QUALITY OF HOPS AT DIFFERENT DRYING TEMPERATURES IN CHAMBER DRYER

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Abstract
The drying temperature during the measurement reached 60°C (conventional method) and 40°C (low temperature method). During this measurement, we monitored the output qualitative parameters of the Saaz hop variety in the form of essential oils. During the measurement, an analytical method to determine humulinones, which are one of the components of essential oils in hops and hop products, was newly developed. The measurement confirmed that when drying hops in chamber dryer at a temperature of the drying medium being 40°C, the drying period is extended by approx. 46%. The graphs clearly show the difference in the amount of essential oils contained in the hops dried at 60°C and 40°C. Based on the analytical results it can be concluded that by drying a large majority of the essential oil components is reduced to the approximately same extent, therefore the relative representation in the mixture does not change significantly.

Key words: *hop; drying; belt dryer; moisture.*

INTRODUCTION
This paper builds on the previous articles covering the comparison of drying process in an experimental chamber dryer at the conventional drying method and low-temperature drying.
Currently, there are 205 fully functional hop dryers available in the Czech Republic. Out of this number, 79 pcs are chamber dryers. Based on the international experience, their drying principle has the potential for further use (*Doe & Menary, 1979*).
Hops are composed of numerous substances. The hop quality both in their fresh and dried state can be assessed in several ways – for instance by means of the moisture content, HIS (Hop Storage Index), alpha and beta bitter acids, prenylflavonoids, humulinones, or hop essential oils. Hop essential oils are the most important group of substances contained in hops responsible for the hop aroma. Depending on the variety, hops contain 0.5 to 3.0% of essential oils which, together with resins and other substances, accumulate in lupulin glands during the process of cone formation and maturation. Hop essential oils are a mixture of several hundreds of natural volatile substances of different chemical composition. Some of these are represented in the order of tens of percent (myrcene, humulene), some other occur in small or even trace amounts. However, all of these together are involved in the formation of the characteristic hop aroma. The constituents of hop essential oils can be divided into three groups. The largest share accounts for the hydrocarbon fraction which forms 70-80% of the total essential oil weight, 20-30% account for the oxygen fraction. The remaining share accounts for the oxygen and sulphur substances (*Krofta, et al., 2017; Münsterer, 2006*).
During the process of drying the moisture content in hop cones reduces from initial approx. 75 up to 85% to approx. 10-12%. Inside the dryer hops are exposed to a drying temperature of 55-60°C for 6-8 hours (conventional method) (*Podsedník, 2001; Kořen, et al., 2008; Rybka, et al., 2018*). With this drying method the temperatures are too high, particularly in the final stage of drying. This is bad for some heat-labile substances and it leads to their losses. In particular, these are hop essential oils contained in quantities between 0.5 and 3.5%, depending on the hop variety (*Hofmann, et al., 2013; Kumhála, et al., 2013*).
Another technology is the method of low-temperature drying (with the drying medium temperature being approximately 40°C) (*Heřmánek, et al., 2017*). This drying method enables to optimize the drying parameters (the drying medium temperature and the hop layer height) mainly for the special hop varieties in which it is desirable to preserve their original composition to the largest degree possible (*Rybáček, et al., 1980; Srivastava, et al., 2006; Kumhála, et al., 2016*). The heat-labile substances will be able to

be used in the manufacture of medicines and food supplements (*Aboltins & Palabinskis, 2016; Aboltins & Palabinskis, 2017; Jokiniemi, et al., 2015*).
Hop drying follows the hop picking line and constitutes an operation which is very important for maintaining the quality of hop product. Low-temperature technology of drying at a temperature of the drying medium of 40°C is suitable for preserving greater amounts of the essential oils contained in a dry hop product (*Vitázek & Jurik, 2015*).
Hop aroma depends on the amount of essential oils contained in hops. Depending of their variety, hops contain 0.5 to 3.0% of essential oils. Hop essential oils are a mixture of several natural volatile substances with various chemical composition. Some occur in the order of tens of percent (e.g. myrcene, humulene), others are present in small or trace quantities. Yet all of these together are the primary contributors of the distinctive hop aroma.
The object of this measurement was to find out whether hops can be dried in an operational chamber dryer at 40°C and at the same time to compare the qualitative characteristics in the form of selected essential oils when hops are dried using the conventional method and low-temperature method.

