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Experimental chamber dryer for drying hops at low temperatures

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Abstract. Hop drying takes a significant part in growers' costs of the final product processing. The current drying technology is based on drying at the drying air temperature of 55–60 °C for 6–9 hours to the final moisture content of about 10%. However, the process results in irreversible transformations and losses of, inter alia, heat labile substances contained in hops.
The experimental chamber dryer was tested at harvest in 2016. Assays hop drying were carried out at a temperature of the drying medium 40 °C. The research results in the form of an experimental new experimental chamber dryer will be used for testing of drying technologies at lower temperatures of the drying medium.
This is what will enable to preserve the quality of aroma as well as other characteristics of the components contained in hops.

Key words: hop, drying, chamber dryer, moisture.

INTRODUCTION

Besides brewing parameters there are other heat labile substances contained in hops that are important and for which the current drying temperatures in the final stage of drying are too high. For some special aroma hop varieties, whose content and composition of essential oils are key qualitative parameters, such losses result in a reduced quality of the product. Aroma hops are applied by means of so called dry hopping technique that is widespread especially in the segment of small and restaurant breweries. Based on the above it is concluded that for special hop varieties it is necessary to develop technology and technique suitable for a careful (low-temperature) drying method that would preserve to the extent possible the original composition of hops.

The chemical composition of hops depends inter alia on the variety and post-harvest treatment. On average, hops contain about 10% of water, 15% of total resins, 4% of polyphenol-type substances, 1% of essential oils, 3% of waxes, lipids, 15% of nitrogen compounds, 44% of carbohydrate compounds and 8% of mineral substances.

For the quality of hops the content of valuable brewing constituents, mainly of resins, polyphenols and essential oils, is crucial. Hop resins are responsible for the bitter flavour in beer and they are composed of a group of alpha bitter acids, consisting mainly of cohumulone, and of a group of beta bitter acids, consisting mainly of colupulone. Hops also consist of less active soft and hard resins.

Hop polyphenols or hop tannins have significant technological properties such as their precipitation effect on high and intermediate molecular weight proteins during hopping, and they also contribute to a pronounced and crispy beer taste. One of these constituents is desmethylxanthohumol (DMX).

According to the literature in the Czech Republic, no one had a problem drying hops at a lower temperature than 55 °C (Jech et al., 2011). Low-temperature drying is used with other crops and products, but not with hops (Aboltins et al., 2016). Drying hops at ambient temperature above 55 °C have been discussed by some authors (Bernášek et al., 2007). Both authors describe the drying curve and the energy consumption of hop drying, wherein the drying air has a temperature of about 60 °C. Foreign sources only describe the drying temperature of the drying medium to be 65 to 68 °C (Münsterer, 2006).

The research objective was therefore to design and assemble an experimental chamber dryer including the heater, measurement devices and accessories, allowing hop drying at temperatures below 50 °C.

In 2016, the drying process at a low temperature of the drying air (40 to 45 °C) was monitored in an adapted chamber dryer and simultaneously the hop cone quality was assessed during the process of drying in the experimental chamber dryer and in comparative measurements in operation (60 °C), in a laboratory dryer (40 and 55°) and with fresh green cones.

MATERIALS AND METHODS

The dryer is heated by electric hot air aggregate with a maximum thermal input of 18 kW, and the heated air temperature can be set by means of an indoor thermostat to 40–45 °C. The heated air is blown into the dryer by a fan. The amount of blown air is possible to regulate through a change in the fan's rotation frequency by means of a frequency converter. Above the hop layer there was a forced-draught fan placed to drive the air coming through the hop layer away (Fig. 1). This whole device is the actual design. The experimental chamber dryer is in the form of a self-supporting steel structure with inserted wooden boxes measuring 0.9 x 0.9 x 0.3 m for storing dried hops. It is possible to insert up to 3 boxes one above the other into the dryer. The weight of green hops inside one box may be approx. 20 kg (Fig. 2) (Heřmánek et al., 2016).

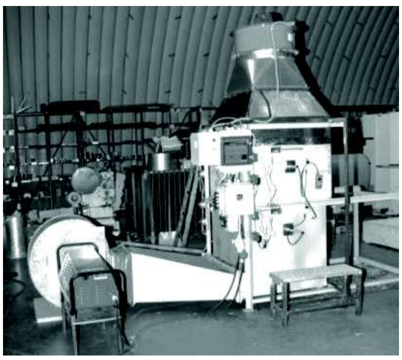

Figure 1. View of an experimental chamber dryer with a draught fan.

