Barley varieties registered in the Czech Republic after the harvest of 2019

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Abstract

The study presents results of malting quality and agronomic characters determined within varieties of Avus, Fandaga, and LG Tosca after a three-year period of testing and Adam and LG Ester after four years of testing with the purpose of obtaining the registration of these spring barley varieties in the Czech Republic. Adam and LG Ester were recommended for the production of beer with the Protected Geographical Indication "České pivo". Extract from the varieties was at the levels of 82.6 and 81.9%. They exhibited the required lower level of proteolytic modification and apparent final attenuation. Cytolytic modification was also low. Avus, Fandaga, and LG Tosca had a high extract in malt dry matter, which ranged from 83.4 to 84.1%. The varieties had optimal to strong proteolytic modification (the Kolbach index of 46.8–55.6%). Fandaga exhibited the highest content of free amino nitrogen (246 mg/l). Amylolytic and cytolytic modifications were at the optimal level. Wort quality was optimal (apparent final attenuation was between 82.1 and 83.2%). LG Tosca always provided clear wort while other varieties provided weakening opalizing wort.

Keywords: barley, variety, malting quality

1 Introduction

New barley varieties are registered in the Czech Republic under Act 219/2003 on the basis of a three-year long period of testing which is carried out according to the Methodology of Barley Utility Value Testing (Dvořáčková, 2019). In the framework of the tests for the registration of new varieties, the utility value, i.e. yield and other yield characteristics, resistance to diseases, lodging and traits characterizing malt quality are monitored. Quality of malt samples in our study was assessed on the basis of the characters given in the Malting Quality Index (further only MQI) (Psota and Kosař, 2002).

In the last decades, malting barley varieties with strong enzymatic activity, high extract content and high degree of final apparent attenuation were preferred. For historical reasons, the Czech brewing industry has preserved a decoction production of pale lager. For the beer production of the Czech type, spring malting barley varieties are suitable as they allow production of beer with a higher level of residual extract, strong palatefulness, excellent foaming and a relatively low alcohol content (Kosař et al., 2004).

Two groups of varieties are evaluated in this study: the varieties recommended for the production of beer with the Protected Geographical Indication (further only PGI) "České pivo"/Czech Beer (Adam and LG Ester) and the malting barley varieties with a high enzymatic activity (Avus, Fandaga, and LG Tosca).

2 Material and Methods

In the presented study technological and agronomic characters of spring barley varieties of Adam, Avus, Fandaga, LG Ester, and LG Tosca were assessed (Table 1). After the harvest of 2019 all these varieties were officially regis-
tered after a period of testing. Further, also non-malting
two-row winter varieties of Neptun and Sobell and six-
row varieties of Beckenbauer, Camilla, KWS Wallace, LG
Zoro, Rumcajs, and SU Lauvira were registered (Table 1).
In non-malting varieties, the utility value is given only in
a table without a verbal description (Table 5).

Malting quality of spring barley was assessed upon
a micromalting test, following (bio)chemical analysis,
and determination of technological parameters of malt
and wort. The grain samples for the micromalting tests
were delivered by the National Plant Variety Office of the
Central Institute for Supervising and Testing in Agricul-
ture (CISTA) in Brno between 2016 and 2019.

Information on agronomic characteristics of the
malting and non-malting varieties was acquired within
the state varietal tests of the Czech Republic from the
testing stations belonging to CISTA and other collaborat-
ing institutions (Tables 4 and 5).

Samples of barley varieties (500 g) were malted in
the automatic micromalting equipment of KVM (Un-
čov, Czech Republic). The Research Institute of Brew-
ing and Malting (further only RIBM), always uses the
same regime of steeping, germination and kilning for
varietal testing. A method traditionally used in the
RIBM was employed for laboratory malting. The meth-
method is basically identical to the MEBAK method (2011),
see Table 2.

Steeping was conducted in a steeping box. The tem-
perature of both water and air was kept at 14.0 °C. The
length of steeping was 5 hours on the first day and on

| Variety/Code     | Maintainer/Agent in the CR                          |
|------------------|----------------------------------------------------|
| **spring barley**|**malting varieties**                               |
| Adam             | NORDSAAT Saatzucht GmbH                            |
| NORD 15/1107     | SAATEN - UNION CZ s.r.o.                           |
| Avus             | Saatzucht Streng - Engelen GmbH & Co.KG            |
| STRG 687/15      | B O R , s.r.o.                                     |
| Fandaga          | NORDSAAT Saatzucht GmbH                            |
| NORD 14/2404     | SAATEN - UNION CZ s.r.o.                           |
| LG Ester         | Limagrain Europe                                   |
| LGBHE3254B       | Limagrain Central Europe Cereals, s.r.o.           |
| LG Tosca         | Limagrain Europe                                   |
| LGBN14223-2      | Limagrain Central Europe Cereals, s.r.o.           |
| **winter barley**|**non malting varieties**                          |
| **6-row varieties**|                                                  |
| Beckenbauer      | W. von Borilis-Eckendorf GmbH & Co.KG              |
| BE2008024004D    | Ing. Marian Špunar                                 |
| Camilla          | Saatzucht Donau Ges. m.b.H. & CoKG                 |
| SZD 2213A        | PROSEV s.r.o.                                      |
| KWS Wallace      | KWS LOCHOW GMB                                     |
| KW 6-1541        | SOUFFLET AGRO a.s.                                 |
| LG Zoro          | Limagrain Europe                                   |
| LGBB15W003       | Limagrain Central Europe Cereals, s.r.o.           |
| Rumcajs          | Saatzucht Streng-Engelen GmbH & Co.KG              |
| STRG 568/15      | SELGEN, a.s.                                       |
| SU Lauvira       | NORDSAAT Saatzucht GmbH                            |
| NORD 13078/8     | SAATEN - UNION CZ s.r.o.                           |
| **2-row varieties**|                                                  |
| Neptun           | Sejet Planteferedling I/3                          |
| SJ 128045        | SELGEN, a.s.                                       |
| Sobell           | Sejet Planteferedling I/5                          |
| SJ 128113        | Limagrain Central Europe Cereals, s.r.o.           |
Germination was conducted in a germination box. The temperature during germination was 14.0 °C. The total time of steeping and germination was 144 h.

