HUMIDITY AND QUALITY OF BALED HOPS STORED AT GROWERS*

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Due to the transition of pressing dry hops into bales instead of sacks, where the specific weight is by 22% higher, the attention of growers focuses on moistening of dry hops before baling. On the one hand, with higher moisture the hop mustiness hazard increases, and on the other, there is a risk of shattered cones with lower moisture. Our task was to find out how hop moisture at baling influences further moisture development and hop quality. In the course of 10 days we observed the moisture of hops stored in bales with the initial moisture ranging from 9.2 to 16.2%. Samples were divided according to moisture into three variants – dry, regular, and moist. Hops were stored right in the space of the hop dryer where the air temperature ranges from 7 to 40°C. At the end of the measurement we carried out a laboratory analysis of all samples to find out about moisture, content of the α-bitter acid, and cone shatter. With the moist variant the average moisture dropped during storage from 14.2 to 12.7%, and with the dry variant it increased from 9.37 to 11.1%. Cone shatter was the highest with the dry variant, namely 28.2%, and contrarily the lowest with the regular variant (12.3%), which is by 43% less. However, no direct dependency of hop moisture on shatter was proved. As for the content of the α-bitter acid, there were no substantial differences between the variants. The highest content was measured with the moist variant, namely 4.9%, and there was also proved a direct dependency of hop moisture on the content of the α-bitter acid. Judged from the assessed results of cone shatter and the α-bitter acid content, the best results were with the regular variant with the moisture from 11.2 to 11.6%.

Humulus lupulus, moisture; storage; bale; product quality

INTRODUCTION

Former hop sack, into which dry moistened hops are pressed, is a cylinder shaped of 0.6 m in diameter and 2 m high. Recently there has been a tendency to abandon hop sacks and prefer the automated pressing of hops into a bale (Fig. 1) sized 0.6 × 0.6 × 1.2 m (http://chmelarstvi-zavodmechanizace.cz/EN/hranolovy-lis.html). The main advantage of a bale compared to a sack is the maximum utilization of space both for transport and storage. Another advantage is a smaller volume of stored hops. A hop sack is pressed for a weight of approximately 60 kg, which at a volume of 0.635 m^3 corresponds to a specific weight of 94.5 kg m^{-3}. The bale is pressed for a weight of 50 kg and at a volume of 0.43 m^3 it gives a specific weight of 115.7 kg m^3 of baled hops. Because of a higher specific weight, by 22% compared to a sack, there is a higher risk of mustiness for hops moistened by an air-conditioning line. After baling hops with a high moisture, the temperature relatively quickly increases and the surface cone moisture rises, an effect that is denoted as cone mustiness (Rybáček et al., 1980).

This process even more aggravates cone damage, which is high at a mechanized harvest. Drying and moistening of hops is in most cases carried out automatically, which complicates measuring the actual hop moisture (Rossbauer et al., 2003). At a high water content (15% and more) there arises a danger of rendering the hops worthless by becoming musty and in bigger volumes there is even a hazard of spontaneous ignition (Krofta, 2008). The temperature and moisture of too moist stored hops increase compared to loose hops. This is due to an increased intensity of hop cone breathing, release of H_2O and CO_2, and impossibility of the released energy outlet (Vent, 2012). An increased breathing intensity causes hop cones to lose important brewing substances, thus decreasing the quality of the final product. Besides, consumption of oxygen, which when lacking is gained intramolecularly through decomposition of organic substances, increases (Vent et al., 1963). Skinner et al. (1977) states that a decrease in the content of important brewing substances depends on storage time, amount of present air, and variety. According to Virant et al. (2003) the brewing quality of hops after storage is influenced

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Fig. 1. Pressed hops in bales

Fig. 2. Measurement of hop moisture content in a bale

by three basic elements: time, temperature, and cone damage. Hop mustiness is generally prevented by a lower moistening of baled hops. The lower moisture though causes a high percentage of cone shatter. When overdried, cones become fragile and easily crushing at mechanical strain. Overdrying of little cones may occur also at an uneven cone size (Krofta, 2008). When hops are overdried, their quality declines, and also moistening before baling becomes more difficult (R o s s b a u e r et al., 2003).