MATERIALS AND METHODS

By comparing the above-mentioned technologies, it is possible to support or refute the presumed hypothesis. We carried out the in-process measurements of both drying technologies at the researcher Rakochmel Ltd. in Kolešovice in its 4KSCH chamber dryer (Fig. 1). In recent years, during the measurement we put the emphasis on the assessment of the solution benefits in a small experimental chamber dryer (*Heřmánek, et al., 2017; Rybka, et al., 2018*). In 2017 and 2018 we carried out these measurements in an operating dryer in order to assess the impact of preserving the maximum amount of thermally labile substances contained in hop cones – the essential oils.

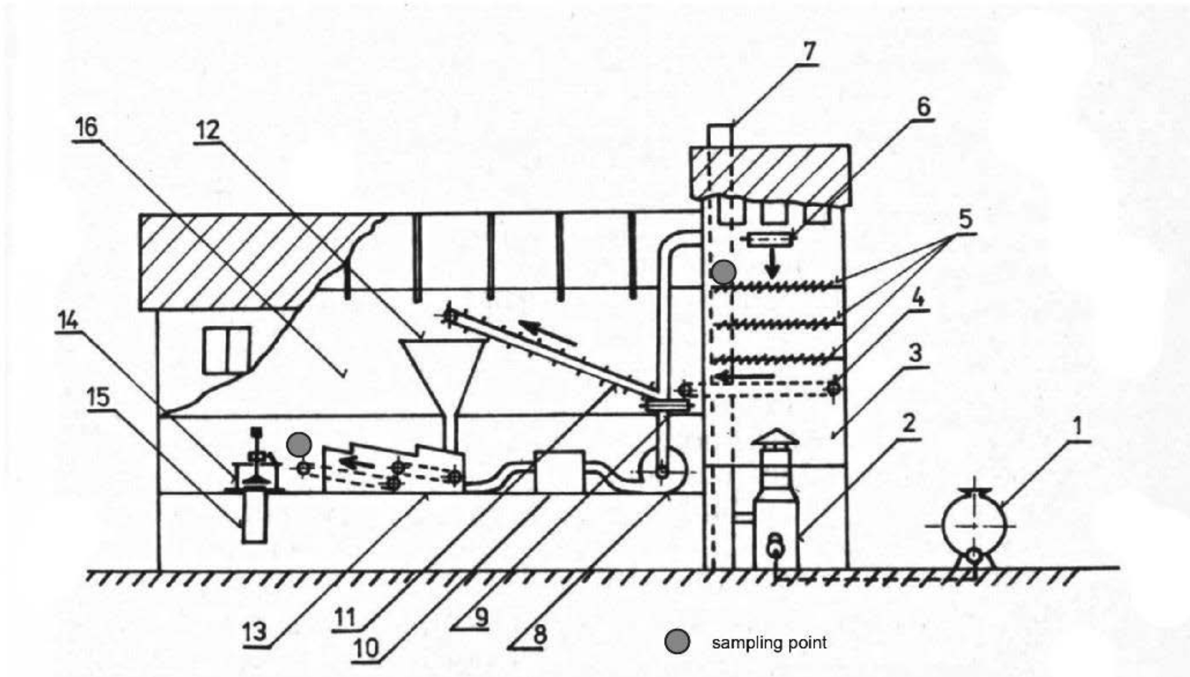

Fig. 1 Scheme of chamber dryer with sampling points for the purposes of laboratory analyses.
1 – fuel tank, 2 – hot-air aggregate, 3 – drying chamber, 4 – discharge conveyor (4th slat box), 5 – slat system, 6 – filling conveyor, 7 – stack, 8 – draught fan, 9 – unloading cross conveyor, 10 – air purifier, 11 – staging conveyor, 12 – hopper, 13 – conditioning, 14 – press, 15 – prism, 16 – storage space.

The hop variety used in this experiment was Saaz. This variety had been chosen because it forms approximately 80% of the hop production in the Czech Republic and that company grows it. The measurement was carried out in two chambers of the dryer, at a temperature of 60°C in its first chamber and at a temperature of 40°C in its third chamber.

