Germination Index as an Indicator of Malting Potential

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Abstract

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The malting industry requires malt with a high extract yield, high levels of enzyme activity, and good modification to manufacture beer of excellent quality. The basic raw material for the beer production is the malting barley whose quality is of primary significance. Therefore, barley must be able to germinate vigorously and be post-harvest mature to meet these requirements. We find out to what extent barley physiological parameters influence the changes of malt technological parameters during post-harvest storage. The malt technological parameters investigated were the extract, relative extract at 45°C, Kolbach index, apparent final attenuation, friability, and wort β-glucan in relation to the germination energy and germination index. On the basis of the results obtained, it was found out that the germination index is the most suitable physiological parameter in view of the correlations with malt technological parameters, mainly the extract (r = 0.57) and relative extract at 45°C (r = 0.77). The germination index could be therefore used in the malting industry as a suitable indicator of the malting potential.

Keywords: barley; germination; malt; technological parameters

The quality of the malt is of primary significance in the manufacture of beer of excellent quality. To increase the brewing yield and efficiency, malts with high extract values, high enzymatic activities, and good modification are essential. To produce malt that meets these requirements, the barley employed must have minimal post-harvest dormancy and be able to germinate rapidly and uniformly (Riss & Bang-Olsen 1991; Woonton *et al.* 2005a). Freshly harvested grain is not recommended for immediate malting due to uneven germination, thereby reducing the resultant malt quality (Carreck & Christian 1997; Woonton *et al.* 2005b). Optimal germination performance such as the high vigour and germination capacity or viability of barley at the time of the malting process is without any doubt the most important quality criterion for malting barley (Swanston & Taylor 1990; Larsenet 1994; Briggs 1995; Lu *et al.* 2000; Munck & Moller 2004).

Within the malting industry, the ability of barley to germinate is measured using standard tests called the germination energy (GE) and the germination index (GI) (EBC 1998). The value of the germination energy does not sufficiently manifest the deepness of the post-harvest maturation and acceptability of a given sample for malting. For that reason, the germination index has been introduced characterising the germination rate (Riss & Bang-Olsen 1991).

Malting includes the controlled germination of barley in which hydrolytic enzymes are synthesised and the cell walls, proteins, and starch of the endosperm are largely digested, making the grain more friable (Enari & Sopanen 1986; Bamforth & Barclay 1993). Malt extract is primarily a function of the starch content, but it is influenced by other characteristics of the barley kernel, such as the hull content and cell wall thickness, and may be modified by the water

absorption, enzyme distribution, and endosperm modification characteristics (Burger & Laberge 1985). In full scale malt production, a high amount of extract and low β-glucan values in wort are very important economic criteria (Molina-Cano *et al.* 1995a,b; Chandra *et al.* 1999; Palmer 2000; Moller 2004). Malt extract is perhaps the most important quality parameter for maltsters and brewers when selecting or purchasing malting barley. The amount of extract that a malting cultivar can produce in the brew house will always be of crucial economic importance, as it determines the amount of beer that can be produced.

The main aim of this study was to determine the extent to which barley varieties changed during post-harvest storage and how these changes influenced the germination characteristics and malting potential and, moreover, to determine if there is any interaction between the germination characteristics and the quality of the final malt.

MATERIAL AND METHODS

Newly selected spring malting barley genotypes SK 5976, SK 5734, and the Nitran variety were evaluated in this work. Genotypes were collected from different climatic and growing locations of Slovakia. The barley samples originated from the localities Sládkovičovo (southern Slovakia), Veľké Ripňany (southern Slovakia), and Jakubovany (western Slovakia) and were obtained from the harvest year 2006. They were collected directly after the harvest and were stored under laboratory conditions at temperature 20–25°C. The term of achieving full ripeness of the studied genotypes at the localities Sládkovičovo and Veľké Ripňany was in the second week in July, and that at the locality Jakubovany in the first week of August. The harvest date at the localities Sládkovičovo and Veľké Ripňany was in the third week in July and at the locality Jakubovany in the second week of August. The barley samples were analysed in the first, second, fourth, sixth, and twenty-fifth weeks after the harvest, and the malt samples in the sixth and twenty-fifth weeks after the harvest in duplicates. All determinations were carried out according to the European Brewery Convention recommended methods (EBC 1998) and the determination of the relative extract at 45°C was carried out according to MEBAK method (2006).