MATERIAL AND METHODS

The measurement was carried out in August 2012 on PSH 750 belt hop dryer (Nové Mesto nad Váhom, Slovakia) in Oploty run by Chmel-Vent s.r.o. For statistical assessment of results three bales for each variant were prepared. A bale is a rectangular package measuring 0.6 × 0.6 × 1.2 m into which dry hops are pressed by HL-60/M (Chmelarstvi druzstvo Zatec, hop machinery, Zatec, Czech republic) fully automated square bale press with a constant pressure. Each of the three bales contained hops with approximately known moisture, at which they were adjusted in advance in the air-conditioned line of the dryer. The driest hops with moisture of 9–10% were pressed into the bales for dry variant, hops with standard moisture of 11–12% were pressed into the bales for regular variant, and the bales for moist variant contained overmoistened hops with moisture of 13% and more. The hops were stored right in the space of the hop dryer (Fig. 1) where the temperature ranges from 7 to 40°C.

Moisture was measured by WILE 25 moisture meter (Farmcomp, Tuusula, Finland) in 8-h intervals. On the moisture meter there was a 45 cm long W-251 bar probe (FARMCOMP). The moisture meter did not have the logging function, so the data had to be recorded manually. Moisture was always measured twice with each bale. Once in the upper and once in the bottom part (Fig. 2), each time in the same spot, at a depth of 30 cm. The resulting moisture of a given bale was the average value of these two measurements. The measurements were carried out 3 times a day in 8-h

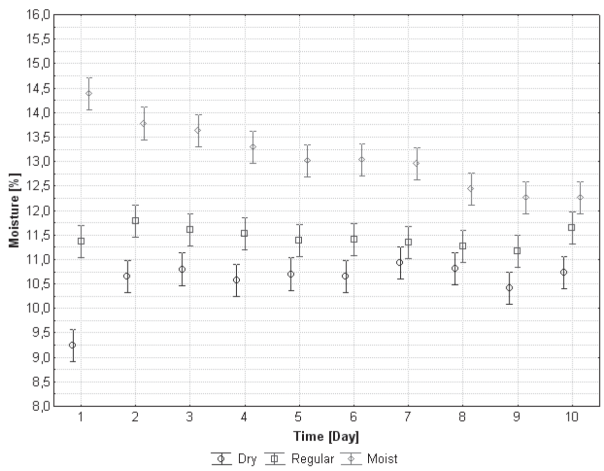

Fig.3. Graphic depiction of compared moisture averages during the measurement

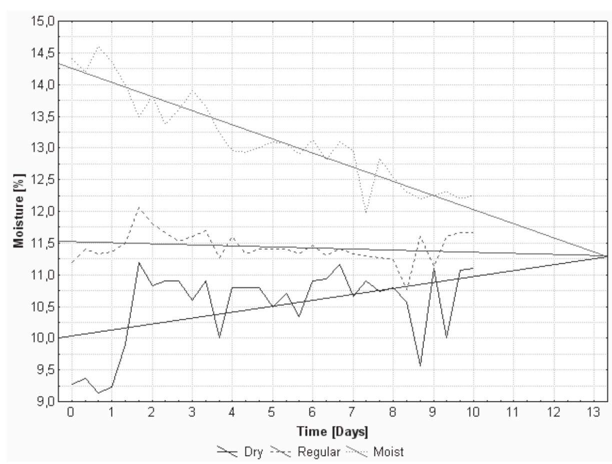

Fig.4. Development in moisture of individual variants with fit lines

intervals over 10 days, each day at the same time – at 8 a.m., 4 p.m., and at midnight.