During the measurements the drying air temperature and relative humidity were monitored in both chambers by means of data loggers and installed fixed sensors (*Heřmánek, et al., 2017*). Samples were taken from dried hops to determine a decline in the content of essential oils (*Krofta, et al., 2017*). The hop resins include these substances: beta-Pinene, limonene, linalool, geraniol, 2-Undecanone, caryophyllene, caryophyllene-epoxide, humulene epoxide II, myrcene, farnesene and humulene.
Graph courses were drawn up (Fig. 2) based on the drying cycle in both chambers. The essential oils content is illustrated in Fig. 3 and 4.

RESULTS AND DISCUSSION

The above-mentioned measurement proved that drying hops in a operating chamber dryer at a temperature of 40°C will extend the drying period by approx. 45% while maintaining the consumption of LFO per a ton of dry hops (during drying at a temperature of 40°C the layer of inserted hops had been lowered).
The courses of the values of the drying ambient temperature and relative humidity from both measurements are depicted in the graph of Fig. 2 which clearly shows a decline in moisture depending on the measurement time, and differences between drying at a temperature of 60°C and 40°C. The drops in temperature and rises in the drying air relative humidity are due to the technology of pouring the hops, when heaters and fans are stopped because this is the time when the operator fills the upper slat box with green hops.

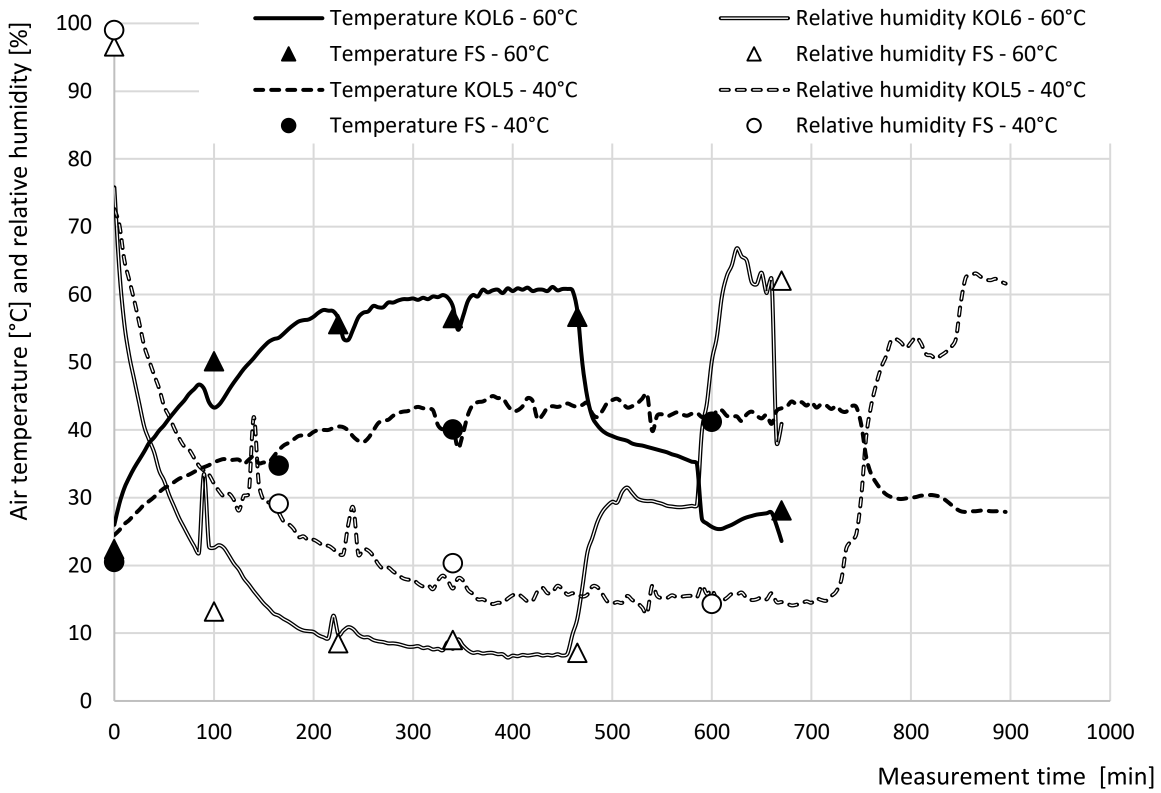

Fig. 2 Dependence of drying air temperature and relative humidity on measurement time (FS – fixed sensors, KOL5, KOL6 – data loggers).

