Agronomy Research **12**(1), 197–204, 2014

Storage technologies of picked hops during harvest

L. Vent* and A. Rybka

Czech University of Life Sciences Prague, Faculty of Engineering, Kamýcká 129, Praha 6 – Suchdol, Postcode 16521, Czech Republic;
*Correspondence: lvent@tf.czu.cz

Abstract. To prevent interrupting the process of drying or picking due to lack or surplus of hops coming out of picking line, in most cases there is placed a storage container as a capacity equipment. In a container, however, hops are layered, thus temperature and relative humidity increase owing to an increased intensity of hop cones breathing and an insufficient airing, i.e. they mowburn. In the process of breathing a cone loses important substances which results in its worse quality and correspondingly in worse quality of the final product. This work builds on research from 2011. There were monitored changes of physical characteristic of picked hops during storage in container and compared with control variant. This aim of this work is to compare different storage technologies of picked hop in the container. There was a three variants. The control variant was a common stack with a perforated bottom. The second variant was a stack with active ventilation by electric fan. The third variant was a covered stack with passive air circulation. Al stacks had one cubic volume. Data of temperature and relative humidity were continually recorded by MINIKIN TH measuring equipment by EMS Brno company. Another analogue sensors to measure relative humidity and temperature were independently installed for check. The monitoring was each time carried out for 24 hours. Next there were collected a samples for laboratory analysis for product quality. During storage both the temperature and relative humidity of the control variant increased substantially, with temperature values reaching up to 41°C and relative humidity values 100%. The progress of temperatures was almost identical with all the measurements, that is why we present only the average values. The relative humidity of active ventilated variant increased up to 100% but temperature only up to 15°C. The values of humidity of passive ventilated variant were the same (100%) but values of temperature were lower instead of control variant. The highest measured temperature was about 22°C. The conclusion we may draw here says that the best way is passive air circulation. The lowest temperature was measured at variant with fan and it is most important for storage quality of hops but this variant is more expensive due to electric power.

Key words: *hops, storage, alpha and beta acids, hop storage index.*

INTRODUCTION

Nowadays, the most important parameter for trading with hops is content of brewing important substances (alpha and beta bitter acids). Their content is monitored from hop grower to the final processor. The biggest influence on the content of these substances have a climatic condition during the grow season, but we can not control them and the second is postharvest processing, including storaging. Any reduction of the content of these substances have a economic impact for the hop grower. Hop cones, relative humidity of which ranges between 76 and 82% according to Vent et al. (1963), react to separation from the plant in a specific way, primarily by a higher intensity of respiration. The product's relative humidity and temperature will influence and even direct events that occur during storage and may sometimes lead to spoilage and self-heating (Milss, 1989). A higher intensity of respiration results in releasing of relative humidity and energy so that the temperature as well as the surface relative humidity of cones increases. According to Vent (2013) 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 an important brewery substance which makes the final product less quality. 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) states 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 Ltd. company in Oploty. For the purpose of the measurement three storage containers had been assembled (Fig. 1). Their volume was 1 m^3 and their bottom was made of perforated sheet steel 1 mm thick, with holes of 8 mm in diameter to allow access of air. The first container served as a check sample. Another container was assembled with the air driven through the perforated bottom. As the source of air flow served MASTER CD 5000 radial ventilator, with power of 2,300 $m^3 h^{-1}$ at a rotational frequency of 1,200 min^{-1}.

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

The third variant was represented by a closed container, for which the air outlet was secured by a stack of 0.2 m in diameter and a length of 5 m. 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 humidity both inside the container and of the surroundings as for all the three variants at the same time. The relative humidity and temperature were measured by special sensors MINIKIN TH with dataloger made by EMS Brno company (Fig. 2). Three repetitions were carried out 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 alpha and beta bitter acids by spectrophometric method and the aging 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.

Figure 2. Temperature and relative humidity sensors Minikin Th by EMS Brno company.

RESULTS AND DISCCUSION

The first task of the measurement was to determine temperature and relative humidity changes of the picked hops inside the containers. For all the three repetitions the trend of the temperature and relative humidity was very similar. The regular air temperature outside the building ranged from 13°C to 29°C during the three days of measuring. These values do not correspond directly to the air temperature inside the steel warehouse, where the containers with picked hops had been placed. The figure depicting development of the average temperatures (Fig. 3) shows clearly these temperature fluctuations, mostly from 11 a.m. to 2 p.m. 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 check 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 increase began as soon as after 20 min of measuring. The average temperature kept on rising continually (Fig. 3), achieving its maximum of 37.8°C at 23:03 which means 15 hours from the container filling. This value could still be recorded for another 18 min and after that started falling slowly (the highest temperature, 41.3°C was recorded during the first repetition), thus confirming Vent's results (2013). The average air temperature at this time ranged from 14.3 up to 14.5°C which is 23.3°C less. The temperature kept on falling until the measurement was finished, when we recorded a temperature of 30.8°C, that is a decrease by 10.1°C during 9 h. A very substantial temperature drop by app. 4°C in the last 20 min was caused by an error in the measurement and is not taken into account.

