Physical characteristics of picked hops during storage

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Abstract. To prevent interrupting the process of drying or picking due to lack or surplus of hops coming out of the picking line, hops, in most cases are placed in a storage container.. In a container, however, hops are layered, thus temperature and 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 deteriorated quality and correspondingly in the poor quality of the final product. Our task was to observe the course of hop temperature and humidity in a storage container and to compare it with the check variant, which was loosely spread hops outside the container. Data of temperature and humidity were continually recorded by COMET D 3631 measuring equipment with N1ATG8/C measuring probe by the Comet System company. Other analogue sensors to measure humidity and temperature were independently installed for checking. The monitoring was each time carried out for 24 hours. During storage both the temperature and humidity of the hops in the container increased substantially, with temperature values reaching up to 49 °C and humidity values 100%. The progress of temperatures was almost identical with all the measurements, that is why we present only the average values. The highest temperature inside the container was in the range of 39 °C to 49 °C with individual measurements. The temperatures of the check samples were identical with the air temperature in the daytime with all the repeats. The maximum temperature of the check samples ranged from 21 °C to 27 °C with each measurement. In the same way as with the temperature, during the individual measurements the humidity showed similar progress and the measurements did not differ from each other in any substantial way. The humidity level in the container rose up to the maximum value of 100% already two hours after the measurement had started and stayed like this until the end. The humidity of the hop check samples was 2.24% higher than the air humidity, which might be explained by water vapour emission due to an increased intensity of hop cones breathing. The conclusion we may draw here says that with an increasing volume and, probably above all, height of the stored hops layer, the influence of the surroundings on the conditions inside the container will decline.

Key words: hops, storage container, quality, storage, temperature, humidity.

INTRODUCTION

For various technological and organisational reasons picked hops are stored in such a container even for a longer time. Hop cones, the humidity of which oscillates between 76 and 82% according to Vent et al. (1963), react on separation from their plants in a specific way, mostly with an increased intensity of breathing. An increased intensity of breathing results in released humidity and energy, thus temperature is relatively quickly increased and the surface cone humidity rises, which is denoted as cone mowburn (Rybáček et al., 1980). At an increased breathing intensity cones lose important brewery substances, thus the final product quality declines. An increased breathing intensity of cones provokes an increased consumption of oxygen which, if lacking, is gained intramolecularly through decomposition of organic substances (Vent et al., 1963). Hops oxidation products alter the taste of beer substantially and therefore they lower the hop brewing value (Hops and hop products, 1997). The chemical composition of hops depends on the hop variety, district, growing conditions, time of harvest, storing and drying (Narziss, 1985). Storage of dry hops and a belated sale makes the storage of humid hops an important parameter determining the hop brewing quality (Virant & Pavlovic, 2001). Furthermore, Vent et al. (1963) states that the maximum storage time of mechanically picked hops is two hours.

MATERIAL AND METHODS

The measurement was carried out on a hop picking line owned by Chmel – Vent Ltd. company in Oploty. As it was not possible, for technical reasons, to measure qualities of hops on a long-term basis directly in the picking line stationary container, the measurement was simulated next to the actual container. The hop cones coming from the picking line were poured into a laminate vessel of a volume of 500 l. Next, a sensor measuring humidity and temperature was installed into the vessel. Data were continually recorded by COMET D 3631 measuring equipment with N1ATG8/C measuring probe by the Comet System company. Other analogue sensors to measure humidity and temperature were independently installed for checking. There were hop cones loosely spread on the ground serving as a check. Here the temperature and humidity were measured with data continually recorded by MINIKIN TH-datalloger device. The same device measured the temperature and humidity of the surroundings. The collected data were continuously backed up onto an external hard drive and further assessed in detail. Within the measurement there were three repeats with the variety of Zatec semi-early red-bine hop Osvald's clone 72. The monitoring was each time carried out for 24 hours, and the samples were taken in four-hour intervals. The measuring itself was each time begun at 8 o'clock in the morning. The results were then processed in program Statistica ver.9.0.

RESULTS AND DISCUSSION

The progress of temperatures was almost identical with all the measurements, that is why we present only the average values (Fig. 1). The highest temperature inside the container was in the range of 39 ºC to 49 ºC with individual measurements. The temperature inside the container began increasing in a more substantial way already after 4 hours. However, a more noticeable increase in temperature was monitored only after 16-hour storage by up to 2.26 ºC h^{-1}. With the second and third measurement the temperature stopped rising in any considerable way after 22-hour storage and in the last hour of the measurement it barely changed. This lowering of the temperature increase might have been caused by lower temperatures which at those morning hours oscillated around 6.99 °C with the first repeat and 8.69 °C with the second repeat. On the contrary, with the third measurement the temperature was still rising substantially even after 22 hours of measuring. The temperature increased by 2.59 °C h^{-1} which was also the maximum value of the whole measuring. During this second measurement the morning air temperature oscillated around 10.91 °C. The maximum temperature of the check samples ranged from 21 °C to 27 °C with each measurement. The temperatures of the check samples were identical with the air temperature in the daytime with all the repeats. In the course of 24 hours of the measuring the biggest average temperature deviation was +0.34 °C at 8 am and -1.29 °C at 2 pm. On average the check sample temperature was by 0.46 °C lower than the air temperature (Fig. 1). The average air temperature ranged from 9.01 °C to 24.38 °C.