Kilning was performed in a one-floor electrically heated kiln. The total kilning time was 22 h, prekilning took place at 55 °C, and the kilning temperature was maintained at 80 °C for 4 hours.

The present study evaluates spring barley varieties registered in the Czech Republic after the harvest of 2019 according to the MQI (Psota and Kosař, 2002). In the case of the varieties recommended for the production of beer with the PGI “České pivo”, the requirements for quality of malt and wort given in the application for the PGI “České pivo” were considered (Commission Regulation, 2008).

In the course of the above mentioned tests, we measured MQI parameters, i.e. nitrogenous substances in non-malted grain, extract in malt dry matter, relative extract at 45 °C, the Kolbach index, diastatic power, apparent final attenuation, friability, β-glucans in wort, wort clarity and haze. The tests were conducted according to the methods presented in MEBAK publications (2011) and by EBC Analysis Committee (2010). Wort clarity was determined visually and was assessed as follows: 1 = clear, 2 = weakly opalizing, 3 = opalizing (Table 3).

### Results

Content of nitrogenous substances in barley non-malted grain is an important factor affecting malt quality. The adhesion between the starch granules and protein matrix reduces the rate of starch degradation during malting (Brennan et al., 1996; Zou et al., 2015). Holtekjølen et al. (2006) found a significant negative correlation between the content of nitrogenous substances and starch. The nitrogenous substance content in barley grain can be easily affected by the course of weather, farming practices, etc. For this reason, samples of the assessed varieties had an approximately similar content of nitrogenous substances preferable at the optimal level (10.2–11.0%) or similar. Content of the nitrogenous substances in grain of the studied varieties ranged from 10.1% in LG Tosca to 11.4% in LG Ester.

Malt made from the barley grain with a higher content of nitrogenous substances provides a lower content of fermentable extract (Briggs, 1998). This relationship was partly observed in the studied varieties. Extract content in grain of the studied varieties ranged from 81.9% in LG Ester to 84.1% in LG Tosca (Table 3).

The Kolbach index informs about the successfulness of proteolysis and characterises a relationship between the total amount of nitrogenous substances in malt and the amount of nitrogenous substances that pass during mashing to wort. The Kolbach index

### Table 2  Conditions and schedule of malting

| Time | Temperature of ingoing air | Temperature of outgoing air | Fan speed | Air recirculation |
|------|-----------------------------|----------------------------|-----------|-------------------|
| Steeping |                             |                            |           |                   |
| Wet period | 5.0                          | 14.0                       | 0         |                   |
| Dry period | 19.0                         | 0                          | 0         |                   |
| Wet period | 4.0                          | 14.0                       | 0         |                   |
| Dry period | 20.0                         | 0                          | 0         |                   |
| Wet period | * 24.0                      | 14.0                       | 0         |                   |
| Germination | 72.0                        | 14.0                       | 70        |                   |
| Kilning |                             |                            | 70        |                   |
| 1.0 | 14.0 to 55.0 | 14.0 to 25.0 | 70 | |
| 11.0 | 55.0 | 25.0 to 35.0 | 70 | |
| 1.0 | 55.0 to 60.0 | 40.0 to 45.0 | 40 | |
| 1.0 | 60.0 to 65.0 | 45.0 to 50.0 | 40 | |
| 2.0 | 65.0 to 70.0 | 50.0 to 55.0 | 40 | |
| 1.0 | 70.0 to 75.0 | 55.0 to 65.0 | 40 | |
| 1.0 | 75.0 to 80.0 | 65.0 to 78.0 | 80 | |
| 4.0 | 80.0 | 78.0 | 80 | |

Notes: * Water content was adjusted to 45% by steeping or spraying.
### Table 3  Important malting properties of spring barley varieties

