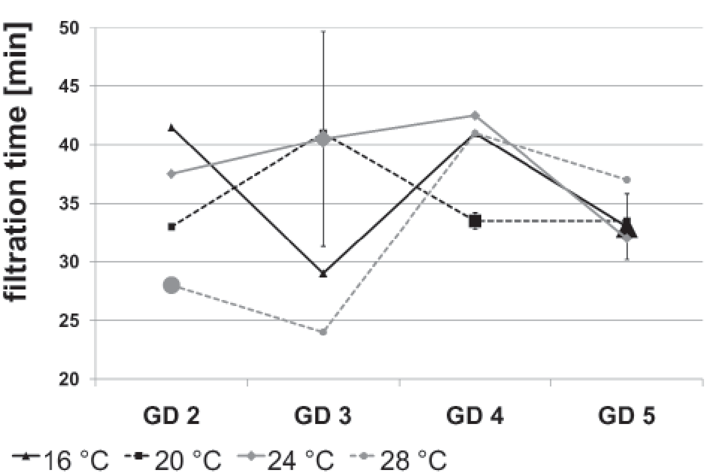

Fig. 6 Comparison of the filtration time of congress worts for the important malt samples achieving comparable malting losses according to MEBAK (standard deviation of the duplicate determination)

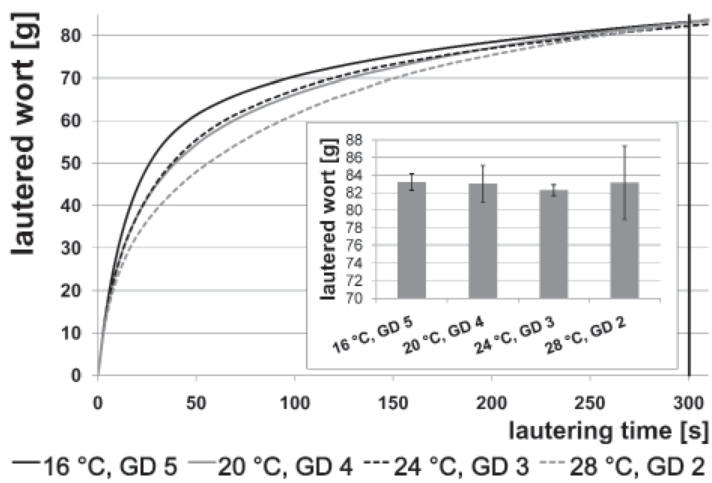

Fig. 7 Comparison of the lautering properties for the important malt samples achieving comparable malting losses, evaluated by an in-house laboratory lautering test; (standard deviation of the triplicate determination)

4 Conclusion

The influence of germination temperatures between 16 and 28 °C on the resulting malt quality and homogeneity was investigated. Constant steeping and kilning parameters as well as the same steeping degree of 45 % during germination were thereby a basic requirement for investigating the germination temperature exclusively. The main aim was to find out the necessary germination time reduction depending on the applied germination temperature for achieving similar or lower malting losses gained with the reference temperature of 16 °C. Therefore, samples were kilned after two to five germination days.

Applying temperatures up to 24 °C compared to 16 °C led to a faster start to germination, comparable to improved malt qualities, especially the cytolytic modification and comparable to improved homogeneities achieved in less time. Thereby, malting losses seem to be compensable by shortening by one to two days depending on the temperature. By shortening the malting process and applying higher temperatures during germination, energy can be saved due to less and shorter necessary cooling of air used to temper and aerate the grain bed. Observed reduced but still sufficient FAN contents, when using an accelerated germination program, can be advantageous for improved flavour stability due to fewer precursors for the formation of staling-related compounds. Furthermore, it could be shown that applying higher germination temperatures did not lead to detectable differences in lautering performance which was determined by the filtration time according to MEBAK and an in-house laboratory lauter test.

Taking all data together, the optimal steeping temperature was observed to be ranged between 20 and 24 °C for producing malt in less time without decreasing the malt quality and negatively affecting the malting losses. According to the findings in the present study, germination temperatures above 24 °C should generally be avoided.

In future, further improvements could be achieved when combining higher steeping and germination temperatures. Higher steeping temperatures up to 25 °C were found to be advantageous for an enhanced cytolytic modification, higher malt homogeneities and improved lautering [10].

It seems that today's barley varieties, whose properties have been steadily improved during the last decades, may be less heat sensitive and more suitable for applying high germination temperatures. Nevertheless, barley cultivars should be checked before malting if they are suitable for an accelerated germination regime applying higher temperatures.

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