Germination analyses. Two various germination analyses were carried out using 100 seeds in four replicates. The samples were tested immediately in the first week after harvest and later on they were monitored in the second, fourth, sixth, and twenty-fifth weeks of storage. In both methods, the germinated kernels were removed after 24 h, 48 h, and 72 h and the percentages of germinated kernels were calculated.

(1) Determination of the germination energy (GE) (EBC method)

The kernels were germinated in 90 mm Petri dishes with two layers of filter paper (Whatman No. 1) wetted with 4 ml H_2O. The samples were placed in a dark thermostat at 20°C. The germinated grains were counted at 24, 48, and 72 hours. The counts of the 4 ml sample over 72 h provided the estimate of the germination energy (EK):

$$EK\ (\%) = (n_{24} + n_{48} + n_{72})$$

where:

n_{24}, n_{48}, n_{72} – numbers of germinated kernels at 24, 48, and 72 h

(2) Calculation of the germination index (GI) (EBC method)

The germination index (IK) was calculated from the results of the germination energy determination according to EBC method:

$$IK = 10 \times (n_{24} + n_{48} + n_{72})/(n_{24} + 2n_{48} + 3n_{72})$$

where:

n_{24}, n_{48}, n_{72} – numbers of germinated kernels at 24, 48, and 72 h

Malt analyses. Micro-malting and malt analyses were performed on all samples using micro-malter Seeger (Schmidt-Seeger Company, Beilngries, Germany).

The standardised steeping program was in the first day: 3 h with water, temperature 14°C, 21 h air-break; second day: 6 h with water, temperature 14°C, 18 h air-rest, third day: 6 h with water, temperature 14°C, 18 h air-rest. The germination was performed together with steeping during 6 days. The kilning program was 20 h at 50°C and 4 h at 85°C and at the end the samples were deculming.

The determinations of the extract, Kolbach index, apparent final attenuation, friability, and wort β-glucan were carried out according to EBC methods (EBC 1998). The determination of the

elative extract at 45°C was carried out according to MEBAK method (MEBAK 2006).

The statistical analysis of the data was performed using the statistical method Statistical Analyses System (SAS Institute, Cary, USA). The data were analysed by the analysis of variance (ANOVA), and the correlations were analysed by Person's correlation coefficient.

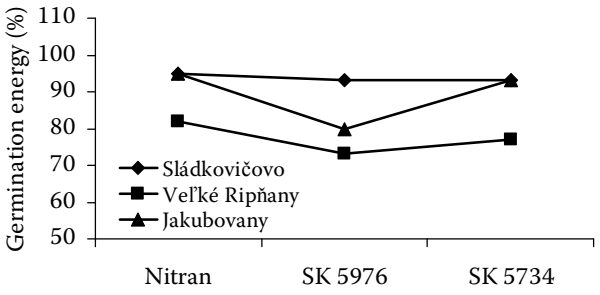


Figure 1. Germination energy values in the first week after harvest at three tested localities