Samples of hop cones were taken during the measurement at the completion of pour and upon leaving the conditioning. Sampling was carried out in both chambers in order to compare the effect of different drying air temperatures. The samples were assessed for the presence of preserved essential oils.
As the etalon was set the content of essential oils in green hops taken at the pour into the dryer. The measurement results are shown in Tab. 1.

Tab. 1 Results of laboratory analyses of hop cones to determine the content of essential oils in green cones, in cones dried at a temperature of 40°C and 60°C in 2018.

Variety	Drying conditions	Essential oils amount	Relative ratio [%]
Saaz	Green hops	0.52	100
	Drying at a temperature of 40°C	0.44	84.6
	Drying at a temperature of 60°C	0.41	78.8

The qualitative assessment of the essential oil composition is expressed as a relative percentage, as a ratio of integrated constituent area to the total integrated area of all essential oil constituents. In quantification the integration parameters are selected so that 50-70 parts of essential oil constituents are quantified. The largest share is formed by terpenic hydrocarbons myrcene, caryophyllene, humulene, farnesene and selinenes that constitute 50-70% of the total essential oils weight.
The graphs in Fig. 3 and 4 show the difference between the drop in the essential oils contained in hops dried at a temperature of 60°C and 40°C.

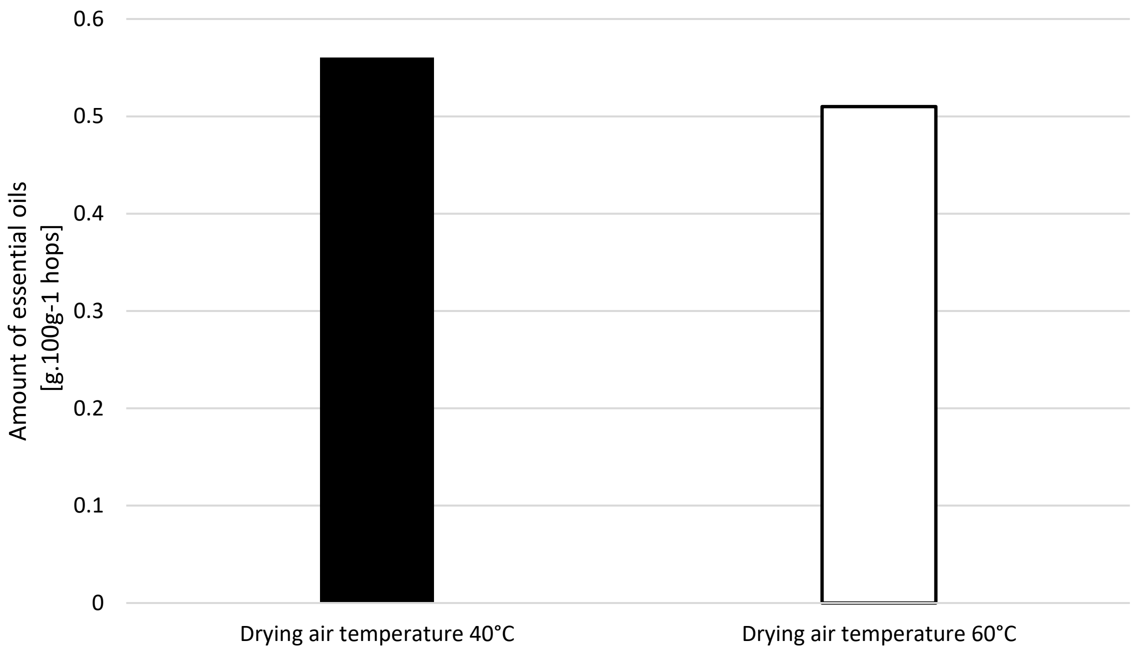

Fig. 3 Content of essential oils in hops dried at different drying air temperatures in a chamber dryer – Saaz 2017.