| Methods | Units | References | 2016–2019 | 2017–2019 |
|---------|-------|------------|-----------|-----------|
|         |       |            | S         | S         |
|         |       |            | S         | S         |
|         |       |            | S         | S         |
|         |       |            | S         | S         |
| Protein content of barley (factor 6.25) | % | EBC 2010 | 11.5 | 11.4 |
|         |       |            | 11.3 | 10.5 |
|         |       |            | 10.4 | 10.8 |
|         |       |            | 10.8 | 11.4 |
|         |       |            | 11.1 | 11.6 |
| Starch content of barley | % | NIR | 63.7 | 63.0 |
|         |       |            | 63.5 | 63.8 |
|         |       |            | 63.9 | 63.9 |
|         |       |            | 63.3 | 63.3 |
|         |       |            | 63.7 | 63.6 |
| Degree of steeping 1 | % | Briggs 1998 | 31.8 | 32.7 |
|         |       |            | 31.8 | 31.4 |
|         |       |            | 32.5 | 31.5 |
|         |       |            | 31.7 | 32.7 |
| Degree of steeping 2 | % | Briggs 1998 | 39.3 | 40.4 |
|         |       |            | 39.3 | 41.6 |
|         |       |            | 39.2 | 40.0 |
| Malt yield d. m. | % | Briggs 1998 | 91.2 | 90.9 |
|         |       |            | 91.2 | 90.6 |
|         |       |            | 91.8 | 91.7 |
| Respiration losses d. m. | % | Briggs 1998 | 4.2 | 4.6 |
|         |       |            | 4.3 | 4.8 |
|         |       |            | 4.0 | 4.1 |
| Rootlet losses d. m. | % | Briggs 1998 | 4.6 | 4.5 |
|         |       |            | 4.5 | 4.6 |
|         |       |            | 4.3 | 4.7 |
| Extract of malt, congress mash | % | Briggs 1998 | 82.2 | 82.2 |
|         |       |            | 82.1 | 82.4 |
|         |       |            | 82.6 | 81.9 |
| Mash method according to Hartong and Kretschmer VZ 45 °C | % | Briggs 1998 | 37.4 | 43.0 |
|         |       |            | 38.4 | 42.6 |
|         |       |            | 50.6 | 41.8 |
| Kolbach index | % | Briggs 1998 | 41.3 | 48.7 |
|         |       |            | 42.8 | 46.6 |
|         |       |            | 52.3 | 41.4 |
| Diastatic power WK | % | Briggs 1998 | 78.5 | 82.5 |
|         |       |            | 79.6 | 81.8 |
|         |       |            | 81.8 | 83.2 |
| Final attenuation of laboratory wort from malt | % | Briggs 1998 | 83 | 91 |
|         |       |            | 83 | 86 |
|         |       |            | 98 | 81 |
| Friability | % | Briggs 1998 | 0.1 | 0.1 |
|         |       |            | 0.2 | 0.2 |
| High molecular weight β-glucan content of malt, FIA | mg/l | Briggs 1998 | 170 | 52 |
|         |       |            | 169 | 172 |
|         |       |            | 37 | 272 |
| Protein content of malt (factor 6.25) | % | Briggs 1998 | 10.7 | 10.6 |
|         |       |            | 10.4 | 9.6 |
|         |       |            | 9.4 | 9.9 |
| Total nitrogen of malt, Kjeldahl method | % | Briggs 1998 | 1.71 | 1.69 |
|         |       |            | 1.67 | 1.54 |
| Soluble nitrogen of wort, Kjeldahl method | mg/l | Briggs 1998 | 785 | 940 |
|         |       |            | 801 | 805 |
|         |       |            | 894 | 729 |
| Soluble nitrogen of wort, Kjeldahl method | mg/100g | Briggs 1998 | 700 | 820 |
|         |       |            | 711 | 713 |
| Viscosity of laboratory wort from malt | mPa.s | Briggs 1998 | 1.467 | 1.442 |
|         |       |            | 1.482 | 1.466 |
| Colour of malt, visual method | EBC 2010 | 2.78 | 3.16 |
|         |       |            | 2.86 | 3.50 |
| Saccharification time | min | Briggs 1998 | 11 | 10 |
|         |       |            | 11 | 11 |
| Glassy corns | % | Briggs 1998 | 0.1 | 0.1 |
|         |       |            | 0.2 | 0.2 |
| Partly unmodified grains | % | Briggs 1998 | 1.8 | 0.5 |
|         |       |            | 1.7 | 1.2 |
| Homogeneity (by friabilimeter) | % | Baxter, O’Farrell 1983 | 98.2 | 99.5 |
| Appearance (clarity) of wort | EBC 2010 | 1.06 | 1.06 |
|         |       |            | 1.06 | 1.06 |
| Haze of wort (90°) | EBC 2010 | 0.91 | 0.85 |
|         |       |            | 0.98 | 0.89 |
| Haze of wort (12°) | EBC 2010 | 0.94 | 1.04 |
|         |       |            | 1.09 | 1.00 |
| Total polyphenols in wort | mg/l | Briggs 1998 | 66.4 | 70.0 |
|         |       |            | 64.3 | 88.8 |
| Free amino nitrogen | mg/l | Briggs 1998 | 162 | 200 |

S = standard varieties
## Table 4  
**Important agricultural properties of spring barley varieties**