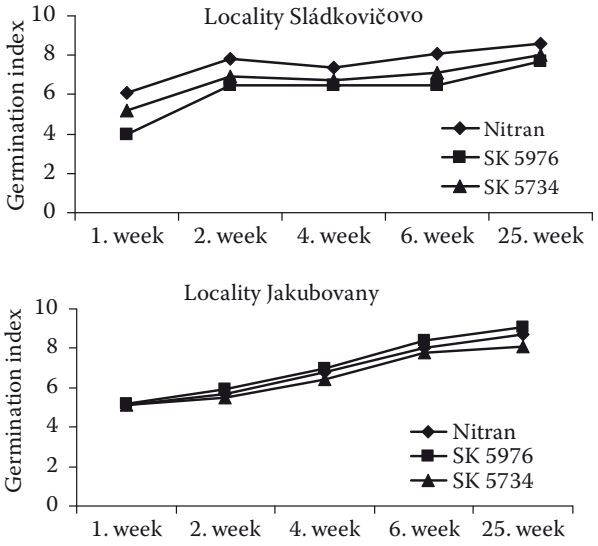
RESULTS AND DISCUSSION

Germination results

The testing of the barley samples indicated that, in the first weeks after the harvest, the germination energy and germination index reached low values due to the persisting dormancy. The lowest germination energy was found with genotype SK 5976 (73%) (Figure 1). In our experiments, the germination rate increased in all three varieties in the course of the observation. The germination energy values reached about 99% and remained high throughout the post-harvest storage period. The germination index values increased gradually from 4 to 9 over the post-harvest storage period and they did not change significantly (Figures 2–4). Using the germination index as a barley physiological parameter, it was possible to distinguish the rate of germination among the varieties very accurately. It was possible to differentiate genotypes SK 5976, SK 5734, and the Nitran variety immediately after the harvest and also during the post-harvest maturation. According to the germination index, some genotypes germinated rapidly and uniformly even in the sixth week after the harvest. According to Woods and McCallum (2000), Prokeš (2003), and Li *et al.* (2008), in the time of malting, barley should have finished dormancy to reach maximal germination energy and germination speed which is considered to be the prereguisite for a good modification of malt. The results of Frančáková and Líšková (2009) conclude that the germination index is considered to be the best predictor of the dormancy depth. High values of the germination index refer to high quality and homogeneity of malt (Woonton *et al.* 2005a). The results of our study showed that the germination energy and germination index values remained high over the post-harvest storage period. Significant was the effect of the growing locality on the development of the germination index ($P \leq 0.05$), but the effect of genotype was not significant ($P > 0.05$) (Table 1). The most balanced germination values were shown by the varieties coming from the locality Sládkovičovo and, on the contrary, the varieties coming from the locality Veľké Ripňany

Table 1. Effect of growing locality, genotype and terms of monitoring on development of germination index (ANOVA)

Source	DF	Sum of squares	Mean Square	*F* value	Pr > *F*
Growing locality					
Model	2	17.80942857	8.90471429	6.53	0.0036
Error	39	53.20200000	1.36415385	–	–
Corrected total	41	71.01142857	–	–	–
Genotype					
Model	2	2.87285714	1.43642857	0.82	0.4470
Error	39	68.13857143	1.74714286	–	–
Corrected total	41	71.01142857	–	–	–
Terms of monitoring					
Model	4	45.82031746	11.45507937	16.82	< 0.0001
Error	37	25.19111111	0.68084084	–	–
Corrected total	41	71.01142857	–	–	–



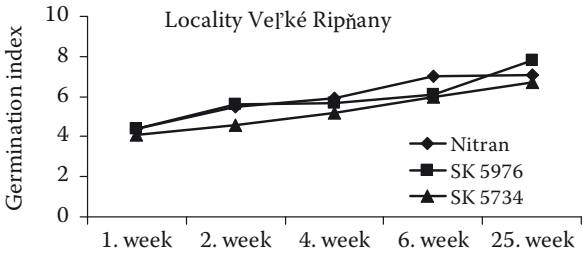


Figure 2. Development of germination index values in terms of genotypes from locality Sládkovičovo, Veľké Ripňany, and Jakubovany

showed significant differences in the germination index values. The effect of the monitoring terms, on the development of the germination index was highly significant from the first to the twentieth-fiftieth weeks (Table 1).

Malting results

The quality of malt produced from the stored barley gradually increased throughout the study period. Table 2 present the values of the malt technological parameters. The examination of the data in these tables shows that there were differences between the barley samples and, as expected, the germination time had a significant effect upon the malting parameters (Table 3). When comparing the 6th and 25th weeks after harvest, during the time of post-harvest ripening, the values of extract, relative extract at 45°C, Kolbach index, apparent final attenuation, and friability increased with increased germination

Table 2. Technological parameters (in %) of individual genotypes with regard to locality and genotype in the sixth and in the twenty-fifth week after harvest