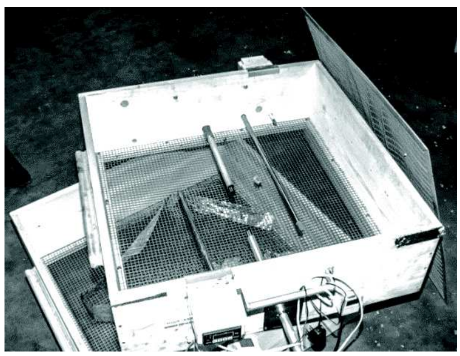

Figure 2. A wooden box.

The hop layer thickness in the experimental chamber dryer was 0.3 m following Table 1 when initiating the drying, i.e. the same as the height of the wooden box (Fig. 2). The air velocity and temperature sensors had been located approx. 0.05 m above the wooden box bottom. Data loggers had been placed in the middle of the layer of the hops being dried, evenly in the shape of a triangle.

The main objective was drying hops at low temperatures which are essential for preservation of valuable substances in hops. The temperature inside the dryer was kept within the range of 40–45 °C. This temperature was achieved by means of a hot-air aggregate and a fan controlled by a frequency converter. The drying temperature was adjusted through the change in the rotation frequency. Relevant parameters of the experimental chamber dryer are listed in Table 1.

Table 1. Parameters of the size of dryer, fans and heater

Equipment	Producer	Type	Parameter	
Chamber dryer	Chmelařství, cooperative Žatec, CZ		Dimension of box 0.9 x 0.9 x 0.3 m	Layer height 0.3 m
Hot air aggregate	Thermobile, Breda, NL	VTB 18000	Flow of air 1,000 $m^3 h^{-1}$	Temperature 40–110 °C
Fan – input	Janka Engineering, Milevsko, CZ	RSH 500	Flow of air 2500–12,500 $m^3 h^{-1}$	Species Radial, medium pressure
Fan – output	ZVVZ, Milevsko, CZ	APZC630	Flow of air 4500–10,800 $m^3 h^{-1}$	Species axial, overpressure

The values from the measuring apparatus were recorded at a pre-determined interval. Every two hours samples were taken to determine the hop moisture content by means of analyses in the laboratory of Hop Research Institute Co. Ltd., Žatec.

Following drying, the hops were left in the slat box overnight (stabilization of hops). Next day in the morning the moisture content in hops was higher, therefore further drying of samples was necessary for all varieties.

During the measurement (Heřmánek et al., 2016) we monitored:

- air temperature and relative humidity under the layer of hops – data logger COMET R0110 (Comet system, Rožnov pod Radhoštěm, CZ),
- air velocity under the layer of hops – probe GREISINGER GIA 2000/GIR 2002 (Greisinger, Würzburg, D),
- air pressure under the layer of hops – pressure gauge GREISINGER 3100 (Greisinger, Würzburg, D),
- air temperature and relative humidity over the layer of hops – data logger COMET R0110 (Comet system, Rožnov pod Radhoštěm, CZ),
- air velocity over the layer of hops – probe GREISINGER GIA 2000/GIR 2002 (Greisinger, Würzburg, D),
- temperature of blown air – thermostat FAMATEL (Famatel-CZ, Prostějov, CZ),
- energy consumption – electricity meter NOARK EDN 3412 (Noark Electric Europe, Praha, CZ),
- radial fan rotation frequency– frequency converter.

The values were recorded online. The figures show examples of the values obtained from all the sensors. The resulting values of the drying air humidity and temperature were obtained as the mean of the sensors applied.

RESULTS AND DISCUSSION

The measurement was made on the premises of Chmelařství, Cooperative Žatec, the Machinery Plant. The measurement results for the variety Vital are presented below. Regarded the fact that the measurements were carried out with Vital variety in the first year, the measured data could not be analysed statistically. The authors suppose further measurements to be carried out in the season of 2017 and compared with the values already measured.

The product input and output values are presented in Table 2.

Table 2. Input and output values for Vital variety

Parameter	Input values	Output values
weight of green hops in the box	23.8 kg	6.8 kg
hop moisture content	75.0%	12.0%

Moisture content = wet basis.

