

The effect of weather and the term of malting on malt quality

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ABSTRACT

The effect of the weather on the physiological and malting parameters of spring barley was studied. The dependence of malt quality on the course of weather during the caryopsis growth and development in the ear was statistically confirmed. Germinating caryopses responded statistically significantly to a higher sum of precipitation over the entire growing period ($r = -0.48$), and higher temperatures ($r = -0.43$) and radiation ($r = -0.43$) in the 14-day period before harvest by a lowered ethylene production, malting yield increased with the reduced ethylene production ($r = -0.35$). Reduced content of carbon dioxide released by germinating caryopses depended highly statistically significantly on higher temperatures ($r = -0.86$) and radiation during 14 days before harvest ($r = -0.88$). β -glucan content in wort ($r = 0.50$) and malt modification ($r = -0.21$) depended statistically significantly on the precipitation sum over the entire vegetation period (the more precipitations, the lower β -glucan content). Malt modification was in positive statistically significant correlation with the sum of temperatures ($r = 0.46$) and radiation in the 14-day period before harvest ($r = 0.39$).

Keywords: *Hordeum vulgare* L.; dormancy; grain; germination; solar radiation

Although dormancy in spring barley caryopses is genetically encoded (Gualano and Benech-Arnold 2009, Castro et al. 2010), its depth is also affected by weather conditions (Simpson 1990, Woods et al. 1994, Hradilík et al. 2000).

Li et al. (2003) emphasized genetically-based relationship between dormancy and malt quality, namely extract, diastatic power, α -amylase activity, and free amino acids in connection to the rainy weather during harvest and grain sprouting. The cultivars with low dormancy were susceptible to preharvest sprouting. Lin et al. (2008) found a significant correlation between α -amylase activity and caryopsis germination capacity and dormancy. Caryopses with a higher α -amylase activity were less resistant to sprouting.

The dynamics of production of native ethylene released by germinating caryopses during post-harvest ripening was reported (Fišerová et al. 1996, Hradilík et al. 2000). Genetically given parameters of dormancy are intensified or weakened by the external conditions. Caryopses are the most sensi-

tive to weather in the stage of milk ripeness. The highest ethylene production along with the highest ABA (abscisic acid) content have been proven at the stage of wax ripeness in the caryopses with higher dormancy supported by a wetter and colder weather during the growth and development of caryopses in the ears. Dormancy also increased with a higher content of phenolic compounds in caryopses, content of phenolic compounds raised with rainfalls and a decline in temperatures during the stage of caryopses ripening. Cytokinin and auxin contents in caryopses were higher at the stage of milk ripeness and at ripening; with the onset of dormancy, contents of both these hormones declined. Similarly, Frančáková and Líšková (2009) reported the effect of the colder weather during the growing period and barley harvest on deeper dormancy which they assessed by germination energy, germination rate and germination index.

Dormancy in barley caryopses can be controlled by exogenous ethylene (Beltrano et al. 1994), which

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increases α -amylase activity and breaks dormancy. Oh et al. (2006) increased germination capacity of dormant barley caryopses by applying gibberellin and exposing caryopses to low temperatures (10°C).

α -amylase activity and β -glucan content in caryopses are malt quality indicators, their genetic dependence in relation to the environment has been studied by many authors (Wang et al. 2004, Therrien 2006). Other authors have pointed to the important relationship between β -glucan content in caryopses and malt quality. Gianinetti et al. (2007) claimed that β -glucanase activity degraded as much as 93% of β -glucans during malting. According to Altunkaya et al. (2001), β -glucan content in caryopses changes depending on the weather conditions of the growing location.

Agu and Palmer (2001) studied the content of nitrogenous substances in caryopses in relation to α -amylase activity and β -glucans. They confirmed that low content of nitrogen in caryopses increased malt extract but did not affect α -amylase activity. β -glucan content was often higher in caryopses with a higher content of nitrogenous substances; this finding, however, has not been statistically proven yet.

Chandra et al. (1999) explored structural differences of barley caryopses in relation to starch granules in the endosperm. They determined the differences in protein and β -glucan concentrations and found that the caryopses with small starch granules contained more proteins and β -glucans, reaching thus a lower degree of modification during the malting process.

According to Lalic et al. (2010), malt made from spring barley cultivars compared to malt made from winter barley has statistically significantly higher extract, lower yield, viscosity, higher β -glucanase activity, lower β -glucan content in malt and higher friability.