Parameters	Week*	Locality			Genotype		
		Sládkovičovo	Veľké Ripňany	Jakubovany	Nitran	SK 5976	SK 5734
F	6th	75.5 ± 5.89	82.7 ± 6.14	76.2 ± 5.23	88.5 ± 3.32	71.1 ± 3.78	74.8 ± 2.50
	25th	77.3 ± 4.98	84.3 ± 5.33	79.3 ± 3.84	89.0 ± 3.06	74.3 ± 3.28	77.7 ± 1.33
RE 45	6th	36.7 ± 0.32	35.9 ± 0.07	37.5 ± 0.31	37.0 ± 0.55	36.5 ± 0.59	36.6 ± 0.32
	25th	38.1 ± 0.15	37.0 ± 0.45	37.5 ± 0.33	38.1 ± 0.15	37.3 ± 0.45	37.3 ± 0.45
KI	6th	37.7 ± 0.42	40.1 ± 0.35	39.6 ± 0.73	39.9 ± 0.79	38.5 ± 0.90	39.1 ± 0.81
	25th	39.3 ± 0.30	40.5 ± 0.38	40.5 ± 0.49	40.7 ± 0.52	39.6 ± 0.49	40.0 ± 0.35
AFA	6th	80.9 ± 0.17	80.3 ± 0.23	80.4 ± 0.12	80.9 ± 0.18	80.4 ± 0.25	80.4 ± 0.15
	25th	81.2 ± 0.20	80.4 ± 0.28	80.9 ± 0.23	81.3 ± 0.17	80.7 ± 0.25	80.6 ± 0.26
E	6th	81.4 ± 0.18	81.7 ± 0.32	81.6 ± 0.03	81.9 ± 0.22	81.3 ± 0.23	81.5 ± 0.19
	25th	81.6 ± 0.38	81.8 ± 0.50	82.0 ± 0.17	82.2 ± 0.09	81.5 ± 0.35	81.4 ± 0.44
BGw	6th	1.9 ± 0.15	2.0 ± 0.22	1.9 ± 0.33	1.7 ± 0.26	2.2 ± 0.15	2.0 ± 0.15
	25th	0.05 ± 0.01	0.06 ± 0.02	0.08 ± 0.01	0.05 ± 0.01	0.08 ± 0.01	0.07 ± 0.01

*weeks after harvest; values represent the mean (n = 3) ± SD; F – friability; RE 45 – relative extract at 45°C; KI – Kolbach index; AFA – apparent final attenuation; E – extract; BGw – wort β-glucan

Table 3. Statistical significance of technological parameters in terms of locality, genotype and monitoring weeks evaluated by (ANOVA)

Source	DF	Sum of squares	Mean Square	*F* value	Pr > *F*
Locality					
Friability	2	44.5016667	22.2508333	5.28	0.0102
Relative extract	2	4.83444444	2.41722222	3.16	0.0714
Extract	2	0.58777778	0.29388889	0.32	0.7298
Kolbach index	2	12.99111111	6.49555556	10.11	0.0017
Apparent final attenuation	2	1.40777778	0.70388889	3.28	0.0659
Wort beta glucan	2	1.33000000	1.22600000	1.23	0.1432
Genotype					
Friability	2	918.137778	459.068889	22.71	<.0001
Relative extract	2	3.82111111	1.91055556	2.30	0.1348
Extract	2	5.04111111	2.52055556	4.09	0.0383
Kolbach index	2	5.12711111	2.45566666	3.96	0.0493
Apparent final attenuation	2	1.18111111	0.59055556	2.57	0.1098
Wort beta glucan	2	2.93111111	1.81022226	0.30	0.1568
Monitoring weeks					
Friability	2	62.3211111	30.2510000	7.15	0.0041
Relative extract	2	49.1850000	24.5925000	6.04	0.0058
Extract	2	1.44500000	1.44500000	1.80	0.1984
Kolbach index	2	17.83166667	8.91583333	8.54	0.0010
Apparent final attenuation	2	0.40500000	0.40500000	1.53	0.2334
Wort beta glucan	2	945.146668	558.078889	32.15	<.0001

time while the values of wort β-glucan decreased (Table 2).

With regard to the physiological parameters, after half a year of storage (in the 25th week after the harvest) the genotypes were prepared for the malting process due to the acceptable germination index values (Figure 2) as well as malt parameters values (Table 2). The results of Mareček *et al.* (2000) and Sychra *et al.* (2001) revealed that the storage of barley for two years helped to increase the values of the qualitative technological parameters like extract or friability, and to decrease the values of wort β-glucans. Moreover, the results of this study revealed that the growing locality influenced the changes of the malt technological parameters (Table 3). The locality Sládkovičovo was the driest and the most arid locality in comparison to the localities Veľké Ripňany and Jakubovany. Therefore, better values of the malt technological parameters were obtained with genotypes coming from the localities Veľké Ripňany and Jakubovany.

During the time of storage, with regard to the genotype the variety Nitran reached the best values in the malting parameters. Genotypes SK 5734 and SK 5976 even in the twenty-fifth week after harvest did not accomplish the requirements for acceptable malting quality with regard to some malting parameters (Table 3).