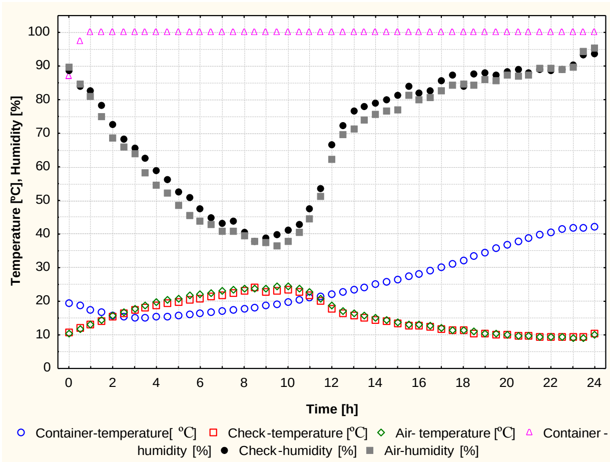

Figure 1. Progress of average values of temperature and humidity.

In the same way as with the temperature, during the individual measurements the humidity showed similar progress and the measurements did not differ from each other in any substantial way. The humidity level in the container rose up to the maximum value of 100% already two hours after the measurement had started and stayed like this until the end. The measured humidity values of the check samples copied the values of the air humidity, but they were usually a little higher. On average, the humidity of the hop check samples was 2.24% higher than the air humidity, which might be explained by water vapour emission due to an increased intensity of hop cones breathing (Fig. 1).

The lowest average air humidity was measured between the 9^{th} and 10^{th} hour of measuring. The lowest humidity of the hop check sample was measured an hour earlier, i.e. between the 8^{th} and 9^{th} hour of measuring. The statistical assessment of the individual temperatures of all measurements is to be found in Fig. 2. The air temperature inside the container was with each measurement provably statistically higher than the temperature of both the hop check sample and the air. However, differences between the individual measurements inside the container were proved, when the highest average temperature of 30.39 °C was measured with the first, 25.23 °C with the second, and 20.97 °C with the third and last repeat. With these values any correlation with the daily temperatures cannot be observed. A dependency though is visible between the temperature of the check sample and of the air (Fig. 2). The lowest air temperature correlates with the lowest check sample temperature and vice versa. For this reason, with the check samples and the air, there were discovered statistical differences in the averages of the first and the last repeats. The check sample temperature corresponded to the air temperature all the time with minimal deviations and there was not observed any statistically significant difference between them.

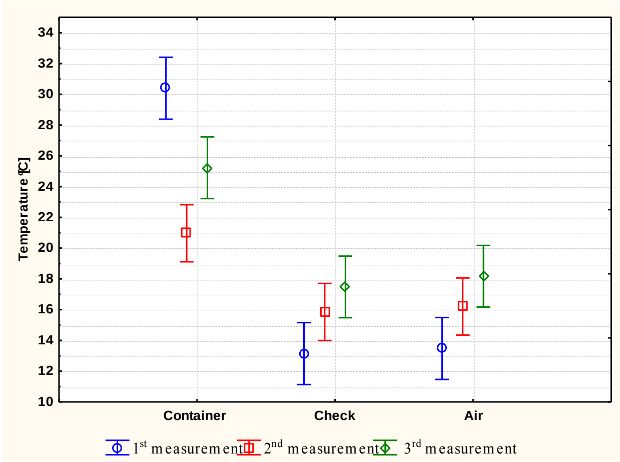

Figure 2. Graphic depiction of compared temperature averages.

In the case of the humidity, individual measurements were much more even contrary to the temperature. With individual variants (container, check, air) there were not observed any substantial differences between the repeats (Fig. 3).

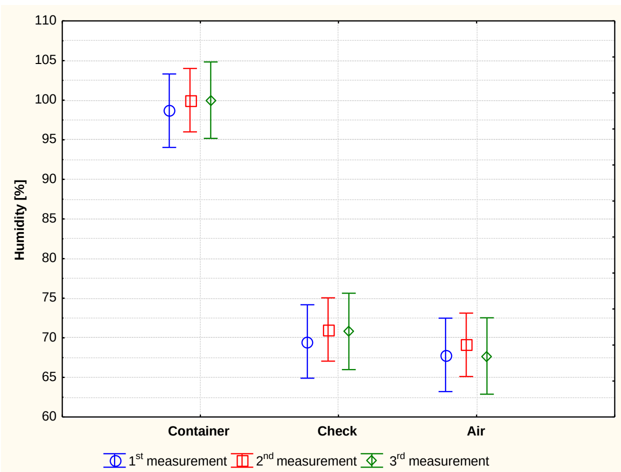

Figure 3. Graphic depiction of compared humidity averages.

