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Analysis of Hop Drying in Chamber Dryer

A. Rybka*, P. Heřmánek and I. Honzík

Czech University of Life Sciences Prague, Faculty of Engineering, Department of Agricultural Machines, Kamýcká 129, CZ165 00 Praha 6 – Suchdol, Czech Republic
*Correspondence: rybka@tf.czu.cz

Abstract. This article is aimed at the analysis of the hop drying process that has been carried out in the chamber dryer of Rakochmel Co. Ltd. in Kolešovice with the Saaz hop variety. The values measured by means of dataloggers as well as fixed sensors show an identical trend. When the hops fall over from one slat box onto another, the drying air temperature declines and the relative humidity rises. A sharp increase in the relative humidity gradually decreases starting with the first slat box and finishing with the emptying conveyor, which points to a gradual levelling of the relative humidity and hop moisture. The hop moisture content, determined from laboratory samples, logically decreases depending on the measurement time. In comparison to belt dryers, chamber dryers clearly ensure continuous and more gentle drying during which the hops are not overdried and a moisture content of 10% is achieved practically only at the outlet of the dryer prior to conditioning.

Key words: hop cones; dryer monitoring; quality of hops.

INTRODUCTION

The vast majority of growers uses belt dryers for hop drying, most of them date back to the 60s of the last century and are technically outdated. Parallel to these also some older types of chamber dryers are partially used. Based on foreign experience, their principle of drying has the potential for further usage (Doe & Menary, 1979; Kořen et al. 2008).

During the process of drying the moisture content in hop cones is reduced from the initial approx. 75–85% to 5–7% which is a significant excessive drying due to required drying of the cone strig. Inside the dryer the hops are exposed to a drying temperature of 55–60% for 6–8 hours. Afterwards, the hop cones need to be conditioned to their final moisture of 10–12% (Rybka et al., 2017). However, for some heat-labile substances the drying temperatures mainly in the final stage of drying are too high, besides the long period of drying. This procedure leads to irreversible transformations and losses. Such substances are for instance hop essential oils that are contained in the amount of 0.5–3.5%, depending on hop variety (Hofmann et al., 2013; Kumhála et al., 2013). The pilot studies showed that under current conditions there is a decrease of 15 to 25% of the overall content of essential oils present in the hops prior to drying (Kieninger & Forster, 1973; Kirchmeier et al., 2005).

One possible solution to the above-mentioned state is developing a new concept for low-temperature drying of some special hop varieties in a chamber dryer (Heřmánek et al., 2017). In case of low-temperature drying at a drying temperature of approx. 40% no energy savings can be expected, but the main economic benefit will lie in the improvement of the product quality and the growers will be able to sell this product for higher prices (Podsedník, 2001; Hanousek et al., 2008). The new method of drying must enable to diversify temperatures and optimise drying parameters primarily for special hop varieties for which it is desirable to preserve, to the extent possible, their original composition (Rybáček et al., 1980; Srivastava et al., 2006; Kumhála et al., 2016). The heat-labile substances will be able to be used in processing in the sector of medicines and food supplements.

The study objective is therefore an analysis of the current state of hop drying in chamber dryer which needs to precede in content the innovation in the entire process of hop drying (Aboltins & Palabinskis, 2016; Aboltins & Palabinskis, 2017).

MATERIALS AND METHODS

The measurement was carried out in 4KSCH chamber dryer of Rakochmel Co. Ltd. Kolešovice with the Saaz hop variety. The given variety has a long tradition in the Czech Republic and is grown on approx. 87% of hop acreage. The Rakochmel company grows only this variety on an area covering 152 ha. The company is equipped with a chamber dryer suitable for the given experiments. The chamber dryer has four drying chambers located in twos in separate shafts with independent heating aggregates. The measurement each time involved one chamber in each shaft (the first and third chamber).

Inside the dryer temperature and air-conditioning parameters of the drying medium as well as qualitative parameters of dried hops (temperature, moisture, HSI – Hop Storage Index, alpha and beta bitter acids, drying time) were measured. The measured data were subsequently assessed.

The parameters were identified in three different ways:

- by measuring the air temperature and humidity using fixed sensors installed on the dryer wall,
- by measuring the air temperature and humidity using inserted dataloggers,
- by means of a laboratory analysis of the samples.

Each of these methods had different conditions for measuring and different measurement accuracy (Vitázek & Havelka, 2014).

Apart from monitoring the dryer, another objective was to assess the methods applied and to compare them between themselves.