Correlations between the germination and malting parameters

The correlations between the barley physiological parameters and malt technological parameters were evaluated using Pearson's correlation coefficient. With regard to the germination energy, no significant correlation with the malt technological parameters was found. On the other hand, it was found out, in the germination tests carried out that the germination index significantly positively correlated with the extract (r = 0.57) and with the

Table 4. Statistical significance of physiological barley parameters and technological malt parameters evaluated by Pearson's correlation coefficient

Parameter		F	RE 45	E	KI	AFA	BGw	GE	GI
F	*r*	1.00000	0.23398	0.54052	0.56864	0.07783	–0.39054	0.21260	0.27464
	P		0.4416	0.0565	0.0426	0.8005	0.1870	0.4856	0.3638
RE	*r*	0.23398	1.00000	0.34595	0.20918	0.36868	–0.50321	0.32645	0.77494
	P	0.4416		0.2469	0.4928	0.2151	0.0796	0.2763	0.0019
E	*r*	0.54052	0.34595	1.00000	0.29033	0.41156	–0.60214	0.23833	0.57405
	P	0.0565	0.2469		0.3359	0.1623	0.0294	0.4330	0.0402
KI	*r*	0.56864	0.20918	0.29033	1.00000	–0.12316	–0.34090	–0.20485	0.05028
	P	0.0426	0.4928	0.3359		0.6885	0.2544	0.5020	0.8704
AFA	*r*	0.07783	0.36868	0.41156	–0.12316	1.00000	–0.41878	–0.24902	0.26487
	P	0.8005	0.2151	0.1623	0.6885		0.1544	0.4120	0.3818
BGw	*r*	–0.39054	–0.50321	–0.60214	–0.34090	–0.41878	1.00000	–0.20880	–0.53913
	P	0.1870	0.0796	0.0294	0.2544	0.1544		0.4936	0.0573
GE	*r*	0.21260	0.32645	0.23833	–0.20485	–0.24902	–0.20880	1.00000	0.58406
	P	0.4856	0.2763	0.4330	0.5020	0.4120	0.4936		0.0361
GI	*r*	0.27464	0.77494	0.57405	0.05028	0.26487	–0.53913	0.58406	1.00000
	P	0.3638	0.0019	0.0402	0.8704	0.3818	0.0573	0.0361	

F – friability; RE 45 – relative extract at 45°C; E – extract; KI – Kolbach index; AFA – apparent final attenuation; BGw – wort β-glucan; GE – germination energy; GI – germination index; *r* – correlation coefficient; *P* – significance

relative extract at 45°C ($r = 0.77$), thus indicating that the germination index is a good indicator of the malting potential (Table 4). This points out that with increasing germination index the values of extract and relative extract at 45°C also increase. The correlation analyses showed a low negative significant correlation between the germination index and wort β-glucan content ($r = –0.53$) (Table 4). This indicates that with post-harvest ripening the wort β-glucan content decreases, but this correlation was not so evident. Reuss *et al.* (2006) found out in his experiments that malting of dormant barley influenced the values of some malting parameters such as Kolbach index, wort β-glucan content, diastatic power and apparent final attenuation. Similar results were also obtained by Mareček *et al.* (2000). The studies on non-dormant European barley confirmed that storage for one year helped to increase the values of Kolbach index and relative extract (Woonton *et al.* 2001). An improvement of the malting quality due to the storage time was also observed in the studies on New Zealand barley (Coles *et al.* 1996). On the contrary, in the studies on Australian barley no significantly increased values of the germination energy and malt quality were observed after a year of storage (Samuro *et al.* 1980).

CONCLUSION

The data presented in this paper indicate that the barley germination characteristics improved during the post-harvest storage and underwent significant changes associated with dormancy decay which resulted in improved malt quality. The germination index proved to be a good indicator of dormancy decay and by using it was possible to differentiate the rate of germination among the varieties. Moreover, the germination index proved to be the best physiological indicator to consider the correlations with malt technological parameters such as the extract and relative extract at 45°C. We can conclude that the germination index should be therefore used in the malting industry as a suitable indicator for the prediction of the malting potential. It is very essential to verify these results in other climatically different years and using different genotypes. Using the germination index as a malt quality indicator would help to shorten the duration of the time-consuming methods used in the malting industry for the malt quality detection. The results have practical importance to the barley breeders and maltsters seeking to supply malt that satisfies the requirements for malt by their brewing customers.

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