Between the individual repeats there were no significant differences in the measured humidity values. The check samples humidity was on average 2.34% higher than the surrounding air. Such a rise may be explained by an increased intensity of breathing which causes emission of water vapour as a consequence of an increased release of metabolic energy. From the point of view of statistics, this difference was not found significant, as seen in Fig. 3. The humidity inside the container was in each case provably higher than with the loosely spread hops, which is proved by the calculated significance value p, that is noticeably lower than the chosen significance level $\alpha = 0.05$.

Next we observed the influence of storage time and surrounding temperature on the temperature inside the container. The correlative characteristics of these parameters are shown in Fig. 4 and 5.

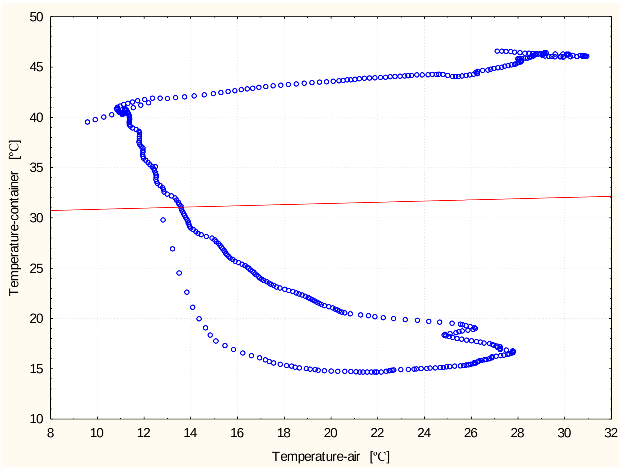

Figure 4. Graphic depiction of correlation field of the temperature inside the container and the air temperature.

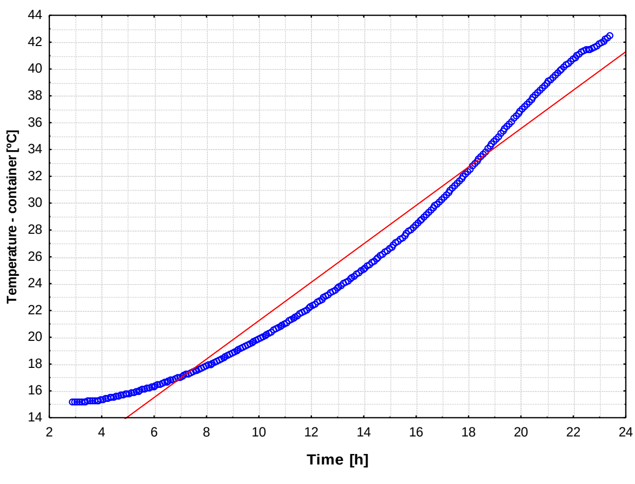

Figure 5. Graphic depiction of correlation field of the temperature inside the container and the storage time.

It is apparent from Fig. 4 that there is no dependence of the temperature inside the container on the surrounding air temperature. From the results analysis in Fig. 1, which depicts progress of the temperature inside the container and the air temperature, we can observe a noticeably negative correlation. Within the 24 hour interval of measurement this fact was influenced by the choice of the measurement beginning, but according to the calculated correlation coefficient $r = 0.031$ and the significance level $p = 12.036$ there is a clearly provable very weak and statistically insignificant correlation.

On the contrary, the graphic depiction of correlation between the temperature inside the container and the storage time (Fig. 5) shows an apparent very close direct dependency. Given the calculated correlation coefficient $r = 0.862$ and its significance level $p = 0.000$, we can state that the temperature inside the container depends significantly on the storage time. This model explains the described correlation in 74%. Another noticeable dependency is apparent with the temperature of the check and the surrounding air. This dependency is through calculated regression function explained in 99.7% ($r = 0.998$, $p = 0.000$). There is the same correlation between the humidity of the check sample and the surrounding air. In that case the correlation coefficient is $r = 0.997$ and the calculated significance level is $p = 0.000$. The dependency is described through regression function in more than 99%.

CONCLUSION

After assessing the results it is possible to draw some provable conclusions. The air temperature and humidity inside the container with picked hops is considerably higher than the temperature and humidity of loosely spread hops, which is caused by an increased intensity of hop cones breathing resulting in emission of H_2O and CO_2. An increased intensity of cones breathing is apparent also with the air humidity values measured with the loosely spread hops, which within the whole measuring was 2.34% higher than the humidity of the surrounding air, owing to emission of mostly H_2O by hop cones as a protection against stress caused by separation from the plant and overheating. The air temperature and humidity of the check sample do not keep increasing owing to the air flow and the possibility of H_2O and CO_2 evaporation into their surroundings, as opposed to the conditions inside the container where heat accumulates. On the contrary, with loosely spread hops there is a very close direct dependency on the surroundings for both temperature and humidity. The conclusion we may draw here says that with an increasing volume and, probably above all, height of the stored hops layer, the influence of the surroundings on the conditions inside the container will decline.

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