INFLUENCE OF STORAGE TECHNOLOGY ON THE QUALITY OF FRESH HOPS*

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To prevent interrupting the process of drying or picking due to the lack or surplus of hops coming out of the picking line, in most cases there is a storage container placed to function as a capacity device. The disadvantage is the hops layering inside the container, resulting in temperature and humidity rise due to increased cones respiration and insufficient airing, i.e. mustiness. Owing to respiration, cones lose important substances leading to a drop in their quality, or more precisely to a drop in the quality of the final product. The objective of this research was to monitor and verify different technologies in the storage of picked hops, comparing them with a control variant. In the course of our measurements we took samples of hops which were put to laboratory analyses determining toluene conductometric value, content of α -and β- bitter acids by spectrophotometric method, and the hop storage index (HSI).

hops; storage; alpha and beta acids; hop storage index

INTRODUCTION

Hop cones, humidity of which ranges between 76 and 82% (Vent et al., 1963), react to separation from the plant in a specific way, primarily by a higher intensity of respiration. The moisture content of the product, temperature influences, and even direct events that occur during storage may sometimes lead to spoilage and self-heating (Milss, 1989). A higher intensity of respiration results in releasing moisture and energy so that the temperature as well as the surface humidity of cones increases. According to Vent, Rybka (2013) and Vent (2012), the temperature in the container reaches up to 49°C and the relative humidity up to 100%. This process is described as cone mustiness (Rybáček et al., 1980) and it is intensified by cone damage which is high at mechanical harvest. When the respiration intensity increases, cones lose important brewery substances and the quality of the final product is reduced. Unlike inert materials such as sand, agricultural products in storage change physically and chemically and need to be managed carefully (Sinha, 1973). Furthermore, consumption of oxygen rises, thus it has to be gained intramolecularly by decomposing the organic substances (Vent et al., 1963). Garetz (1994) stated that oxidation processes during storage cause beta acids to become bitter, although they are not bitter in standard conditions compared to α-acids, which get bitter when brewed in the process of isomerization.

MATERIAL AND METHODS

The measurement was carried out in the picking line run by CHMEL – Vent s.r.o. company in Oploty. For the purpose of the measurement three storage containers were assembled (Fig. 1). Their volume was 1m^3 and their bottom was made of 1 mm thick perforated sheet steel with holes of 8 mm in diameter to allow access of air. The first container served for control. Another container was assembled with the air driven through the perforated bottom. MASTER CD 5000 radial ventilator (MASTER, Yardley, Pennsylvania, USA) (power 2300 m^3.h^{-1}, rotational frequency 1200 rpm) served as the source of air flow.

The third variant was represented by a closed container, for which the air outlet was secured by a 5 m long stack with 0.2 m in diameter. Such a concept supposed passive air circulation based on the difference between air intake and air outlet pressures and the air temperature inside the container. The measurement as such included continual (every 3 min) recording of temperature and relative moisture both inside the container and in its surroundings in all the three variants simultaneously. Three repetitions were carried out

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Fig. 1. Storage container with active ventilation (on the left), with passive ventilation (on the right) and check container (in the middle)