| Variety | Intensity | Mean of the standard varieties | Variety | Intensity | Mean of the standard varieties |
|---------|-----------|--------------------------------|---------|-----------|--------------------------------|
|         | S         | S                              | S       | S         | S                              |
| maize growing region | N | 6.24 | 6.10 | 6.13 | 6.27 | 6.10 | 6.60 | 6.20 | 6.47 | 5.62 | 5.45 | 5.62 | 5.69 | 5.71 | 5.85 | 5.75 | 5.90 |
| T | 6.62 | 6.55 | 6.54 | 6.69 | 6.26 | 7.03 | 6.51 | 6.68 | 6.04 | 5.99 | 5.94 | 6.08 | 6.17 | 6.24 | 6.17 | 6.15 |
| sugar beet and cereal growing regions | N | 7.36 | 7.23 | 7.32 | 7.32 | 7.39 | 7.56 | 7.61 | 7.56 | 7.14 | 6.98 | 7.07 | 7.15 | 7.35 | 7.49 | 7.32 | 7.51 |
| T | 7.75 | 7.62 | 7.54 | 7.76 | 7.80 | 8.02 | 7.85 | 7.76 | 7.52 | 7.43 | 7.32 | 7.54 | 7.80 | 7.79 | 7.67 | 8.11 |
| potato and forage growing regions | N | 6.71 | 6.29 | 6.55 | 6.97 | 6.97 | 6.78 | 6.79 | 6.90 | 6.75 | 6.39 | 6.61 | 6.97 | 7.03 | 7.17 | 6.97 | 7.24 |
| T | 7.54 | 7.22 | 7.20 | 7.92 | 7.45 | 7.91 | 7.75 | 7.44 | 7.68 | 7.53 | 7.28 | 7.99 | 7.92 | 8.31 | 8.24 | 8.24 |
| Grain over 2.5 mm (t/ha) | maize growing region | N | 4.96 | 4.88 | 5.05 | 4.62 | 5.06 | 5.18 | 5.25 | 5.45 | 4.14 | 4.22 | 4.49 | 3.80 | 4.06 | 4.83 | 4.11 | 4.35 |
| T | 5.33 | 5.53 | 5.20 | 5.19 | 5.16 | 5.56 | 5.43 | 5.50 | 4.38 | 4.59 | 4.41 | 4.09 | 4.43 | 5.11 | 4.27 | 4.56 |
| sugar beet and cereal growing regions | N | 6.58 | 6.57 | 6.59 | 6.57 | 6.73 | 6.47 | 6.90 | 6.93 | 6.22 | 6.15 | 6.12 | 6.25 | 6.34 | 6.99 | 6.35 | 6.57 |
| T | 7.13 | 7.16 | 6.90 | 7.13 | 7.25 | 7.20 | 7.28 | 7.20 | 6.82 | 6.91 | 6.59 | 6.77 | 7.00 | 7.41 | 6.90 | 7.37 |
| potato and forage growing regions | N | 6.38 | 6.11 | 6.21 | 6.60 | 6.66 | 6.31 | 6.50 | 6.62 | 6.43 | 6.24 | 6.31 | 6.64 | 6.53 | 6.99 | 6.46 | 6.86 |
| T | 7.28 | 7.03 | 6.95 | 7.62 | 7.23 | 7.60 | 7.49 | 7.24 | 7.37 | 7.34 | 6.99 | 7.62 | 7.54 | 8.12 | 7.85 | 7.97 |
| Agronomic data | straw length (cm) | 74 | 73 | 70 | 72 | 73 | 74 | 73 | 72 | 71 | 68 | 70 | 75 | 69 | 67 |
| earliness of ripening** | 113 | 112 | 112 | 113 | 112 | 112 | 112 | 111 | 111 | 111 | 111 | 111 | 111 | 111 | 111 | 111 |
| standing power (lodging resistance) | 7.0 | 6.8 | 5.9 | 4.9 | 7.2 | 7.1 | 7.0 | 7.3 | 7.3 | 6.7 | 6.7 | 7.6 | 7.3 | 7.5 |
| Resistance to diseases | powdery mildew (Blumeria graminis) | 5.8 | 8.9 | 8.9 | 8.9 | 6.6 | 8.8 | 8.8 | 5.7 | 8.8 | 8.9 | 8.7 | 8.7 | 8.9 | 8.8 |
| leaf brown rust of barley (Puccinia hordei) | 7.1 | 6.3 | 5.0 | 6.1 | 7.2 | 6.8 | 6.9 | 7.3 | 6.5 | 5.2 | 5.2 | 6.9 | 5.9 | 6.0 |
| complex of leaf spot (Pyrenophora teres) | 6.9 | 6.0 | 6.7 | 6.6 | 5.5 | 6.5 | 6.3 | 7.1 | 6.2 | 6.9 | 6.6 | 6.9 | 6.5 | 6.9 |
| scald of barley (Rhynchosporium secalis) | 8.0 | 7.3 | 7.1 | 8.1 | 6.0 | 8.3 | 7.7 | 8.0 | 7.6 | 7.3 | 7.9 | 7.5 | 8.4 | 7.9 |
| fusarium head blight (Fusarium graminearum, F. culmorum, Microdochium nivale etc.) | 5.4 | 7.0 | 6.5 | 6.8 | 5.9 | 5.4 | 7.1 | 6.2 | 7.2 | 7.1 | 6.6 | 7.2 | 6.1 | 7.0 |
| physiological leaf spots of barley | 7.8 | 5.9 | 8.3 | 8.4 | 8.1 | 7.9 | 7.1 | 7.6 | 6.0 | 8.3 | 8.1 | 7.9 | 8.5 | 8.5 |
| Grain quality | 1000 grain weight (g) | 47 | 45 | 46 | 47 | 45 | 49 | 48 | 47 | 44 | 45 | 46 | 51 | 46 | 45 |
| sieving fractions over 2.5 mm (%) | 90 | 88 | 88 | 90 | 86 | 90 | 90 | 88 | 86 | 85 | 84 | 92 | 85 | 86 |

**Comments:**  
S = standard varieties  
*Limited data  
Point evaluation  
1 = fully lodging, fully attacked  
9 = non lodging, resistant to diseases  
Weight of 1000 grains relates to sieving fractions over 2.0 mm at 14% humidity.  
** days from sowing to harvest maturity  
Intensity:  
N – non treated with fungicides and morphoregulators  
T – treated with fungicides and morphoregulators
is one of the parameters that distinguish between the varieties recommended for the production of beer with the PGI “České pivo” from other malting varieties and this was also confirmed in this study. The values of The Kolbach index recorded in Avus, LG Tosca, and Fandaga were 5 to 14% higher than those detected in Adam and LG Ester (Table 3). Avus, LG Tosca, and Fandaga had a higher content of soluble nitrogenous substances in wort, with the highest content of soluble nitrogen (997 mg/l) recorded in Fandaga. As for the studied set of varieties, Fandaga also contained the highest content of free amino nitrogen in wort.