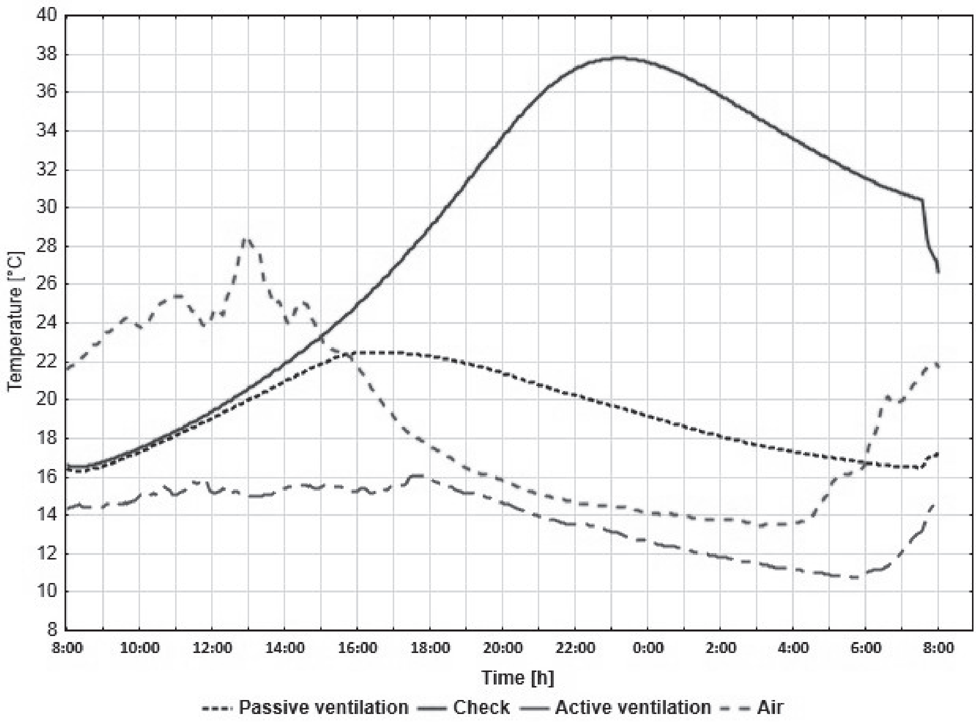

Figure 3. Development of the average temperature of individual variants and the air temperature.

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 four hours of measuring it was evident that warming slowed down compared to the check and reached its maximum of 22.5°C as soon as 8:15 h after filling. At that time the check container temperature was by 2.91°C higher. Already after three minutes, i.e. 8:18 h after filling, the temperature began falling, keeping this trend until the end of the measurement and achieving its final value of 17.0°C. Thus the temperature dropped by 5.5°C during 15 hours which represents a drop by 0.3°C h^{-1}. A substantial temperature drop in the last 20 min was also caused by an error in the measurement and is 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 from 14.3°C up to 16.1°C which at the same time was the maximum value achieved at the time of 9:48 hours from filling. During another 12 h the temperature dropped to the lowest value of the whole measurement, that is 10.8°C at the time of 21:39 hours from filling. In the last two hours of the measurement the temperature inside the container rose by 4.0°C. Fig. 3 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 the temperature of the surrounding air. In the contrast, temperature in the container without ventilation does not depend on the temperature of the surrounding air which confirm with results of Vent (2012).

Together with temperature we also measured relative humidity inside the containers. At each measurement of all variants the relative humidity 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 between the relative humidity values which confirm results of Vent & Rybka (2013).

Fig. 4 illustrates that it was the other way round with the measured values of temperature. There were proved significant statistical differences ($\alpha = 0.05$) between individual variants. The highest average temperature was achieved, as it was supposed, by the check variant with no air circulation, namely 28.7°C. The variant with passive air circulation had by 9.46°C or by 33% lower temperature, namely 19.3°C. The lowest average temperature was measured with the variant with active air circulation, 13.8°C, which is by 15.0°C or by 52% lower than with the check variant. In 2011 there was measured by Vent (2012) highest temperature 49°C in the container and they stated that the temperature inside the container depends significantly on the storage time.

