JMBFS

Journal of Microbiology, Biotechnology and Food Sciences

International peer-reviewed scientific online journal

Published by Faculty of Biotechnology and Food Sciences

QUALITY ASSESSMENT OF SPRING BARLEY VARIETIES INTENDED FOR MALTING PROCESS

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https://doi.org/10.55251/jmbfs.9250

ARTICLE INFO

Received 27. 7. 2022
Revised 10. 10. 2022
Accepted 12. 10. 2022
Published 21. 12. 2022

Regular article

OPEN ACCESS

ABSTRACT

The suitability of a barley grain for malt production depends upon a large number of quality parameters that are crucial for the identification of high-quality malt varieties. The grain and malt technological quality parameters of five samples of four spring malting barley varieties were studied in order to estimate their malting potential. Selected barley varieties proved to be of satisfactory malting quality in terms of analyzed technological parameters. First-class grain percentage in the analyzed samples ranged from 84.9 to 94.6 %. Hectoliter weight reached values from 634.2 to 737.1 $g.dm^{-3}$. Barley samples also contained a relatively high starch content of 63 to 68 %. Nitrogenous substances ranged from 9.9 to 11.3 % and all tested varieties met the requirement for nitrogen content. These samples were micro-malted and resulting malt was analyzed. All tested malt samples achieved high and satisfactory extract content of 82.4 - 84.3 %. Statistically significant ($p<0.05$) the highest extract content was confirmed in variety LG Tosca (84.3 %) which was found to be relatively the best technological quality also for its kernel size and optimal starch and protein content. The average value of friability was 98 %. The intensity of proteolytic modification among varieties was satisfactory (Kolbach index 39.18 - 47.17 %). The viscosity of the wort reached values from 1.41 to 1.47 $mPa.s^{-1}$, varieties provided clear wort in all cases. Based on the results of grain and malt quality parameters it can be concluded that all tested spring barley varieties are suitable for malting process.

Keywords: barley, micro-malting, malt, malting quality

INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the most important cereals in the world. It is commonly used in the production of alcoholic and non-alcoholic beverages or as animal feed. Currently, barley is used worldwide as fodder (50 - 70 %), for malt production (30 - 40 %), seed production (5 %) and human diet (3 %) (**Deme *et al.*, 2020**). Double-row barley and six-row barley varieties are used for malting, while double-row barley is more suitable in terms of its technological quality (**Su *et al.*, 2020**). Two-row barley produces malt with a large extract, lighter color, and less enzyme content than the six-row type. Barley is suitable raw material for process of malting mainly due to its good starch and protein ratio (**Deme *et al.*, 2020**).
Barley grain makes up 80 - 88 % dry matter and 12 - 20 % water. Dry matter contains nitrogenous and nitrogen-free organic compounds and inorganic substances. The representation of individual components depends on the genetic characteristics of the variety, growing conditions, soil composition, agricultural technology and climatic conditions (**Basařová *et al.*, 2015**). **Baik and Ullrich (2008)** describe the substances represented in barley. Whole barley grain contains about 65 - 68 % starch, 10 - 17 % protein, 4 - 9 % β-glucans, 2 - 3 % free lipids and 1.5 - 2.5 % mineral substances. The total fiber content ranges from 11 to 34 % and of which soluble fiber from 3 to 20 %. Barley grains are a rich source of nutrients and bioactive compounds such as β-glucans, arabinoxylans, oligosaccharides and phenolic compounds (**Su *et al.*, 2020**). The effect of phenolic acids is associated with the ability of barley to inhibit human LDL cholesterol and scavenge free radicals (**Deme *et al.*, 2020**).
Malting barley growers prefer varieties that are easy to grow, disease-resistant and have a higher yield. From a maltster's point of view the moisture content, nitrogen content, germination capacity, husk fineness, grain varietal uniformity and proportion of first class grains of barley are considered to be the most important parameters when receiving barley at the malting plant (**Basařová *et al.*, 2015**). The quality of barley grain for the malting industry is a complex feature, genetically determined and largely influenced by agro-ecological cultivation conditions (**Psota *et al.*, 2017; Hartman, 2018).**
Process of malting uses internal biochemical reactions in barley grain, which are determined by the ability of the grain to synthesize enzymes that ensure the hydrolysis of grain components (**Kuntz and Bamforth, 2007; Nishantha *et al.*, 2018**). Malting process consists of three basic procedures: steeping, germination and kilning **(Kunze, 2014)**. Each step must take place under controlled conditions such as temperature, humidity and oxygen concentration (**Daneri-Castro *et al.*, 2016; Carvalho *et al.*, 2021)**. Malting is forced germination, performed to acquire a certain amount of proteolytic and amylolytic enzymes (**Habschied *et al.*, 2020**).
Currently, there is a need for finding new methods to improve the malt quality by increasing germination ability and reducing the time of sprouting (**Müller and Methner, 2015**). The production of hydrolytic enzymes is essential for the hydrolysis of endosperm cell wall carbohydrates and protein matrix. Malting is 5 - 7 days process. In terms of the original chemical composition of barley grain, it can be stated, that germination leads to enzymatic transformation of the primary components into simpler substances (sugars, amino acids and fatty acids), which are used to nourish the embryo, and later to feed the yeast during brewing (**Betts *et al.*, 2020**). During malting, the high molecular weight compounds (starch and proteins) present in the barley grain must be partially degraded by hydrolases to simpler low molecular weight components (sugars and amino acids) (**Schmitt and Wise, 2009; Rani and Bhardwai, 2021**). Therefore the aims of malting are degradation of high molecular compounds such as proteins and hemicelluloses, and especially β-glucan (**Gianinetti, 2009**), in the cell walls of the grain's endosperm to achieve a sufficient processability of the malt during brewing with respect to high extract yield, proper fermentation and sufficient filtration processes (**Müller and Methner, 2015)**.
Each variety has characteristics that are specific to the variety and allow in malting process to produce malt with parameters that meet the requirements of the customer, e.g. brewery (**Psota *et al.*, 2018**). Yield and grain quality of barley depends greatly on the varietal characteristics (**Havrlentová *et al.*, 2020; Deme *et al.*, 2020**).
The aim of this work was to analyse the barley grain technological quality and malting potential of selected spring barley varieties intended for malting process.