Relative extract at 45 °C is an indirect indicator of the activity of cytolytic and proteolytic enzymes. It represents the proportion of extract obtained at 45 °C, which is the optimal temperature for the activity of cytolytic enzymes. Also, in this parameter the varieties recommended for the production of beer with the PGI “České pivo” show lower values than Avus, Fandaga, and LG Tosca.

The activity of amylolytic enzymes hydrolysing starch, mainly β-amylase, was at the optimum level in the studied set of varieties. The varieties recommended for the production of beer with the PGI “České pivo” had

| Variety  | Intensity | Mean of the standard varieties | Leopard | Padura | Neptun | Sobell | Mean of the standard varieties | KWS Meridian | Titus | Beckenbauer | Camilla | KWS Wallace | LG Zoro | Rumcals | SU Lauvka |
|----------|-----------|--------------------------------|---------|--------|--------|--------|--------------------------------|-------------|------|-------------|---------|------------|--------|---------|----------|
| Number of rows | 2 | S | S | 6 | S | S |
| Grain yield (t/ha) | N | 7.60 | 7.40 | 7.81 | 7.76 | 7.90 | 7.55 | 7.62 | 7.49 | 8.05 | 7.85 | 7.82 | 7.81 | 7.93 | 7.56 |
| T | 8.70 | 8.62 | 8.78 | 8.77 | 8.77 | 8.74 | 8.83 | 8.65 | 9.28 | 9.02 | 9.19 | 9.24 | 9.08 | 8.92 |
| Grain over 2.5 mm (t/ha) | N | 5.99 | 5.13 | 6.84 | 6.24 | 5.41 | 6.53 | 6.59 | 6.47 | 6.47 | 6.34 | 6.42 | 6.39 | 6.88 | 6.64 |
| T | 7.09 | 6.39 | 7.78 | 7.34 | 6.31 | 7.79 | 8.03 | 7.56 | 7.56 | 7.58 | 7.90 | 7.97 | 8.09 | 8.17 |

Agronomic data

| Variety | Intensity | Mean of the standard varieties | Leopard | Padura | Neptun | Sobell | Mean of the standard varieties | KWS Meridian | Titus | Beckenbauer | Camilla | KWS Wallace | LG Zoro | Rumcals | SU Lauvka |
|---------|-----------|--------------------------------|---------|--------|--------|--------|--------------------------------|-------------|------|-------------|---------|------------|--------|---------|----------|
| earliness of ripening** | 183 | 182 | 184 | 182 | 182 | 183 | 182 | 183 | 181 | 183 | 182 | 182 | 182 | 182 |
| number of ears (pcs/m²) | 894 | 873 | 950 | 993 | 572 | 514 | 544 | 612 | 550 | 585 | 501 | 582 |
| plant length (cm) | 77 | 87 | 82 | 81 | 95 | 103 | 94 | 88 | 92 | 97 | 97 | 93 |
| standing power (lodging resistance) (9–1) | 8.0 | 8.5 | 7.6 | 6.8 | 7.4 | 8.0 | 8.2 | 8.4 | 7.7 | 6.5 | 8.1 | 7.9 |

Resistance to diseases (9–1)

| Variety | Intensity | Mean of the standard varieties | Leopard | Padura | Neptun | Sobell | Mean of the standard varieties | KWS Meridian | Titus | Beckenbauer | Camilla | KWS Wallace | LG Zoro | Rumcals | SU Lauvka |
|---------|-----------|--------------------------------|---------|--------|--------|--------|--------------------------------|-------------|------|-------------|---------|------------|--------|---------|----------|
| powdery mildew (Blumeria graminis) | 7.4 | 7.5 | 7.0 | 7.9 | 7.1 | 7.8 | 6.8 | 6.1 | 6.5 | 7.6 | 7.3 | 8.1 |
| leaf brown rust of barley (Puccinia hordei) | 7.6 | 7.5 | 7.9 | 7.5 | 7.3 | 7.5 | 7.0 | 6.9 | 6.5 | 6.2 | 6.5 | 7.4 |
| complex of leaf spot (Pyrenophora teres) | 6.4 | 7.1 | 6.6 | 7.5 | 7.0 | 6.9 | 6.2 | 6.8 | 6.6 | 7.2 | 7.2 | 6.1 |
| scald of barley (Rynchosporium secalis) | 6.1 | 8.1 | 7.8 | 8.3 | 7.4 | 6.5 | 7.3 | 7.6 | 7.0 | 7.0 | 6.9 | 7.0 |
| fusarium head blight (Fusarium graminearum, F. culmorum, Microdochium nivale etc.) | 7.6 | 8.3 | 8.0 | 7.9 | 7.4 | 7.4 | 7.4 | 7.2 | 7.3 | 6.7 | 7.5 | 7.1 |
| physiological leaf spots of barley | 6.9 | 7.3 | 6.8 | 7.8 | 6.7 | 7.9 | 6.6 | 7.5 | 7.2 | 7.6 | 7.2 | 7.2 |