After the measurement had been finished, a sample was taken from each bale to conduct a laboratory analysis. With each sample we assessed its moisture content according to EBC 7.2 (ANALYTICA EBC, 1998), content of the α-bitter acid by conductometric value according to CSN 432520-15, and cone shatter according to CSN 46 2520-6 (CSN 46 2520, 1994). The measured data were processed and statistically assessed in STATISTICA (Version 10, 2011) program.

RESULTS

The initial values of moisture measured with the dry variant were 9.2, 9.4, and 9.5% with individual bales. With the regular variant the moisture of individual bales was 11.3, 11.3, and 11.6%. And finally the moisture values of the moist variant were 13.1, 13.3, and 16.2%. The last value is higher than was expected, however it did not have a negative impact on further measuring. The development of average daily moisture values for each variant can be seen in Fig. 3. At the beginning of the measurements there was a substantial difference in the moisture content (artificially created) between the individual variants which would gradually decrease in the course of time.

During days 7 and 8 of the measurement the difference between the dry and the regular variant was not even provable. The same case occurred on the last day of the measurement between the regular and the moist variant. As for the moisture development itself, Fig. 4 shows a slight increase with the dry variant and a considerable decline with the moist variant. The regular variant experienced a slight decline in the course of the measurement, but it was insignificant. The average speed of decline in moisture with the moist variant was 0.07% between individual intervals of the measurement. The most considerable decline (by 1%), was recorded on day 7 of the measurement and, on the contrary, one day later an increase by 0.87% occurred. With the regular variant we recorded an average decline of 0.01%. The fastest decline by 0.47% and increase by 0.83% occurred with this variant on day 9 of the measurement. The dry variant showed a substantial increase in the average moisture at the beginning of the measurement. During the first two days the moisture rose from 9.2 to 10.7%. The most considerable changes between the measurements were +1.53% and –1.1% which occurred on day 9 of measuring.

Fig. 4 clearly shows the development of moisture for each measured variant. By fitting the curves we discover that the moisture values of the dry and moist variants incline to the values of the regular variant. During 10 days of measuring all of the variants got in the moisture interval from 11.1 to 12.2% which makes a difference of 1.1%. The initial interval was from 9.2 to 14.4% which makes a difference of 5.2%. Unfortunately, the measurement did not go on. We can only use a theoretical estimation of the moisture development for each variant by prolonging the fit line. Then we discover (Fig. 4) that on day 14 of storage the moisture values of all the three variants would stabilize at a value of 11.3%. However, this estimation is merely theoretical.

The values of cone shatter and of the α-bitter acid content are shown in Fig. 5. Differences in cone shatter are significant. The driest variant showed the highest value of shatter, namely 28.2%. The regular variant had its percentage of shatter by 43% lower. With the moist variant the cone shatter was 16.6%, which is by 34% more than with the regular variant. If we look at the content of the α-bitter acid in the dry matter, there are no significant differences between the three variants. Both the dry and the regular variant have almost the same values, namely 3.76 and 3.93%, respectively. The moist variant has its α-bitter acid content slightly

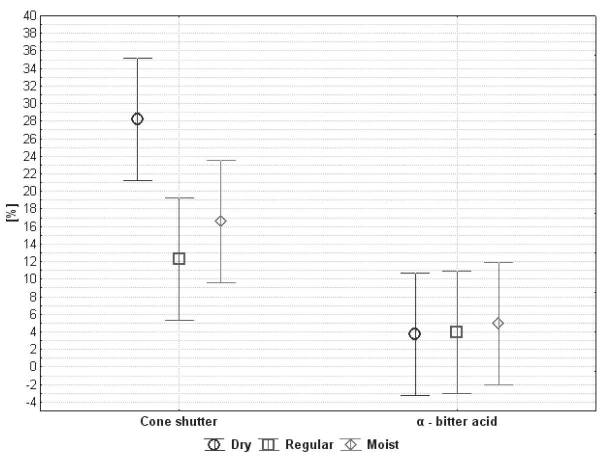

Fig.5. Graphic depiction of compared averages of cone shatter and conductometric values of each variant