MATERIAL AND METHODS

Materials

Five samples of four different two-raw spring barley varieties were analysed, of which four samples were obtained from Slovakia (Malz, LG Tosca, Overture, Odyssey) and one sample was obtained from Hungary (Malz) from harvest year 2021, after overcoming dormancy. Variety Malz obtained from Slovakia was grown at locality Báhoň (western Slovakia). Long-term average temperature for this locality was 9.3 °C, long-term average sum of precipitation was 531 mm and code of soil was chernozem. Variety Overture was grown at locality Veľké Ripňany (western Slovakia). Long-term average temperature for this locality was 9.7 °C, long-term average sum of precipitation was 582 mm and code of soil was brown soil. Variety LG Tosca was grown at locality Želiezovce (western Slovakia). Long-term average temperature for this locality was 9.4 °C, long-term average sum

of precipitation was 588 mm and code of soil was chernozem. Variety Odyssey was grown at locality Beluša (central Slovakia). Long-term average temperature for this locality was 8.6 °C, long-term average sum of precipitation was 642 mm and code of soil was alluvial brown soil. Variety Malz obtained from Hungary was grown at locality with long-term average temperature 9.6 °C, with long-term average sum of precipitation 545 mm and code of soil was meadow soil.
The malting potential was evaluated based on analyses of barley and subsequently malt samples. The samples were cleaned to remove foreign matter as well as broken and immature grains. Micro-malting was conducted in a laboratory micro-malting plant (Ravoz, Olomouc, Czech Republic) provided by Research Institute AgroBioTech at Slovak Agricultural University in Nitra. Weight of each malted sample was 1000 g. Grain fraction over 2.5 mm was malted.
All determinations were carried out according to European Brewery Convention recommended methods (**EBC, 2010**) and the Middle European Brewing Analysis Commission methods (**MEBAK, 2011**).