At a temperature of 60°C, the essential oil content was 0.51 g . 100 g^{-1}, while at a temperature of 40°C the essential oil content was higher, that is 0.56 g . 100 g^{-1}. Although this value is very low in absolute terms, the difference when the drying temperature changes is noticeable. This is shown even more clearly in the following graph (Fig 4).
The graph in Fig. 4 clearly shows the significant difference in the given substances when implementing various drying technologies. Except for geraniol, there is an increase in the amount of all the substances at a lower drying temperature. This is particularly noticeable with terpene hydrocarbon farnesene, but also with humulene and caryophyllene, which together with myrcene form 60 % of the total essential oil weight.

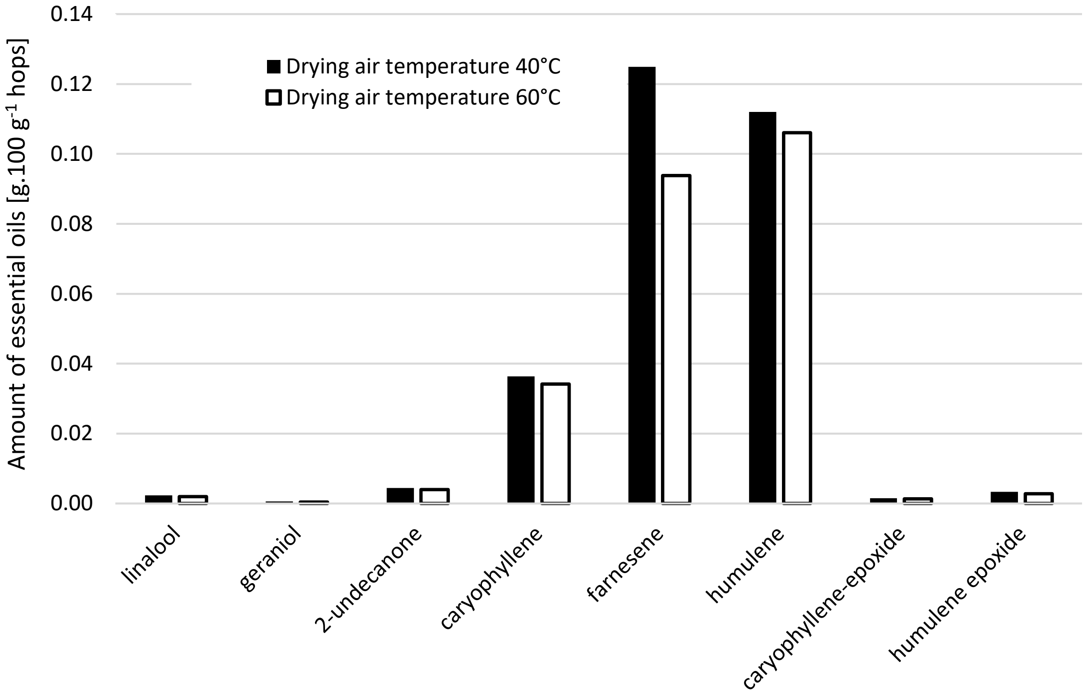

Fig. 4 Content of essential oils in hops dried at different drying air temperatures in a chamber dryer – Saaz 2017.

A study of different temperatures during hop drying has already been published. In the article *(Rybka, et al., 2018)*, the authors dealt with the drying of hops in an experimental chamber dryer. The results of the above measurement in the operating chamber hop dryer show that the lower temperature of drying is preferable from the point of view of maintaining essential oils in hops.

CONCLUSIONS

The object of this measurement was to find out whether hops can be dried in an operational chamber dryer at 40°C and at the same time to compare the qualitative characteristics in the form of selected essential oils when hops are dried using the conventional method and low-temperature method.
With the drying medium temperature being 60°C, hops lose on average 10% of the essential oils content. Based on the analytical results, by drying a major part of essential oils constituents decreases to approximately the same extent, thus the relative representation in the mixture does not change substantially.
Thus, our hypothesis was confirmed both in 2017 and 2018 measuring. When applying the low-temperature technology of drying for aroma hop varieties the result should be at least identical and even better, regarding the higher content of essential oils. In the future we assume further experiments in this area.

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