At the start of the drying process, three data loggers VOLTCRAFT DL-121-TH had been inserted into approximately half of the hop layer (Srivastava et al., 2006). Figs 3 and 4 illustrate changes over time in temperature, relative humidity and air velocity.

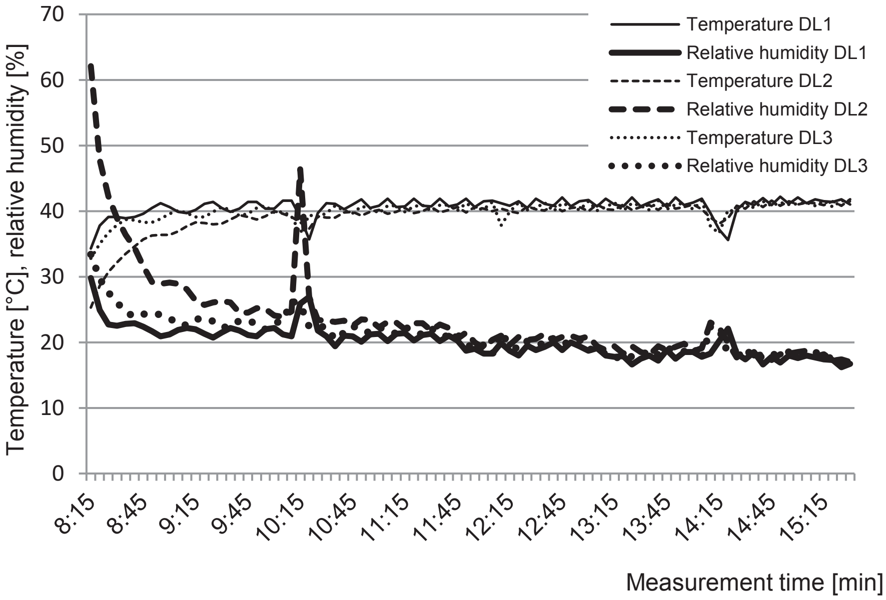

Figure 3. Dependence of the air temperature and relative humidity on the measurement time in a layer of dried hops (data loggers 1 to 3 – DL1 to DL3).

Fig. 3 depicts the changes in temperature and relative humidity prior to entering the drying slat box and over the hops that are being dried measured by means of the data loggers inserted into the hop layer. The graph clearly shows a balanced temperature pattern (approx. 40 °C) as well as relative humidity pattern (approx. 20%) under the hop layer, which confirms an optimal setting of the inlet fan rotation frequency. The values recorded for the temperature and relative humidity of the air coming out of the hop layer stabilised after approx. 3.5 h of drying. Until then the fresh green hops were influencing the gradually increasing temperature and decreasing relative humidity of the air coming through.

Fig. 4 illustrates the changes in the air velocity during drying. Both under and over the hop layer this dependence is largely unbalanced and any conclusions can be drawn only with difficulties. The air velocity depends on drying up of the hop layer and simultaneously also on the change in resistance of this layer which affects the air circulation.

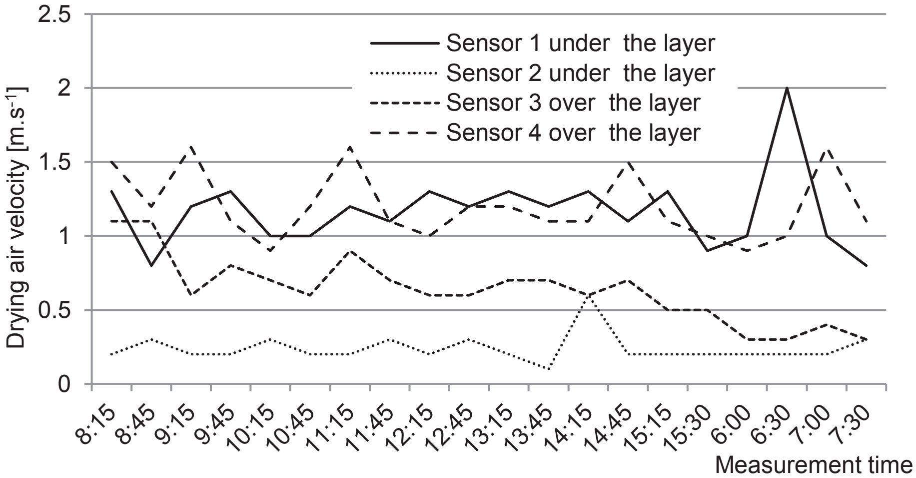

Figure 4. Air velocity during the drying process.