Micro Malting

For laboratory micro-malting the standard malting procedure was used according to MEBAK 1.5.3. The air steeping was conducted in the steeping box. Barley was steeped 2 days at 14 °C, samples were under water the first day 5 hours and the second day 5 hours followed by an air rest, full steeped on water content 45 %. After steeping, barley was transferred to a box for germination. Germination was performed at 14 °C for 3 days to obtain green malt. Total time of steeping and germination was 144 hours. The kilning process was performed on an electrically heated one-floor kiln, with a gentle and gradual increase in temperature up to the kilning temperature of 80 °C for 4 h. The total time of kilning was 22 hours. Immediately after kilning, dry kilned dry malt was degermed in a laboratory degerminating machine.

Barley samples Analyses

Barley analyses were carried out according to the methodology **EBC (2010**) and **MEBAK (2011)** using the following methods: determination of barley moisture content (EBC Method 3.2), starch content (EBC Method 3.13), total nitrogen (EBC Method 3.3.1), thousand grain weight (EBC Method 3.4), hectolitre weight **MEBAK (2011)**, first class proportion over 2.5 mm (EBC Method 1.1.1), germination capacity (EBC Method 3.5.2).

Malt Analyses

Malt and wort analyses were carried out according to the methodology **EBC (2010**) and **MEBAK (2011)**. Congress worts were prepared according to EBC Method 4.5.1. The technological parameters such as extract content (EBC 4.5.1), wort saccharification rate and filtration time (EBC 4.5.1), wort colour (EBC 4.7.1), haze of wort at 90° (EBC 9.29), wort viscosity (EBC 4.8), Kolbach index (EBC, 4.9.1) were also analysed in the samples. In malted samples the friability (EBC 4.15), the malt moisture content (EBC 4.2) and hectolitre weight (MEBAK, 2011) was also determined. Relative extract at 45°C was analysed (by method MEBAK 4.1.4.11) as well as wort clarity (MEBAK 3.1.4.2.6).

Statistical Analyses

The experiment was performed in three replicates. To assess statistically significant differences among barley varieties and malt samples, the LSD multiple comparison test at $p<0.05$ was used.