On the dryer walls, there were installed nine fixed sensors. In the first and third chamber one sensor was placed by each slat and emptying conveyor (i.e. 8 altogether) and the ninth sensor was placed at the conditioning outlet. DL1 datalogger was placed in the first chamber and DL2 datalogger in the third chamber. The samples for the purposes of laboratory analyses were taken at filling and then successively from each of the three slat boxes immediately prior to the hops being poured down, from the emptying conveyor and at the end of conditioning (Fig. 1).

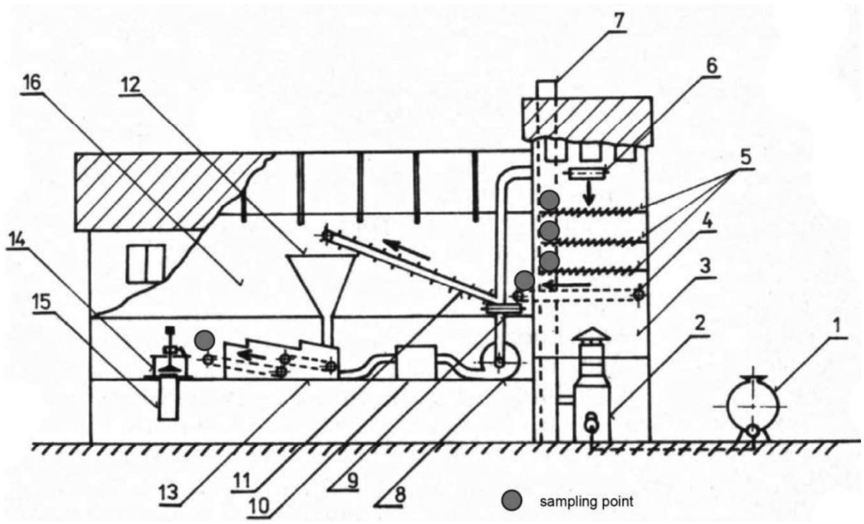

Figure 1. Scheme of the chamber dryer with marked points where samples are collected for laboratory tests: 1 – fuel tank; 2 hot-air aggregate; 3 – drying chamber; 4 – emptying conveyor; 5 – slat system; 6 – filling conveyor; 7 – chimney stack; 8 – draught fan; 9 – transverse takeaway conveyor; 10 – air filter; 11 – elevator conveyor; 12 –container; 13 – conditioning; 14 – press; 15 – prism; 16 – storage area.

Measuring by means of sensors installed on the dryer walls

On the dryer walls the assembly of Comet T3419 temperature and relative humidity fixed sensors was completed. They were always 8 sensors in a row connected to a Comet MS6D multi-channel datalogger. On the dryer 9 sensors and two multi-channel dataloggers had to be installed. All data from the multi-channel dataloggers were automatically stored in the computer on its hard disc.

Comet T3419 sensors had been installed by each of the three slat boxes and the emptying conveyor of the first and third chamber and one more at the outlet of the conditioning. The frequency of reading the values was set to 5 min. Immediate measured values could be read on the connected two-line display, which at the same time showed the actual temperature in °C and relative humidity in %. Together with the data reflecting temperature and relative humidity the exact time of measurement was also stored by means of which the data collected from all the different ways of measuring could be matched up.

Measuring by means of dataloggers

For continuous measurement of the air temperature and relative humidity in a layer of hops being dried VOLTCRAFT DL-121-TH dataloggers were used which enabled to programme the frequency of data storage (Jech et al., 2011; Jokiniemi et al., 2015).

In our case the frequency of data storage was set to 5 min, similarly to the fixed sensors. A datalogger is integrated together with a sensor in a plastic case and its power is supplied by an inserted battery. The plastic case is fitted with a USB connector at its one end via which the stored data are imported into the computer.

To protect the dataloggers against mechanical damage while carried throughout the dryer as well as against dirt we fixed the dataloggers rigidly in polyurethane foam and inserted them between two stainless sieves half-spherical in form. This was the best guarantee of protection and at the same time the sieves did not impede the air permeability (Fig. 2).

The advantage of the dataloggers compared to the rigidly fixed sensors in the dryer was that the dataloggers were carried together with hops through the dryer, continuously sensing the entire drying process. In both chambers the dataloggers were placed one by one in filling. They were removed after having passed through the dryer and conditioning.

Figure 2. Placing a datalogger into a protective sieve.

Laboratory analyses of the samples

The laboratory analyses monitored the moisture content of all hop samples, which was subsequently compared with the drying medium relative humidity measured by means of dataloggers and fixed sensors in the dryer. At the same time the values of HSI and content of alpha and beta bitter acids in hop cones were determined (Claus et al., 1978; Green & Osborne, 1993).

Determination of moisture content in hops.