Our study presents the results of a seven-year monitoring of post-harvest ripening of dormant and non-dormant spring barley cultivars in relation to temperature, radiation and sum of precipitations (so-called climatological factors) in the 14-day period before harvest and the sum of the same parameters over the entire spring barley growing period. The physiological parameters of the course of dormancy included gases produced by germinating caryopses (ethylene, ethane, carbon dioxide) during the malting process in the period immediately after harvest (term of monitoring I),

3 and 6 weeks after harvest (terms of monitoring II and III). In the produced malt, following parameters of quality were determined: α -amylase activity, β -glucan content, modification and malt yield.

MATERIAL AND METHODS

Laboratory trials were conducted with the exactly defined volumes (glass bottle with the volume of 3600 mL closed with a rubber stopper for 24 h) and numbers of barley caryopses (2 000 pieces in a wire basket). Two-day steeping technology (length of steeping: on the 1st and 2nd day for 3 h at water temperature 14°C) was applied. On the 3rd day, water content in caryopses was adjusted by steeping or spraying to 45%. Germination of barley took totally 72 h at 14°C. Laboratory samples were kilned using the standard technology – pre-kilning of green malt at 55°C for 12 h, heating of malt to kiln temperature and final kilning at 80°C for 4 h.

During steeping and germination (6 days), air samples were taken from boxes in the 24-h intervals. The gaseous samples were collected into syringes (2 mL) which after sampling were jabbed in the marked rubber stoppers. Prior to the analysis, the volume of gas in the syringe was adjusted to 1 mL. The samples were analyzed for contents of ethylene, ethane, and CO₂ by the gas chromatography (Fišerová et al. 2001, 2008, Prokeš et al. 2006). Figure 1 shows the results of ethylene, ethane, and carbon dioxide contents for the whole malting time in the individual terms of malting in dormant and non-dormant cultivars including curves of linear dependences. The malt analyses were conducted according to the EBC methods (2009): α -amylase activity (EBC 4.13), β -glucan content in malt (EBC 3.10.2) and malt modification (EBC 4.14). Malt yield was calculated as a percentage of malt dry matter to barley dry matter at the beginning of malting. The malting values including linear dependence are given in Figure 2.

In harvest years 2005 and 2006, the analyses were conducted immediately after harvest (marked as I) and 6 weeks after harvest (marked as III); in experimental years 2007–2011 an additional term of 3 weeks after harvest (marked as II) was added. In harvest years 2005–2008 barley cvs. Jersey (less dormant) and Tolar (deeper dormancy), in 2009–2011 barley cvs. Bojos (less dormant) and Sebastian (deeper dormancy) were used. The barley

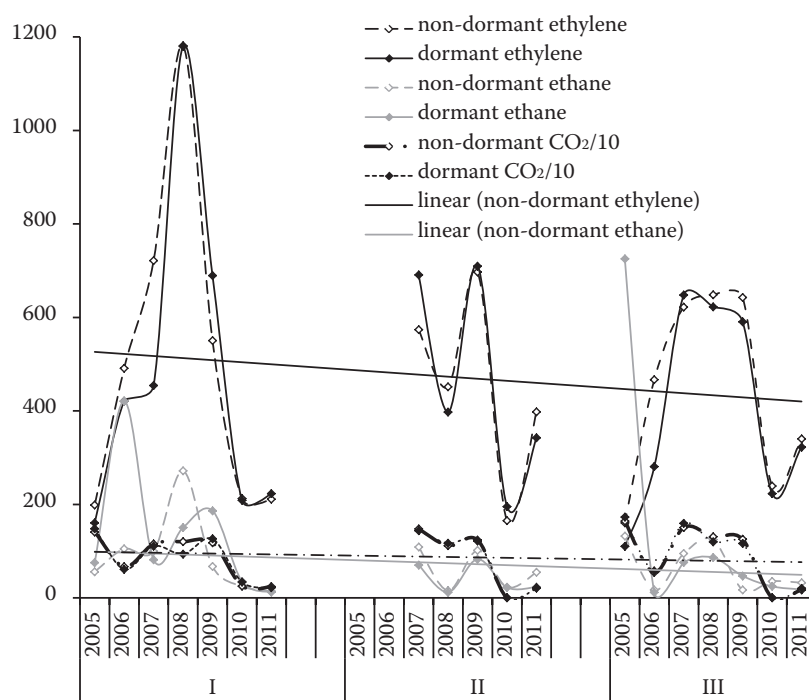


Figure 1. The sums of ethylene, ethane and CO₂ production during malting of dormant and non-dormant barley cultivars immediately after harvest (I) and 3 (II) and 6 (III) weeks after harvest in 2005–2011 with the linear dependence of gas production in the course of post-harvest ripening

cultivars were acquired from the field experimental station of the Mendel University in Brno located in Žabčice (Ehrenbergerová et al. 2010). From this

locality, the climatological values, i.e. temperature, radiation, and precipitation sum in the period of 14 days before harvest and sum of the same pa-