RESULTS AND DISCUSSION

The qualitative level of spring malting barley varieties was assessed in this work. The results of the analyses are presented in tables 1 - 2.
In order to ensure a proper technological quality and hygienic quality of cereals, determination of the dry matter and moisture content is of great importance. Moisture content in tested varieties ranged from 11.71 to 12.40 % (Table 1). According to **Hartman (2017)**, moisture is one of the key indicators in barley storage. Author analysed 18 varieties of malting barley from the harvest year 2016. The average moisture content in the samples was 12.8 %. **Deme *et al.* (2020)** carried out research on barley and analysed varieties originating in Ethiopia. Barley moisture content in the samples ranged from 11 to 16 %.
Average thousand grain weight (TGW) in tested varieties was 38 g and it ranged from 35.0 to 42.20 g. Statistically significant ($p<0.05$) the highest content of TGW was confirmed in variety LG Tosca (42.20 g) and on the other hand the lowest content was detected in varieties Malz (SK) and Overture (Table 1). Similarly, **Psota *et al.* (2017)** found the weight of TGW in tested samples from 43 to 51 g. **Deme *et al.* (2020)** found that the values of TGW ranged from 31 to 52 g. According to **Anonymous (2012)** and **Rani and Bhardwaj (2021)** TGW should be greater than 45 g for two-rowed barley and more than 42 g for six rowed barley.
Proportion of first class grains in tested samples ranged from 84.90 to 94.63 %. Statistically significant ($p<0.05$) the highest content in proportion of the first class grains was confirmed in variety LG Tosca (94.63 %), (Table 1). Similar results were recorded by **Hartman (2017)** who found an average proportion of first class grains of 92.01 %. **Psota *et al.* (2018)** analysed samples of spring barleys from the 2017 harvest and found proportion of the first class grains ranging from 92 to 97 %.
Barley grain with large size, thin cell walls, and loose packing of endosperm takes up water rapidly and allows uniform distribution of water and hydrolytic enzymes (**Deme *et al.*, 2020**). Hectolitre weight is a measure of density and is commonly expressed in kilograms per hectolitre (**Verma *et al.*, 2008**). Hectolitre weight in tested samples reached values ranging from 634.29 to 737.19 $g.dm^{-3}$ (Table 1). Our results are consistent with the claims of **Basařová *et al.* (2015)** who declare that in malting barley, the hectolitre weight should range from 600 to 780 $g.dm^{-3}$. By LSD test were shown differences in hectolitre weight content among varieties. Varieties established five homogeneous groups. Statistically significant ($p<0.05$) the highest content of hectolitre weight was confirmed in variety Malz (HU) (737.19 $g.dm^{-3}$). According to European Brewery Convention, hectolitre weight of malting barley must range from 650 to 750 $g.dm^{-3}$ (**Galano *et al.*, 2008**). **Hoyle *et al.* (2020)** analysed 10 spring barley varieties originating in the United Kingdom. The hectolitre weight in these samples was determined to be in the range of 590 to 670 $g.dm^{-3}$.
Starch is one of the most important indicators of the technological quality of barley. It plays an important role in extract formation. With a lack of starch in the barley, no other technology can increase the percentage of the extract. The starch content in barley dry matter should be in the range of 60 to 65 % (**Basařová *et al.*, 2015**). The average starch content of analysed samples was 64.8 % and it ranged from 63.01 to 68.01 % (Table 1). Statistically significant ($p<0.05$) the highest content of starch was confirmed in variety LG Tosca (68.01 %), which also showed the highest proportion of the first class grains as well as TGW. **Hartman (2017)** set the average starch content in barley at 64 %. **Psota *et al.* (2018)** found a starch content in barley samples ranging from 63 to 65 %. **Krajčovič *et al.* (2016)** determined an average starch content of 64 % in barley grains.
The proteins present in barley grain are essential for the production of quality malt and beer. The high protein content reduces the proportion of carbohydrates in the endosperm and adversely affects the brewing process (**Gupta *et al.*, 2010**). The nitrogenous substances content in tested varieties ranged from 9.90 to 11.30 % (Table 1). Statistically significant ($p<0.05$) the highest content of nitrogenous substances was confirmed in variety Overture (11.30 %) and the lowest content in variety Odyssey (9.90 %). All barley samples had protein content acceptable for malting purposes. According to **Basařová *et al.* (2015)** favourable protein content for malting barley is 9.0 to 11.5 %. However, even low protein content is unsuitable for malting and brewing. Protein content below 7.5 % causes insufficient foaming of beer (**Basařová *et al.*, 2015; Cenci *et al.*, 2020**).
From biological parameters the germination capacity was measured. The average value of germination capacity in tested varieties was 98 % (Table 1) without statistical differences among samples. Germination capacity is a parameter that significantly affects the malting process. According to **Basařová *et al.* (2015)** the value of germination energy should not fall below 97 % and insufficient germination will be reflected in poorly deciphered malt. **Hartman (2017)** found an average germination capacity in malting barley samples at 98.4 %. Later **Hartman (2018)** evaluated up to 277 samples and 20 different barley varieties. The average germination capacity of these barleys was 98.6 %. **Deme *et al.* (2020)** found germination capacity in Ethiopian barley varieties from 94 to 98 %.

Table 1 Technological parameters of barley samples based on multiple comparisons from the LSD test

Technological parameters	Overture (SK)	Malz (SK)	Malz (HU)	LG Tosca (SK)	Odyssey (SK)
Moisture (%)	11.81	12.40	11.90	11.72	11.71
First class grains over 2.5 mm (%)	85.42 a	84.90 a	85.21 a	94.63 c	88.32 b
Hectolitre weight ($g.dm^{-3}$)	634.29 a	718.20 d	737.19 e	681.01 c	655.11 b
One thousand grain weight (g)	36.00a	35.00 a	38.07 b	42.20 c	39.01 b
Nitrogenous substances (%)	11.30 d	11.00 c	10.10 ab	10.30 b	9.90 a
Starch (%)	63.01 a	65.01 b	63.20 a	68.01 c	65.00 b
Germination capacity (%)	98.33 a	98.00 a	98.00 a	98.33 a	98.00 a

different letters at mean represent statistically significant differences among varieties ($p<0.05$)

After performing technological quality analyses, barley samples were malted in the micro-malting plant at the AgroBioTech Research Centre. Quality of malt (malting potential) was assessed on the basis of technologically important properties such as moisture, hectolitre weight, malt extract content, relative extract at 45 °C, friability, Kolbach index, wort colour, wort viscosity, wort haze, saccharification rate and filtration time (Table 2).