The moisture content of hops was determined gravimetrically as the weight loss of a defined amount of water during drying at a temperature of 105 °C for 60 min (Henderson & Miller, 1972; Henderson, 1973).

Determination of HSI in hop cones.

Hop storage index (HSI) is a dimensionless parameter that characterizes the level of hop ageing during storage and processing after harvest. Its numeric value is obtained as absorbance ratio of toluene hop extract in alkaline methanol solution at wavelengths of 275 and 325 nm. In green hops the value of this index is 0.20–0.25, immediately after drying ranges between 0.25 and 0.30. Its value continues rising constantly and irreversibly during further storage. In old hops the HIS values can be measured within an interval of 1.0–2.0.

Determination of alpha and beta bitter acid content and of DMX in hop cones.

Alpha and beta bitter acids as well as DMX are determined by liquid chromatography following the EBC 7.7 conventional method (Ono et al., 1984; Krofta, 2008).

RESULTS AND DISCUSSION

When entering the dryer, harvested hops are checked for their technical ripeness. The cone colour was bright yellow-green with natural gloss, the aroma was distinct and typical for that variety. The presence of biological impurities (leaves, parts of hop vines, stems) was proportionate, non-biological impurities there were none.

The results from the dataloggers as well as from the measurements by means of fixed sensors and the results of laboratory analyses are in Table 1 and graphical compared in Figs 3–6.

Table 1. Parameters of drying process

Measurement date: 24. 8. 2016		Site: Rakochmel Co. Ltd. Kolešovice, **CHAMBER DRYER 4KSCH**									Hop variety: Saaz	
Dryer chamber			1					3				
Sampling point			Filling	1st slats prior to pouring down	2nd slats prior to pouring down	3rd slats prior to pouring down	Emptying conveyor	Filling	1st slats prior to pouring down	2nd slats prior to pouring down	3rd slats prior to pouring down	Emptying conveyor
Sampling time (in hh:mm format)			10:40	12:21	14:21	16:21	8:21	11:43	13:25	15:21	7:21	19:29
Measurement time		min	0	101	221	341	461	0	102	218	338	466
Sensors	Temperature	°C	31.8	37.9	54.6	56.5	54.9	28.4	33.1	51.8	54.9	55.4
	Rel. humidity	%	74.8	55.4	14.0	11.0	10.5	91.9	80.3	18.4	10.0	9.5
DL1 datalogger	Temperature	°C	30.2	46.2	54.3	56.5	56.8					
	Rel. humidity	%	72.7	23.7	14.5	13.7	13.1					
DL2 datalogger	Temperature	°C						29.3	36.9	40.6	52.2	53.2
	Rel. humidity	%						81.4	60.9	31.6	14.8	18.4
Laboratory analyses of hops	Temperature	%	73.6	56.0	39.8	13.4	10.6	81.8	64.4	52.0	29.4	13.8
	HSI		0.239	0.249	0.253	0.252	0.255	0.240	0.241	0.242	0.248	0.250
	Alpha	%	4.49	4.31	4.23	4.18	3.38	4.60	5.03	4.98	4.20	4.26
	Beta	%	7.49	6.47	6.82	6.15	5.25	6.61	7.09	6.71	6.19	6.21

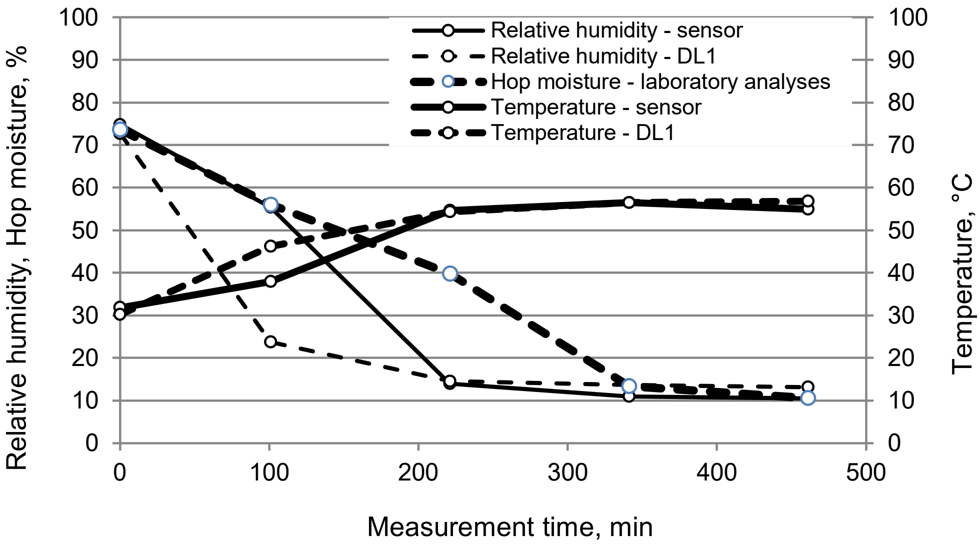

Figure 3. First chamber – datalogger (DL1), fixed sensors and laboratory analyses – dependence of temperature, relative humidity and hop moisture on measurement time.