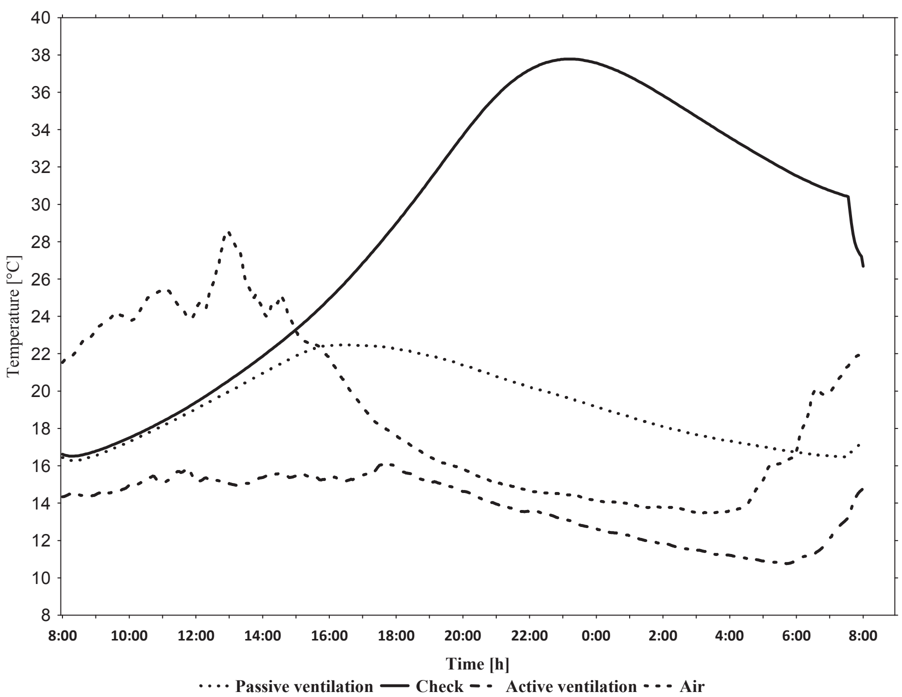
in the course of the whole measurement, each lasting 24 h. After each repetition the containers were emptied and filled with fresh hops. At the same time, both at the beginning and at the end of each measurement we took a mixed sample of hops to determine the toluene conductometric value according to ČSN 462520-15 as well as the content of α- and β-bitter acids by spectrophotometric method and the hop storage index (HSI) following the method ASBC Hops-6 both in the original sample and in the dry matter. The laboratory analyses were provided by Chmelařství, družstvo Žatec laboratory.

RESULTS

The first task of the measurement was to determine temperature and moisture changes of the picked hops inside the containers. For all the three repetitions the trend of the temperature and moisture was very similar. The regular air temperature outside the building ranged 13–29°C during the three days of measuring. These values did not correspond directly to the air temperature inside the steel warehouse, where the containers with picked hops were placed. Fig. 2 depicting development of the average temperatures shows clearly these temperature fluctuations, mostly from 11.00 to 14.00 h. The main reasons lie in the position of the sun in the course of the day towards the glass part of the warehouse and the air circulation.

The temperature inside the control container, i.e. without the air circulation, confirmed the expected development. A slight decline in temperature after the container had been filled at the beginning of the measurement was caused by a lower temperature of hop cones than was the air temperature in early morning hours. The temperature went up as early as after 20 min of measuring. The average temperature kept on rising continually (Fig. 2), achieving its maximum (37.78°C) at 23.03 h, i.e. 15 h after the container filling. This value could still be recorded for another 18 min and after that it started to fall slowly (the highest temperature – 41.33°C – was recorded during the first repetition), thus confirming Vent's (2013) results. The average air temperature at that time ranged 14.41–14.48°C, which is by 23.3°C less. The temperature kept on falling until the end of the measurement, when 30.77°C was recorded, which represents a decrease by 10.1°C during 9 h. A very substantial temperature drop (by approximately 4°C) in the last 20 min was caused by an error in the measurement and was not taken into account.

Fig. 2. Development of the average temperature of individual variants and the air temperature



The development of the temperature inside the container with passive air circulation was at the beginning the same as inside the container with no ventilation. However, after 4 h of measuring it was evident that warming slowed down compared to the control and reached its maximum of 22.48°C as early as 8.15 h after filling. At that time the control container temperature was by 2.91°C higher. As soon as after three minutes, i.e. 8.18 h after filling, the temperature began to fall, keeping this trend until the end of the measurement and achieving its final value of 16.99°C. Thus the temperature dropped down by 5.49°C during 15 h which represents a drop by 0.3°C per h. A substantial temperature drop in the last 20 min was also caused by an error in the measurement and was not taken into account.

The temperature in the container with active air circulation did not show any substantial fluctuation. In the course of the first 10 h of measuring it ranged 14.33–16.06°C which at the same time was the maximum value achieved 9.48 h after filling. During the next 12 h the temperature dropped to the lowest value of the whole measurement (10.76°C attained 21.39 h after filling). In the last two hours of the measurement the temperature inside the container rose by 4.04°C. Fig. 2 illustrates that the temperature inside the container with active air circulation shows with a certain delay a similar trend as the temperature of the surrounding air. This fact can be explained by placing a fan closely to the container, when the air driven into the container had the same temperature as that of the surrounding air.

Along with temperature, also relative moisture inside the containers was measured. At each measurement in all variants the relative moisture value rose immediately after the measurement had started to the maximum value of 100%, staying unchanged until the end of the measurement. Thus there was no statistically provable difference on the significance level $\alpha = 0.05$ discovered among the moisture values.