Malt moisture content in tested samples ranged from 3.92 to 4.47 %. To store the malt under appropriate conditions for several months, the moisture content of malt should remain below 4 % (**Kunze, 2014**).

Average hectolitre weight of malt samples ranged from 473.03 to 530.09 g.dm^{-3} (Table 2). According to **Basařová *et al.*, (2015)**, the hectolitre weight of malt is generally in the range from 480 to 620 g.dm^{-3}, which is consistent with our results. Malt extract is another crucial trait while choosing promising malt variety. Malt extract is a key parameter in assessing the malting quality of grains (**Blšáková *et al.*, 2022**). According to **Fox *et al.* (2003)**, the quality of malt extract is influenced by various factors, including environmental factors, biochemical and genetic factors, malting process and mashing conditions. Malt extract values in western two-rowed types (**Basařová *et al.*, 2015**) should be 79 to 81 %. All tested samples achieved high and satisfactory extract content of 82.40 - 84.30 % (Table 2). Statistically significant ($p<0.05$) the highest extract content was confirmed in variety LG Tosca (84.30 %). This variety also achieved the highest starch content. On the other hand, the lowest extract content was found in varieties Malz (HU) and Overture.

The relative extract content at 45 °C in tested samples ranged from 41.80 to 48.01 % (Table 2). **Dráb *et al.* (2014)** evaluated the relative extract at 45 °C in selected malt samples. The relative extract values were determined in the range from 40 to 48 % which is consistent with our results. **Psota *et al.* (2016)** and **Psota *et al.* (2018)** determined the relative extract content at 45 °C in the range of 37 to 47 %. Cytolytic modification expressed as friability was in average 98 % (Table 2). Friability is used to determine the modification of cell walls of malt grains. Friability value for malt is considered >90 %. This method is beneficial for identification of malt that may yield problems in wort clarification, lautering, or beer filtration (**Schwartz and Li, 2010**). The high values of friability indicate that in the malting process the analysed samples of malt produced were overgrown, which on the other hand could have a favourable effect on the degradation of non-starch polysaccharides of the β-glucan type. **Psota *et al.* (2018)** analysed friability values in malt samples at the level of 90 to 96 %. Results of friability values from the research of **Hoyle *et al.* (2020)** ranged from 89 to 94 %.

The intensity of proteolytic modification among varieties was satisfactory (Kolbach index 39.18 - 47.17 %, Table 2). Statistically significant ($p<0.05$) the highest KI was confirmed in variety LG Tosca (47.17 %). Kolbach index (KI) measures the ratio of soluble nitrogen in the wort to the total nitrogen present in the malt (**Verma *et al.*, 2008**). It is an important indicator of proteolysis occurred during malting and mashing, as greater the hydrolysis of proteins during malting, the more nitrogenous compounds will be soluble. When protein hydrolysis is low, KI is also decreased, resulting in wort filtration problem, lower malt extract, and protein turbidity. When protein hydrolysis is high, KI also increases and the normal proportion of protein components is compromised, resulting in accelerated yeast aging and thin beer taste (**Fang *et al.*, 2019**). KI values of elite malt used in the brewing industry should be within 35 and 41 % (**Rani and Bhardwaj, 2021**). According to **Líšková *et al.* (2011)** the values of the Kolbach index should range from 39 to 44 %.

The colour of wort is characteristic of individual types of produced malts. The wort colour was in the range from 4.20 to 5.10 EBC units (Table 2). **Fox *et al.* (2003)** analysed the colour of wort in malts made from Australian barley varieties. Congress wort colour values ranged from 4.6 to 5.3 EBC units.

Viscosity is the main factor that influences lautering (**Blšáková *et al.*, 2022**). The viscosity of the wort ranged from 1.41 to 1.47 mPa.s^{-1} (Table 2). Our results were similar to findings of **Deme *et al.* (2020)** who also analysed the viscosity of congress wort in selected malts made from malting barley varieties. The viscosity of the congress wort ranged from 1.4 to 1.7 mPa.s^{-1}. Wort viscosity determines the gumminess of wort when compared to water. Higher viscosity values show inadequate hydrolysis of cell wall that result in poor wort and beer filtration. β-glucans and arabinoxylans are primarily responsible for highly viscous solutions (**Deme *et al.*, 2020**). The optimum viscosity for 8 % wort should be around 1.6 mPa.s^{-1} (**Briggs *et al.*, 2004**).