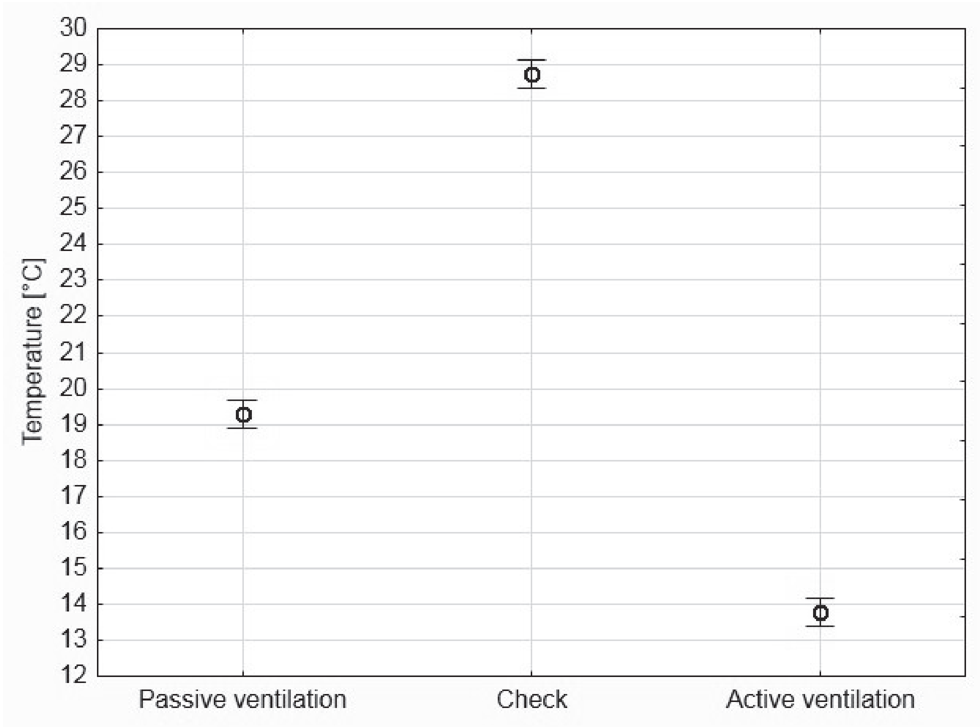

Figure 4. Graphic depiction of compared temperature averages for individual measurement variants with confidence intervals of 0.95.

Another main task of this paper was to verify the influence of technology of picked hops storage on their quality. Four factors were compared, namely the conductometric value, the content of α and β bitter acids by spectrophotometric method, and the aging index value (HSI). The measurement results are shown in Fig. 5, which depicts the average values with confidence intervals 0.95 ($\alpha = 0.05$). The check sample taken before the measurement is termed in the Fig. 5 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 lastly the check variant (Table 1). The aging index value of the variant with passive ventilation is identical with the starting sample value, that is 0.27.

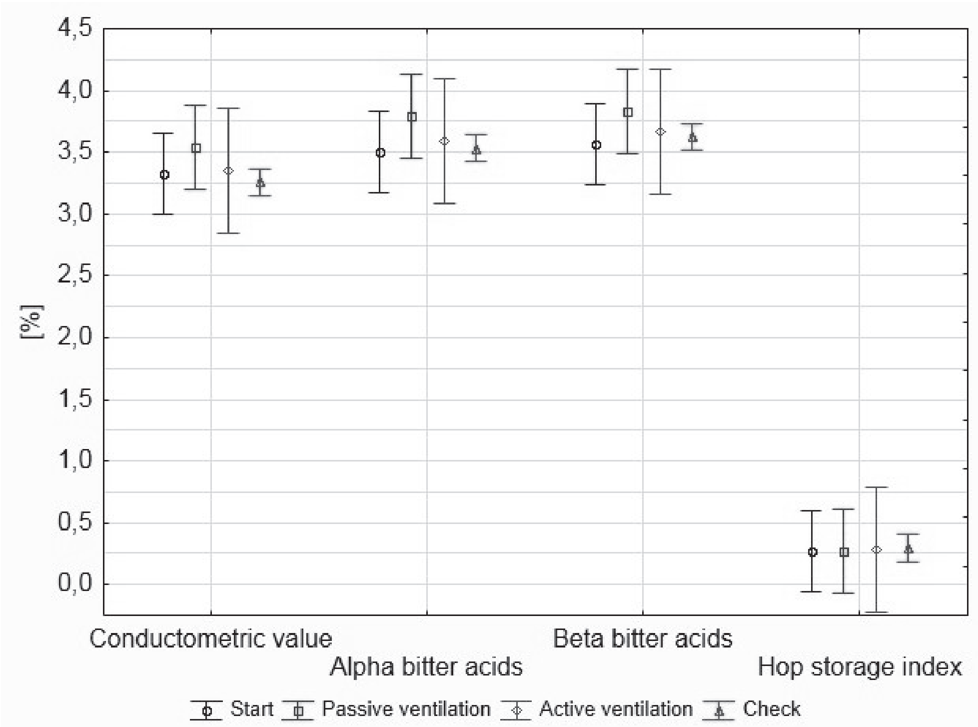

Figure 5. Graphic depiction of compared averages of monitored substances content for individual variants with confidence intervals of 0.95.

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
Check	3.26	3.53	3.62	0.29
Start	3.33	3.50	3.57	0.27

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 22.5°C and the average temperature in the course of 24 hours of storage was 19.3°C (the average air temperature during the measurement was 18.8°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 of 3.54%, the highest content of α-bitter (3.79%) and β-bitter (3.83%) acids determined by spectrophometric method, and together with the original sample the lowest value of storage index 0.27. The check variant with no air circulation achieved the maximum average temperature of 37.8°C (maximum temperature of 41.3°C), thus confirming our measured results from 2011.

ACKNOWLEDGMENTS. This article was written with the support of IGA TF CULS in Prague project number 31160/1312/3115 and NAZV MA CR project number QI101B071.

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