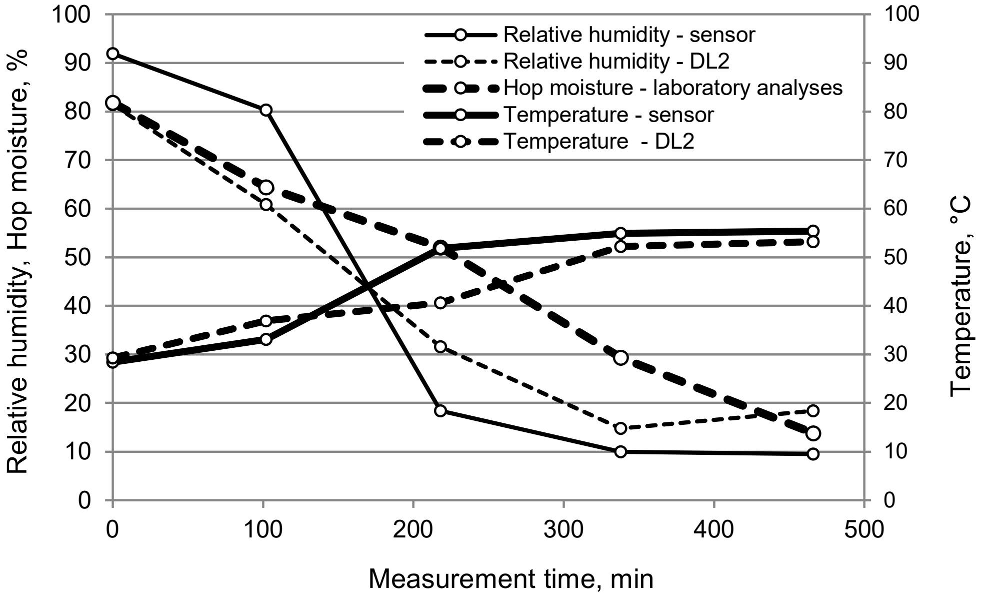

Figure 4. Third chamber – datalogger (DL2), fixed sensors and laboratory analyses –dependence of temperature, relative humidity and hop moisture on measurement time.

Discussion on each measurement

Uniformity in drying in individual chambers

The graphs in Figs 3–4 compare changes in the air temperature and relative humidity in the first and third chamber measured by those dataloggers that passed through the entire drying process in the drying chamber with the values obtained from the fixed sensors and with the values of hop moisture. Drying air temperature measured by dataloggers or fixed sensors is almost identical in both chambers. The relative humidity in both chambers is different with the first two slats, but logically this downward trend in the relative humidity corresponds to the declining hop moisture content. The relative humidity is being gradually equalized with the hop moisture. Contrary to belt dryers, the drying process is clearly continuous and gentle, and the hop moisture content of about 10% is achieved practically only at the outlet of the dryer prior to conditioning.

Laboratory analyses – hop moisture, HSI, alpha and beta bitter acids during the drying process.

The graphs in Figs 5–6 show results of the laboratory analyses of hop moisture, HSI, alpha and beta bitter acids during the process of drying in the first and third drying chamber. Based on the graphical patterns we can assess the changes in values of the moisture, HSI, alpha and beta bitter acids while the hops were passing through the dryer. The HSI values should increase minimally and the values of alpha and beta bitter acids should decrease minimally. The HSI values, according to the growers' long-standing experience with hop drying, subsequent processing and distribution, should not exceed 0.3 at the end of drying. With the first chamber (Table 1) the HSI value rose from 0.239 (filling) to 0.255 (emptying conveyor), which is an increase by 6.69% and it does not exceed the limit value. With the other chamber the HSI value rose from 0.240 (filling) to 0.250 (emptying conveyor), which is an increase by a mere 4.17%. The values of alpha and beta bitter acids were relatively high at the inlet of both chambers, and the decline after passing through the dryer was only within the range of 0.34–2.24%. On the basis of an overall assessment it can be concluded that the process of drying in a chamber dryer has a minimal effect on the principal assessment parameters.