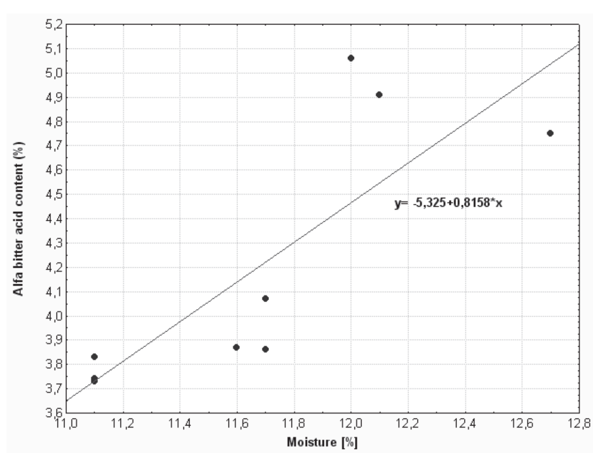

Fig.6. Graphic depiction of the correlation field of the α-bitter acid content and moisture

higher (4.9%). Considering the value of correlation coefficient we may talk about a direct dependency of α-bitter acid on hop moisture, which is described in 69.7% by the given regression function. The value of the calculated significance is lower than the set significance level α = 0.05, which makes it a statistically important correlation coefficient. The graphic depiction of the correlation field of the α-bitter acid content and moisture is seen in Fig. 6.

DISCUSSION

With their moisture, the dry and regular variants correspond to the parameters for a standard quality of hops. The moist variant falls into the non-standard category, because it exceeds the moisture value assessed by Market regulations for hops (12%) (Krofta, 2008). With the moist variant no expected increase in moisture and mustiness occurred. Mustiness did not occur neither with the sample showing the highest moisture (16.2%), which is more than presented by Krofta (2008). Dry hop cones have two adverse features: fragility and hygroscopicity. The hygroscopic feature caused a remarkable increase in moisture content of hop cones in the dry variant. Horejsek et al. (1990) described the effect of air humidity on hop cones absorption of moisture from the atmosphere. The moisture content of hop cones increased from 10 to 12% during 5–7 days. The regular variant had its percentage of shatter by 43% lower, which corresponds to the statement of Rossbauer et al. (2003) and Krofta (2008) who claim that overdried hops bear the risk of higher cone shatter. Besides, no dependency of hop moisture on surrounding air temperature and moisture was proved, a fact which corresponds to the results of Vent (2012), who claims that increasing temperature and hop moisture in a container does not depend on the surrounding air temperature but on the storage time. The experiment was carried out under common conditions with the temperature ranging from 7 to 40°C which, according to Hopfenveredlung St. Johann (2001), does not correspond to a cool anaerobic environment suitable for storing hops. As proven by the results (Kroupa, 2003), to minimize qualitative loss it is necessary to process the baled hops into granules and store them in an air-conditioned environment.

CONCLUSION

From the measured results we may state that with dried hops moistened to 16.2% before pressing into a bale, neither moisture increase nor mustiness occurred. On the contrary, moisture of this sample declined after 10 days by 4.5%. With the dry variant the moisture increased by 1.5% during the storage. Considering the results of our measurement, the best variant appears to be the regular variant which did not show any significant changes in the course of the 10-day storage at the grower. It was a variant moistened for 11.3 up to 11.6% before baling. From the point of view of cone shatter the best proves to be again the regular variant. There was the lowest percentage of shattered cones, namely 12.3%. The shatter value is here by 43% lower than with the dry variant, and by 26% lower than with the moist variant. The α-bitter acid content in the dry matter was similar for all the variants and in this case a direct dependency on the hop moisture was proved. According to the classification into the quality range for Saaz semi-early red-bine hop, all of the samples are considered superior quality. The highest average content was with the moist variant, namely 4.9%.

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