Grain quality

| Variety | Intensity | Mean of the standard varieties | Leopard | Padura | Neptun | Sobell | Mean of the standard varieties | KWS Meridian | Titus | Beckenbauer | Camilla | KWS Wallace | LG Zoro | Rumcals | SU Lauvka |
|---------|-----------|--------------------------------|---------|--------|--------|--------|--------------------------------|-------------|------|-------------|---------|------------|--------|---------|----------|
| sieving fractions over 2.5 mm (%) | 68 | 86 | 79 | 67 | 87 | 85 | 78 | 81 | 82 | 82 | 86 | 88 |
| 1000 grain weight (g) | 49 | 51 | 51 | 47 | 45 | 48 | 43 | 44 | 46 | 46 | 46 | 46 |
| bulk density (g/l) | 642 | 658 | 662 | 645 | 655 | 679 | 637 | 656 | 666 | 658 | 644 | 648 |
| malting quality index (9–1) | - | - | - | - | - | - | - | - | - | - | - | - |

Comments:
2 – 2-row 6 – 6-row
S = standard varieties

Relative extract at 45 °C is an indirect indicator of the activity of cytolytic and proteolytic enzymes. It represents the proportion of extract obtained at 45 °C, which is the optimal temperature for the activity of cytolytic enzymes. Also, in this parameter the varieties recommended for the production of beer with the PGI “České pivo” show lower values than Avus, Fandaga, and LG Tosca.

The activity of amylolytic enzymes hydrolysing starch, mainly β-amylase, was at the optimum level in the studied set of varieties. The varieties recommended for the production of beer with the PGI “České pivo” had
a value of diastatic power several tens of WK un. lower than Avus, FanDaga, and LG Tosca.

The level of final apparent attenuation indicates the actual utilisation of the extract (Bathgate, 2016) and is affected by many factors (Koljonen et al., 1995). Apparent final attenuation is another parameter that clearly distinguishes the varieties recommended for the production of beer with the PGI “České pivo” from those with a high enzyme activity. Adam and LG Ester had the apparent final attenuation below 82%, which is the value required for this group of varieties.

Cytolytic modification is an important factor affecting wort quality. The level of cell wall degradation is described by the following parameters: β-glucan content in wort, wort viscosity and malt friability. Worse levels of cytolytic modification affect negatively the value of apparent final attenuation (Edney et al., 1998). Lower friability values and a higher portion of glassy and semi-glassy grains are indicators of weaker degradation of the endosperm (Allison et al., 1979). The average values of friability, glassy and semi-glassy grains indicate that Adam and LG Ester had a slower degradation of cell walls than Avus, FanDaga, and LG Tosca. The quantity of β-glucans in barley grain but also in wort has a huge impact on the technological quality of the relevant variety (Gupta et al., 2010). Avus, LG Tosca, and FanDaga had a fast degradation of cell walls and thus favourable values of the friability and β-glucan content. In the application for the PGI “České pivo” (Comission Regulation, 2008), cytolytic modification is assessed only by friability, which cannot be lower than 75%. In case of LG Ester and Adam, low values of friability (77 and 81%) correspond to a higher content of β-glucan in wort (238 and 272 mg/l).

The parameters characterizing wort sensorial properties are wort haze measured with a nephelometer or wort clarity determined in a subjective way. Most malt houses operating in the territory of the Czech Republic require wort haze to be assessed for those varieties used in the registration period. In the studied varieties, the average level of wort haze at 90 °C was measured around 1 EBC un., i.e. deeply below the limit of 4 EBC un. (Wackerbauer and Zufall, 1997). Only the variety of LG Tosca had clear wort in all cases. The other varieties gave weakly opalizing wort in some cases.

Adam bred in Germany provided malt with an above average content of extract (82.6%) at the optimal nitrogenous substances content (10.8%) in a non-malted grain. Proteolytic modification was above average (the Kolbach index of 41.4%). Wort exhibited a content of soluble nitrogen at the level of 729 mg/l. Free amino nitrogen content was at a lower level (151 mg/l), forming 21% of soluble nitrogen. Amylolytic modification was at the optimal level (diastatic power 305 WK un.). Cytolytic modification was low. Degradation of cell walls was at the level of 81% and β-glucan content in wort moved around 272 mg/l. The composition of wort was above average (apparent final attenuation of 81.4%). In all cases the variety gave clear wort. The colour of wort corresponded to pale malt (3 EBC un.).

Adam has a malting quality with the point evaluation of 6 (5.6). The Research Institute of Brewing and Malting recommends the variety of Adam for the production of beer with the PGI “České pivo” as it fulfils the requirements given in the application for the PGI “České pivo” (Commission Regulation, 2008).

Adam is a mid early spring barley malting variety of mid high type, medium resistant to lodging, medium resistant to stem breaking. The grain size is medium big to big and portion of sieving fractions over 2.5 mm (90%) is medium high to high. The variety is resistant to powdery mildew on the leaf, medium resistant to a complex of leaf brown rust of barley, medium resistant to a complex of leaf spots, resistant to scald, less resistant to fusarium head blight. There is a very high yield of sieving fractions over 2.5 mm in the non-treated variant when it is grown in sugar-beet and cereal areas, high in the non-treated variant grown in a maize area, medium high to high in the treated variant grown in sugar-beet and cereal areas, medium high in the treated variant grown in a maize area, and medium high in both variants grown in a potato area.