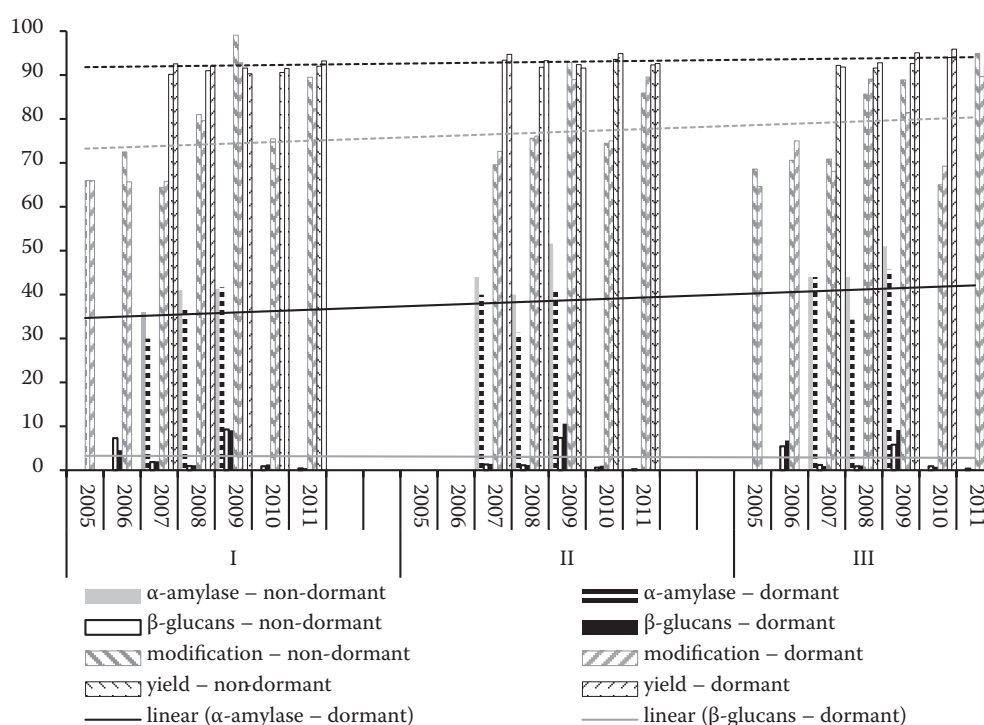


Figure 2. Summary results achieved in the 7-year study of malt quality. Malt was produced in the term immediately after harvest (I); 3 weeks after harvest (II), and 6 weeks after harvest (III). Cultivars with a short time of dormancy (marked as non-dormant – Jersey, Bojos) and longer dormancy (marked as dormant – Tolar, Sebastian) were malted. During malting, α-amylase activity and β-glucan content in caryopses were studied. At the end of the experiment, modification and malt yield were assessed. The graph shows a linear trend line in gas production and malt quality in the individual sample collections

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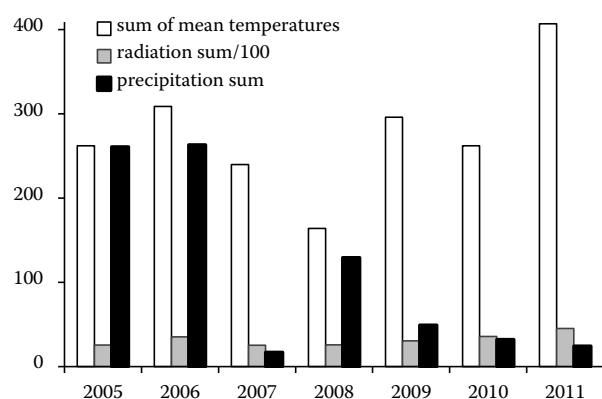


Figure 3. The sum of temperatures (°C) and radiation (J/cm²) in the 14-day period before harvest and the sum of precipitations (mm) over the entire spring barley growing period in 2005–2011

rameters over the entire spring barley vegetation period were obtained. The data that significantly or highly significantly affected post-harvest barley ripening and parameters of produced malts are given in Figure 3.

In this study, mean values of the studied barley cultivars were statistically assessed based on the depth of dormancy (dormant and non-dormant) as according to the results reported by Fišerová et al. (2010) the amount of ethylene released by germinating barley grain does not depend on a cultivar but only on the depth of dormancy. The effect of the weather conditions on the physiological

and malting parameters was statistically assessed using the correlation analysis. The biometric analysis was conducted using the Statgraphics software (Warrenton, USA). The correlation coefficients between the individual parameters are given in Table 1.