Fig. 3 illustrates that it was the other way round with the measured values of temperature. There were proved significant statistical differences ($\alpha = 0.05$) between the individual variants. Supposedly, the highest average temperature was achieved by the control variant with no air circulation, namely 28.74°C. The variant with passive air circulation attained by 9.46°C (33%) lower temperature, namely 19.28°C. The lowest average temperature was measured with the variant with active air circulation – 13.78°C, which is by 14.96°C (52%) less than with the control.

Another main task of this paper was to verify the influence of technology of picked hops storage on its quality. Four factors were compared, namely the conductometric value, the content of α- and β- bitter acids by spectrophotometric method, and the hop storage index value (HSI). The measurement results are shown in Fig. 4, which depicts the average values with confidence intervals 0.95 ($\alpha = 0.05$). The control sample taken before the measurement is termed as 'Start'. The graphic depiction clearly shows that no significant difference between the individual storage variants was proved, thus we may state that regarding the content of important substances, storage technology had no influence on hops quality. However, a closer look shows that the order of individual variants is always the same for all criteria. The best values were achieved by the variant with passive ventilation, followed by the variant with active ventilation, and

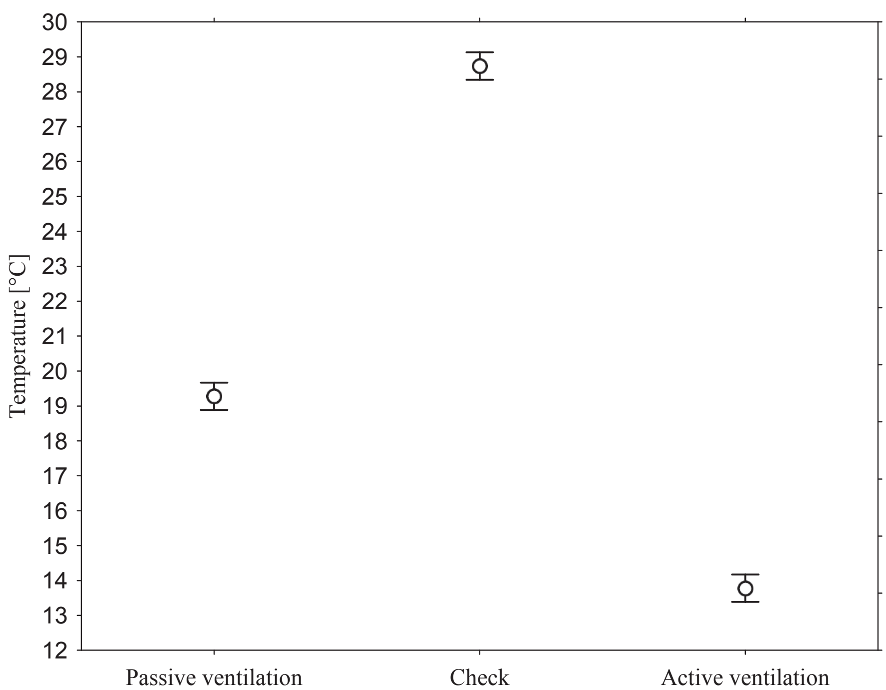


Fig. 3. Graphic depiction of compared temperature averages for individual measurement variants with confidence intervals of 0.95

Table 1. Compared qualitative parameters of hops

	Conductometric value (%)	α-Bitter acids content (%)	β-Bitter acids content (%)	Aging index
Passive ventilation	3.54	3.79	3.83	0.27
Active ventilation	3.35	3.59	3.67	0.28
Control	3.26	3.53	3.62	0.29
Start	3.33	3.50	3.57	0.27

Start = control sample taken before the measurement

lastly the control variant (Table 1). The hop storage index value of the variant with passive ventilation is identical with the starting sample value, that is 0.27.

Last but not least, we evaluated the visual aspect of hop cones (Fig. 5), which constitutes an integral part of hops quality assessment. The smallest impact on the cone appearance was recorded after 24 h of storing with the variant with active ventilation. The cones maintained their original green colour, though due to a strong drying their gloss got lost. At the variant with passive ventilation not only a loss of gloss occurred but also a change in shade, namely to dark green, in some cases even brownish. The cones kept their characteristic hop aroma. In the case of the control variant the cone appearance was the worst. The cones colour was dark green, brown, even greyish with no gloss. Moreover, hop aroma got totally lost, being changed into odour.