The utility value is given by a combination of a very high yield of sieving fractions which are over 2.5 mm in the non-treated variant when grown in sugar-beet and cereal areas, but high yield of sieving fractions over 2.5 mm in the non-treated variant grown in a maize area. Its malting quality meets the requirements for the production of beer with the PGI of “České pivo”. Consequently, a comparison with other registered varieties shows that Adam variety has many benefits.

Malt from the variety of Avus bred in Germany provided a rich content of extract (83.4%) at the optimal nitrogenous substance content (10.6%) in a non-malted grain. Proteolytic modification was optimal (the Kolbach index of 46.8%). Wort exhibited a high content of soluble nitrogen at the level of 835 mg/l. Free amino nitrogen content was at a medium level (186 mg/l), forming 22% of soluble nitrogen. Amylolytic modification was at the optimal level (diastatic power 401 WK un.). Cytolytic modification was optimal. Degradation of cell walls was at the level of 95% and β-glucan content in wort moved around 56 mg/l. The composition of wort was optimal (apparent final attenuation of 82.3%). In most cases the variety gave clear wort. The colour of wort corresponded to pale malt (3 EBC un.).
Considering the values achieved in the studied technological parameters, Avus has a very good malting quality with the point evaluation of 9 (9.0).

According to the EU Plant variety database (European Commission 2019), the variety is registered in Austria and in 2019 it accomplished the state varietal tests in the Slovak Republic with similar results as in the Czech Republic (Psota et al., 2020).

Avus is a mid early to early spring barley malting variety, plants are mid high to high type, medium resistant to resistant to lodging, medium resistant to resistant to stem breaking. Its grain is big and portion of sieving fractions over 2.5 mm (92%) is high. The variety is resistant to powdery mildew on the leaf, medium resistant to a complex of leaf brown rust of barley, medium resistant to resistant to a complex of leaf spots, medium resistant to scald, medium resistant to fusarium head blight. There is a high yield of sieving fractions over 2.5 mm in the treated variant when grown in a potato area, medium high in both variants grown in maize, sugar-beet and cereal areas and in the non-treated variant in a potato area, between high to very high in the non-treated variant grown in a potato area.

The utility value is given by a combination of very high yield of sieving fractions over 2.5 mm in both variants when they are grown in maize, sugar-beet and cereal areas and in the treated variant in a potato area, high to very high yield of sieving fractions over 2.5 mm in the non-treated variant grown in a potato area and between high to very high in the non-treated variant grown in a potato area.

Fandaga is a mid early malting variety of mid high to low type, medium resistant to lodging, medium resistant to stem breaking. Its grain is medium big and portion of sieving fractions over 2.5 mm is medium high. The variety is resistant to powdery mildew on the leaf, medium resistant to a complex of leaf brown rust of barley, medium resistant to a complex of leaf spots, resistant to scald, medium resistant to resistant to fusarium head blight. There is a high yield of sieving fractions over 2.5 mm in the treated variant when grown in a potato area, medium high in both variants grown in maize, sugar-beet and cereal areas and in the non-treated variant in a potato area, between medium high and low in the non-treated variant when grown in a maize area, and low in the treated variant grown in a maize area.

The utility value is given by a combination of a high yield of sieving fractions over 2.5 mm in the treated variant grown in a potato area, malting quality and high content of free amino nitrogen. In comparison with the registered varieties of spring barley, this variety has apparent benefits.

**Fandaga** bred in Germany provided malt with a rich content of extract (83.4%) at the favourable nitrogenous substances content (10.8%) in a non-malted grain. Proteolytic modification was strong (the Kolbach index 55.6%). Wort exhibited a very high content of soluble nitrogen at the level of 997 mg/l. Free amino nitrogen content was at a high level (246 mg/l), forming 25% of soluble nitrogen. Amylolytic modification was at the optimal level (diastatic power 386WK un.). Cytolytic modification was low. Degradation of cell walls was at the level of 96% and β-glucan content in wort moved around 43 mg/l. The composition of wort was suitable (apparent final attenuation of 82.1%). In most cases the variety gave clear wort. The colour of wort corresponded to pale malt (4 EBC un.).

**Fandaga** is resistant to powdery mildew on the leaf, medium resistant to a complex of leaf brown rust of barley, medium resistant to a complex of leaf spots, medium resistant to resistant to scald, medium resistant to fusarium head blight. There is a very high yield of sieving fractions over 2.5 mm in the non-treated variant grown in a potato area.

**Avus** is a mid early spring barley variety of mid high to low type, medium resistant to lodging, medium resistant to stem breaking. Its grain is big and portion of sieving fractions over 2.5 mm (92%) is high. The variety is resistant to powdery mildew on the leaf, medium resistant to a complex of leaf brown rust of barley, medium resistant to a complex of leaf spots, resistant to scald, medium resistant to resistant to fusarium head blight. There is a high yield of sieving fractions over 2.5 mm in the treated variant when grown in a potato area, medium high in both variants grown in maize, sugar-beet and cereal areas and in the non-treated variant in a potato area, between medium high and low in the non-treated variant when grown in a maize area, and low in the treated variant grown in a maize area.