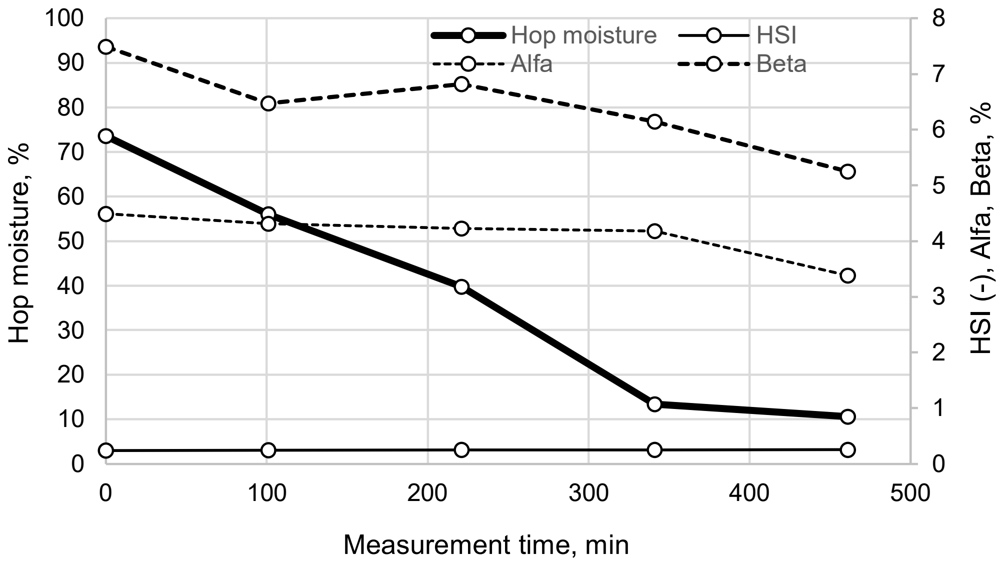

Figure 5. First chamber – laboratory analyses – hop moisture, HSI, alpha and beta bitter acids during the drying process.

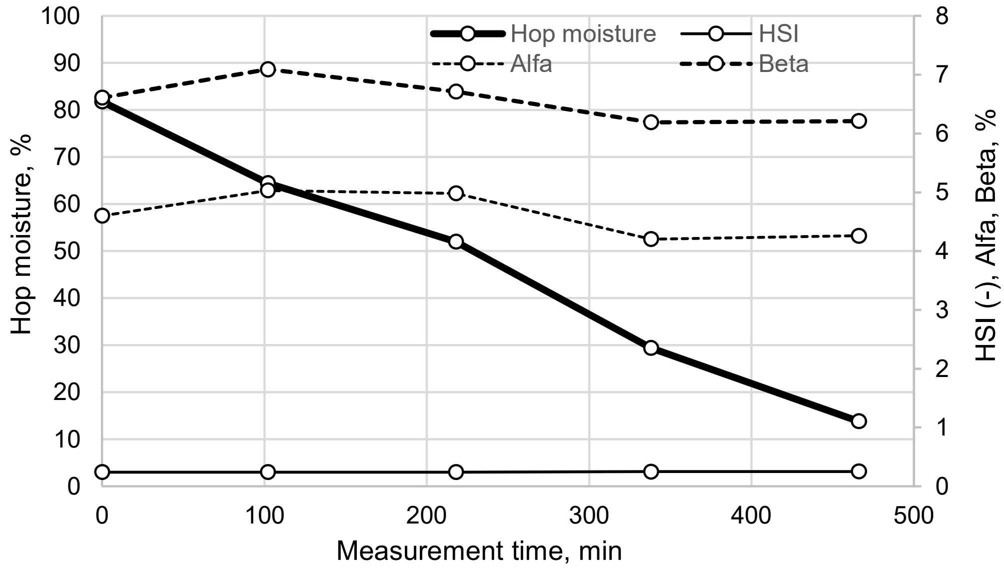

Figure 6. Third chamber – laboratory analyses – hop moisture, HSI, alpha and beta bitter acids during the drying process.

Finally, it has to be noted that by examining both domestic and foreign literature a large amount of information has been obtained about parameters of the drying medium and dried hops of different varieties mostly regarding drying in belt dryers, but these show a large variability affected by varietal, soil and climatic conditions and it is not possible to find any correlative links among them. The measurements summarized in this paper constitute the primary continuous monitoring of changes in air-conditioning and qualitative parameters (temperature, moisture, HSI, alpha and beta bitter acids, drying time) during the process of drying in a chamber dryer. There is a presumption that in the following years similar measurements will be repeated so that the changes in measured data could be gradually analysed more and the drying process could be prepared for so called gentle drying at a temperature of the drying air of up to 40 °C.

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