DISCUSSION

The average temperature of the control variant was rising continually achieving its maximum of 37.78°C 15 h after the container filling (the highest temperature, 41.33°C, was recorded during the first repetition). These values confirm results of V e n t (2013). In his work, the maximum temperature measured was 49°C and average temperature of all repetitions was 44°C. V e n t (2012) stated that the temperature inside the container without air ventilation depends significantly on the storage time.

The temperature inside the container with active air circulation shows with a certain delay a similar trend as the temperature of the surrounding air. This fact can be explained by placing a fan closely to the container, when the air driven into the container had the same temperature as that of the surrounding air. By contrast, temperature in the container without ventilation does not depend on the temperature of the surrounding air which corresponds with the results of V e n t (2012).

At each measurement of all variants the relative moisture value rose to the maximum value of 100% immediately after the measurement had started, staying unchanged until the end of the measurement. Thus no statistically provable difference on the significance level $\alpha = 0.05$ was ascertained among the moisture values which is in accordance with the results of V e n t , R y b k a (2013).

The visual aspect of hop cones, which is an integral part of hops quality, was the worst by the control variant

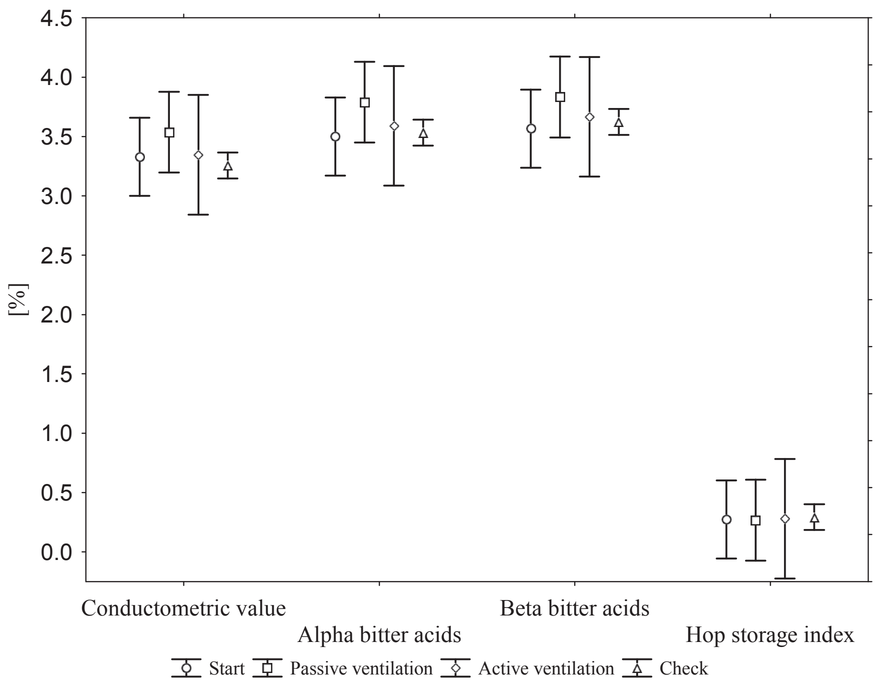


Fig. 4. Graphic depiction of compared averages of monitored substances content for individual variants with confidence interval of 0.95

Fig. 5. Cone samples taken after 24-h of storage with active ventilation

without air ventilation. The cones were dark, brown, even greyish in colour with no gloss and hop aroma got totally lost. Vent et al. (1963) and Rybáček et al. (1980) say that this process is caused by cone mustiness.

CONCLUSION

Given the measured results we may state that of all the tested technologies for hops storage the best results, in all criteria, brought the variant with passive air circulation. The hop cone temperature inside this container did not exceed the value of 22.48°C and the average temperature in the course of the 24-h storage was 19.28°C (the average air temperature during the measurement was 18.81°C). Laboratory tests proved that from a statistical point of view there is no substantial difference between the verified variants. Even despite these minimal differences, the variant with passive air circulation achieved the best results. The highest conductometric value was 3.54%, the highest contents of α- and β-bitter acids determined by spectrophotometry were 3.79 and 3.83% respectively, and the lowest value of storage index including the original sample was 0.27. The control variant with no air circulation achieved the maximum average temperature of 37.78°C (maximum temperature of 41.33°C), thus confirming our measured results from 2011.

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