Dried hops were also tested in the laboratory in terms of the overall product quality. For Vital variety its qualitative parameters from the experimental chamber dryer were compared with hops of the same variety during comparative measurements in operation (60 °C), in the laboratory dryer (40 and 55 °C) and with the quality of fresh green cones.

Hop moisture was determined through gravimetric analysis in the laboratory chamber dryer of Hop Research Institute Co. Ltd., Žatec with forced air circulation according to the EBC 7.2 method (European Brewery Convention Analysis Committee, 2009). Following this method, the weighed hops are dried at a temperature of 105 °C for 1 h. Drying time for hops with moisture content over 30% shall be extended to 1.5 h. With the samples we also monitored the Hop Storage Index (HSI) which had been determined by the official EBC 7.13 spectrophotometric method from a hop toluene extract. Alpha bitter acid content was measured by means of liquid chromatography according to the EBC 7.7 method (Krofta, 2008). The measured value was then converted to an absolutely dry matrix for all the points of the drying curve.

Table 3. Results of drying monitoring in operating conditions for Vital variety

Sampling date	Alpha bitter acids (%DW)	Beta bitter acids (%DW)	DMX (%DW)	Moisture content (%)	HSI
29. 8. 2016 hop field sampling	16.02 14.39	11.31 10.65	0.52 0.48	78.1	0.208
6. 9. 2016 hop field sampling	15.96 15.48	9.56 8.74	0.51 0.46	76.0	0.216
16. 9. 2016 hop field sampling	15.58 15.62	9.32 8.63	0.39 0.38	75.1	0.231
19. 9. 2016 green harvest sample	15.40 15.55	8.71 9.16	**0.40** **0.40**	73.7	0.228
20. 9. 2016 dried harvest sample	14.67 13.87	8.57 8.09	**0.22** **0.20**	9.2	0.295

Table 4. Results of low-temperature drying monitoring for Vital variety

Drying	Alpha bitter acids (%DW)	Beta bitter acids (%DW)	DMX (%DW)	Moisture content (%)	HSI
Memmert 55 °C, 8 h	14.36	8.70	0.24	9.6	0.283
Memmert 40 °C, 10 h	16.90	9.79	0.36	37.1	0.230
Experimental chamber dryer (40 °C)	**14.07** **14.74**	**8.46** **8.92**	**0.29** **0.32**	**12.0**	**0.266**

N.B.: Memmert = laboratory dryer – producer Memmert; Department of hop chemistry Hop Research Institute Co. Ltd., Žatec.

As can be seen from Table 3, the content of chemical substances (alpha and bitter acids, Desmethylxanthohumol), moisture contents and HSI do not vary at the end of the growing season (29.8.2016–16.9.2016) nor during the harvest (19.9. 2016). After drying in a belt dryer following the traditional way of drying (65 to 68 °C), fundamental differences were measured in the content of desmethylxanthohumol (DMX), a valuable bioactive substance, highly sensitive to thermal load. Its content in green hops was 0.40% of weight, after being dried in operating conditions its content dropped by about a half (0.20; 0.22% of weight). For this reason it can be used as an indicator reflecting gentle drying.

The content of DMX after drying in the laboratory dryer (Memmert) and experimental chamber dryer under more favourable conditions in terms of temperature was substantially higher (0.29%; 0.32%). The measurement results are presented in Table 4.

CONCLUSION

The above research indicates that during drying it is necessary to monitor the content of desmethylxanthohumol (DMX), as it is a substance indicating gentle drying. It can also be concluded that this very experimental chamber dryer is suitable for monitoring various drying technologies. At the same time this dryer will serve for further research in the field of low-temperature drying of hops.

For practical use, and further experiments will be necessary to ensure:

- optimum ripeness of hops depending on the variety,
- uniform distribution of hops within the dryer including an optimal height of the layer of hops,
- temperature of the drying medium a maximum of 40 to 45 °C,
- uniform distribution of the drying medium within the dryer,
- continuous monitoring of temperature and moisture of hops,
- continuous monitoring of temperature, humidity and velocity of the drying medium,
- control the velocity and temperature of the drying medium,
- uniform final moisture of hops between 8–10%,
- option air and moisture balancing hops,
- measurement of time and energy consumed during the process of drying,
- documentation of the measured values.

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