The wort haze values ranged from 2.60 to 3.80 EBC units and were little higher in comparison to results of **Psota *et al.* (2016)** and **Psota *et al.* (2018)** who determined haze values for the analysed worts in the range of 0.53 to 1.94 EBC units. **Frančáková *et al.* (2011)** also examined congress wort, where authors determined the wort haze in the range of 2.24 to 6.96 EBC units.

Mashing process consists of gelatinization, liquefication, and saccharification (**Kunze, 2014**). Time taken by the starch to transform into sugars during mashing is called saccharification time. From the point of view of saccharification rate (tested by the iodine solution) and filtration time all samples were filtrated within 60 minutes and saccharification was done within 10 minutes. Good malt saccharifies in less than 10 min (when enzymes initiate hydrolysis of starch), a longer duration is caused by a bad disintegration of the starch (**Kumar *et al.*, 2013**). Furthermore, varieties provided clear wort in all cases.

Table 2 Technological parameters of malt samples based on multiple comparisons from the LSD test

Malting parameters	Overture (SK)	Malz (SK)	Malz (HU)	LG Tosca (SK)	Odyssey (SK)
Moisture (%)	4.30	4.47	3.92	4.15	4.23
Hectolitre weight (g.dm^{-3})	483.02 ab	473.03 a	499.00 abc	512.02 bc	530.09 c
Friability (%)	98.00 b	98.15 b	98.01 b	97.02 a	98.01 b
Extract of malt (%)	82.50 a	83.41 b	82.40 a	84.30 c	83.10 ab
Kolbach index (%)	44.20 c	46.00 d	43.10 b	47.17 e	39.18 a
Relative extract 45 °C (%)	42.60 b	48.01 d	41.80 a	41.80 a	43.20 c
Wort viscosity (mPa.s^{-1})	1.42 b	1.41 a	1.41 a	1.45 c	1.47 d
Wort haze 90° (j. EBC)	3.01 b	3.80 e	2.60 a	3.50 c	3.71 d
Wort colour (j. EBC)	5.10 d	4.90 c	4.20 a	4.70 b	4.20 a
Filtration time (min.)	<60	<60	<60	<60	<60
Saccharification rate (min.)	<10	<10	<10	<10	<10

different letters at mean represent statistically significant differences among varieties ($p<0.05$)

CONCLUSION

Currently there are demands on malting industries to produce high quality barley malt in order to satisfy the needs of the customers e.g. brewery. Technological quality parameters and chemical composition of malting barley are very important for malting and brewing due to this fact the quality of barley must be strictly evaluated. Grain technological quality and malting potential of selected spring barley varieties was investigated in this work. The micro-malting trials of the varieties Overture (SK), Odyssey (SK), Malz (SK), Malz (HU), LG Tosca (SK) were carried out. According to the obtained results, it can be concluded that most barley and malt quality parameters evaluated showed differences among the varieties and the values found were within the acceptable limit of satisfactory technological and malting quality. First-class grain percentage in the analyzed samples ranged from 84.9 to 94.6 %. Hectolitre weight reached values from 634.2 to 737.1 g.dm^{-3}. Barley samples also contained a relatively high starch content of 63 to 68 %. With almost the same content of dry matter statistically significant ($p<0.05$) the highest content of nitrogenous substances was confirmed in variety Overture (11.3 %) and the lowest content in variety Odyssey (9.9 %). The malts showed satisfactory extract content of 82.4 - 84.3 % and the intensity of proteolytic modification among varieties was also optimal (Kolbach index 39.18 - 47.17 %). The values of relative extract at 45°C were acceptable and varieties gave clear worts in all cases. Malting barley variety LG Tosca was found to be relatively the best technological quality for its high extract content, kernel size, starch content and optimal protein content. Overall, it can be concluded that based on the results of the quality parameters of barley and malt, all tested spring barley varieties are suitable for malting process.

Acknowledgments: This publication was supported by the Operational program Integrated Infrastructure within the project: Demand-driven research for the sustainable and innovative food, Drive4SIFood 313011V336, financed by the European Regional Development Fund.

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