RESULTS AND DISCUSSION

During the post-harvest ripening, the amount of gases produced by germinating caryopses declined. In the caryopses with lower dormancy it was only slightly higher than in those with higher dormancy (Figure 1), which is in compliance with the results of Fišerová et al. (1996) and Hradilík et al. (2000). α -amylase activity increased during post-harvest ripening and it was higher in the non-dormant caryopses in colder years 2007–2009. β -glucan content in malt had a declining tendency and non-dormant caryopses contained a lower amount of these substances. In years with a higher temperature and radiation (2010 and 2011), β -glucan content was generally low. It corresponds with the findings of Altunkaya et al. (2001) who reported that β -glucan content in caryopses altered according to the weather conditions of the site. Modification and malt yield increased in the course of post-harvest ripening (Figure 2).

Wang et al. (2004) reported that β -glucan content and β -glucanase activity highly significantly

Table 1. Correlation coefficients of relationships between the sum of produced gases (ethylene, ethane, and CO₂) and the sum of precipitations over the entire vegetation, the sum of temperatures and the sum of radiation for the 14-day period before harvest and malting quality parameters – β -glucan content and malt yield for all years under study in the course of post-harvest ripening

	Sum of days of malt production and all years						
	ethylene	ethane	CO ₂	precipitation Σ	precipitation 14 days	temperature 14 days	radiation 14 days
Precipitations Σ	–0.4774 0.0024–x	0.1415 0.3968	–0.1745 0.2948				
Temperature 14 days	–0.4313 0.0069–x	–0.3194 0.0506–x	–0.8561 0.0000–xx				
Radiation 14 days	–0.4279 0.0074–x	–0.3680 0.0230–x	–0.8829 0.0000–xx				
β -glucan	0.2396 0.1724	0.1516 0.3920	0.3739 0.0294–x	0.5023 0.0025–x	0.3161 0.0686	–0.1739 0.3252	–0.1701 0.3362
Modification	0.2757 0.0938	–0.2005 0.2275	–0.1605 0.3359	–0.2129 0.1994	0.6036 0.0001–xx	0.4615 0.0035–x	0.3937 0.0145–x
Yield	–0.3496 0.0582–x	–0.4271 0.0186–x	–0.2148 0.2544	0.2188 0.2454	–0.0234 0.9023	0.1062 0.5765	0.1235 0.5154

correlated with malting quality indexes, such as Kolbach index, diastatic power, wort viscosity, and malt extract. Passarella et al. (2008) proved increased contents of β -glucans and proteins due to the increased temperature before harvest in the nitrogen treated cultivar. Passarella et al. (2002) reported that with high temperatures during harvest kernel weight lowered, nitrogen content increased, β -glucan content and yield declined. Similarly, Savin et al. (1997) studied the effect of high temperatures in the period of caryopses ripening, claiming that thermal stress reduced starch content (volume and distribution of A- and B-starch granules), increased nitrogen content and reduced β -glucan content and their degradation. Malt yield was not statistically significantly affected. Macnicol et al. (1993) studied water stress and reported that water stress led to a decline in β -glucan content and increase in malt yield, it also increased the activity of β -glucanase, α -amylase and β -amylase. Malt quality was not affected by added thermal stress.

Figure 2 also shows that modification of malt from non-dormant caryopses was higher in samplings I and II; in sampling III modification was sometimes higher also in malt produced from dormant caryopses which, however, at that time had already released from dormancy. Malt yield was usually higher in dormant caryopses.

Caryopses responded significantly by a reduced ethylene production to a higher sum of precipitation for the entire growing period ($r = -0.48$) and by the reduced production to higher temperatures ($r = -0.43$) and radiation ($r = -0.88$) in the 14-day period before harvest (Figures 1, 3, Table 1).

β -glucan content and malt modification depended highly statistically significantly on the sum of temperatures ($r = 0.50$) for the whole growing period (the lower the temperature, the lower β -glucan content and thus also higher malt modification). Increased radiation also affected statistically significantly α -amylase activity. Similarly, homogeneity and modification of malt depended statistically significantly on the temperature and radiation in the 14-day period before harvest (Figure 2, Table 1).

Of the malting and physiological parameters, only homogeneity and modification were statistically highly significantly dependent; of the physiological parameters ethylene with CO_2 and ethane with CO_2 (Figures 1 and 2, Table 1). Relationships

between ethylene and modification and carbon dioxide and β -glucan content were statistically significant. Production of ethylene and ethane responded inversely to malt yield (Table 1).

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