The utility value is given by a combination of a high yield of sieving fractions over 2.5 mm in the treated variant grown in a potato area, malting quality and high content of free amino nitrogen. In comparison with the registered varieties of spring barley, this variety has apparent benefits.

**LG Ester** bred in the Czech Republic provided malt with a below average content of extract (81.9%) at the mildly increased content of nitrogenous substances content (11.4%) in a non-malted grain. Proteolytic modification was optimal (the Kolbach index of 42.3%). Wort exhibited soluble nitrogen at the level of 783 mg/l. Free amino nitrogen content was at a medium level (165 mg/l) forming 21% of soluble nitrogen. Amylolytic modification was at the optimal level (diastatic power 312 WK un.). Cytolytic modification was low. Degradation of cell walls was at the level of 77% and β-glucan content in wort moved around 238 mg/l. The composition of wort was below average (apparent final attenuation of 80.0%). In most cases the variety gave clear wort. The colour of wort corresponded to pale malt (3 EBC un.).

**LG Ester** has malting quality with the point evaluation of 4 (4.1). The Research Institute of Brewing and Malting recommends the variety LG Ester for the production of beer with the PGI “České pivo” as it fulfils the requirements given in the application for PGI “České pivo” (Commission Regulation, 2008).

**LG Ester** is a mid early spring barley variety of mid high type, medium resistant to lodging, medium resistant to resistant to stem breaking. Its grain is medium big, portion of sieving fractions over 2.5 mm is medium high to high. The variety is resistant to powdery mildew on the leaf, medium resistant to a complex of leaf brown rust of barley, medium resistant to a complex of leaf spots, medium resistant to resistant to scald, medium resistant to fusarium head blight. There is a very high yield of sieving fractions over 2.5 mm in the non-treated variant...
grown in maize, sugar-beet and cereal areas, high in the non-treated variant grown in a potato area, between medium high and high in the treated variant of grown in a maize area, and medium high in the treated variant grown in sugar-beet, cereal and potato areas.

The utility value is given by a combination of a very high yield of sieving fractions over 2.5 mm in the non-treated variant growing in maize, sugar-beet and cereal areas, high yield of sieving fractions over 2.5 mm in the non-treated variant grown in a potato area. Its malting quality meets the requirements for the production of beer with the PGI of “České pivo”. In comparison with the registered varieties of spring barley, this one has apparent benefits.

**LG Tosca** bred in Holland provided malt with a rich content of extract (84.1%) at a slightly lower content of nitrogenous substances (10.1%) in a non-malted grain. Proteolytic modification was slightly increased (The Kolbach index of 48.9%). Wort exhibited high content of soluble nitrogen at the level of 817 mg/l. Free amino nitrogen content was at a higher level (190 mg/l), forming 23% of soluble nitrogen. Amylolytic modification was at the optimal level (diastatic power 407 WK un.). Cytolytic modification was at a higher level (190 mg/l), forming 23% of soluble nitrogen at the level of 817 mg/l. Free amino nitrogen content was at a higher level (190 mg/l), forming 23% of soluble nitrogen. Amylolytic modification was at the optimal level (diastatic power 407 WK un.). Cytolytic modification was at the optimal level (diastatic power 407 WK un.).

Considering the values achieved in the studied technological parameters, Tosca achieved a very good malting quality with the point evaluation of 8 (8.5).

LG Tosca is a mid early malting variety. Plants are low, the variety is medium resistant to resistant to lodging, medium resistant to stem breaking. Its grain is big to very big, with a small and dense portion of sieving fractions over 2.5 mm (86%) is medium high. The variety is resistant to powdery mildew on the leaf, medium resistant to a complex of leaf rust of barley, medium resistant to a complex of leaf spots, resistant to scald, medium resistant to fusarium head blight. There is a very high yield of sieving fractions over 2.5 mm in the treated variant grown in sugar-beet and cereal areas, between high and very high in the treated variant grown in potato area, high in the non-treated variant grown in sugar-beet, cereal and potato areas, and medium high in both variants grown in a maize area.

The utility value is given by a combination of a very high yield of sieving fractions over 2.5 mm in the treated variant grown in sugar-beet and cereal areas, high to very high yield of sieving fractions over 2.5 mm in the treated variant grown in potato area, high yield of sieving fractions over 2.5 mm in the non-treated variant grown in sugar-beet, cereal and potato areas. Thanks to a very good malting quality, it meets the requirements for the production of beer with the PGI of “České pivo” and therefore, in comparison with the registered spring barley varieties, the variety has apparent benefits.

### 4 Conclusion

The study presents results achieved by five varieties which were registered in the Czech Republic after the harvest of 2019. Their quality was assessed according to the Malting Quality Index. Content of nitrogenous substances in the studied varieties of spring barley was at the optimal to mildly increased level (10.1 to 11.4%). The spring barley varieties of Adam and LG Ester recommended for the production of beer with the PGI “České pivo” had extract contents, apparent final attenuation and cytolytic modification lower than the other tested varieties. Extracts higher than 83% were recorded in the varieties of Avus, Fandaga, and LG Tosca. LG Tosca showed the average extract content at the level of 84.1%. Proteolytic modification in the studied varieties was favourable, only Fandaga exhibited strong proteolytic modification and the highest content of free amino nitrogen. Diastatic power in all the studied varieties was at the optimal level. Apparent final attenuation and cytolytic modification in Avus, Fandaga, and LG Tosca were at the optimal level.

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