INCREASE IN THE HOP BELT DRYER DRYING INTENSITY

Adolf RYBKA, Petr HEŘMÁNEK, Ivo HONZÍK

Department of Agricultural Machines, Faculty of Engineering, Czech University of Life Sciences Prague, Czech Republic

Abstract
The aim of the experiments was to improve the permeability of the flattened hop layer to the drying air on the first belt of the dryer and intensified drying and fuel saving. For this purpose, one rotor was installed above the first belt and the rotor peripheral speed would be higher than the belt speed. By means of data loggers, three measurements with the rotor switched off and with the rotor switched on were carried out and repeated three times. The average moisture content of hops with the rotor being switched off was 53.03 %, and 48.63 % with the rotor being switched on. The drying process will intensify by 8.30 % with the rotor switched on. Without the rotor installed, the average consumption ELFO (Extra light fuel oil) was 486.5 $l.t^{-1}$ of dried hops, compared to 415.5 $l.t^{-1}$ when the rotor had been installed, resulting in significant fuel savings of 14.59 % when the rotor was used.

Key words: *hops; double-arm rotor; quality of hops; belt dryer; drying air.*

INTRODUCTION

Hops need to be preserved immediately after picking to prevent any loss of their quality. Picked cones have a moisture content of 72-82 %, they breath intensively, increasing the temperature and there is a risk of damage by spontaneous heating that might lead to a gloss loss, change in the basic colour and to a negative impact on the overall cone quality. Therefore, the drying process needs to be initiated rapidly. In the Czech Republic, majority of hop growers use continuous belt dryers for drying, where hops are dried on a set of three successive drying belts, followed by conditioning. Hop cones are dried at a temperature of 55-60°C for 6-9 h which is a very long time that is not beneficial at all for the final product quality, leaving aside the high energy requirements for drying. Dying on the first belt has a significant role as the moisture content is reduced here minimum by a third of total value of the input hop moisture content (*Rybka et al., 2016*).

The experience of the growers brings the knowledge that upon entering the first belt the hop layer flattens and hop cone bracts stick together due to their surface moisture. That causes lower layer permeability (surface crust is created) for the passing air, thus the drying speed decreases (*Rybka et al., 2018*). After this problem had been eliminated, a double-arm rotor located above the first belt of the dryer was designed, installed and verified in operation (Fig. 1).

The rotor was mounted between the first and second inspection window. This double-arm rotor has its arms fitted with reinforcement at their ends and rotates about its horizontal axis perpendicular to the belt motion. The rotor arms reach into the lower level of the hop layer moving on the dryer belt (Fig. 2). The shaft is fitted to the vertical walls of the dryer in bearing housings. It is driven by an electric motor with transmission gearbox. The rotational frequency of the rotor is selected in a way so that its peripheral speed was greater than the belt speed, however, in order to ensure that the rotor would not push the hops off the belt, thus forming vacant spots without hops above the belt through which the drying air would freely penetrate. This, in turn, would lower the intensity of hop drying. The rotor arms in their actual operation break up and rearrange the flattened layer of hops stuck together, thus enable better penetration of the drying air and faster removal of the hop moisture (*Heřmánek et al., 2018; Rybáček et al., 1980*).

The aim of the measurement and the article resulting from them was to improve the permeability of the dried layer of hops through the drying air on the first belt of the belt dryer, to reduce the relative humidity of the drying air more quickly, to intensify drying and to save fuel.

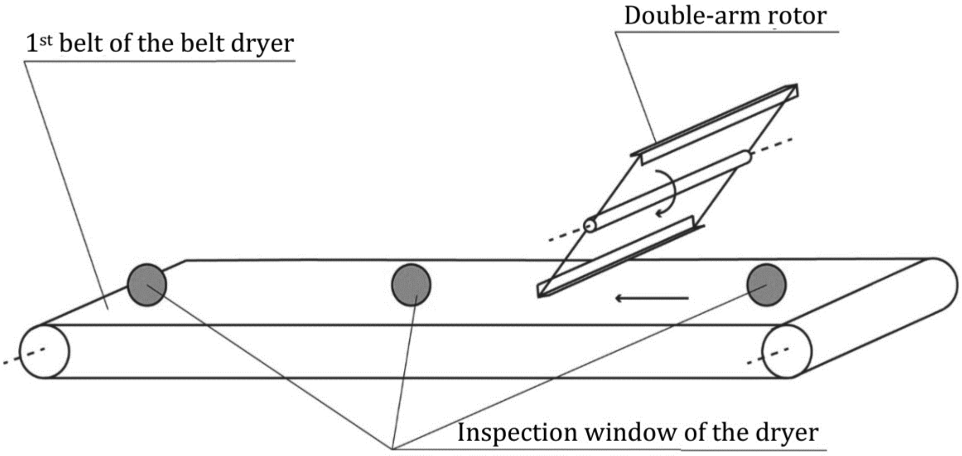

Fig. 1 Scheme showing the location of the double-arm rotor above the first belt of the belt dryer

Fig. 2 Rotor between the first and second inspection window above the first belt of the belt dryer

MATERIALS AND METHODS

Measurement by inserted data loggers

To measure the temperature and relative humidity inside the hop layer continuously we used VOLTCRAFT DL-121-TH data loggers (Fig. 3) which enable to programme the frequency of data storage. In our case this frequency was set to 5 minutes. The data logger internal memory has its storage capacity of 32,000 measured data. The data logger was integrated together with a sensor in a plastic casing and supplied by an inserted battery. The plastic casing had been fitted with a USB connector at one end via which the stored data were imported to a computer (*Jech et al., 2011*).

Fig. 3 VOLTCRAFT DL-121-TH data logger

To protect the data loggers against mechanical damage while carried throughout the dryer as well as against pollution caused by lupulin, the data loggers were fixed rigidly in polyurethane foam and inserted into 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, hence no measurement error occurred (Fig. 4).

Fig. 4 Insertion of a data logger into a protective sieve

The measurements were carried out from 27 to 29 August 2018 with the Saaz variety, which is the most widespread and is grown on 85.19 % of the Czech hop acreage. Three data loggers were placed through the first inspection window onto the first (upper) belt of the PCHB 750 belt dryer in Rakochmel, Co., Ltd. in Kolešovice. Two of them were inserted into a hop layer approx. 0.5 m far from both left and right dryer wall, and one in the middle. Three measurements with the rotor switched off and three measurements with the rotor switched on were carried out and repeated three times, the rotor being located between the first and second inspection window. The average values of the hop moisture content were determined based on these results, the dispersion of the values obtained from three measurements around the mean did not exceed 6 %. The specific values of the drying air temperature and relative humidity are taken as the average data from the three data loggers in passing through the third inspection window at the same time as the samples taken for laboratory determination of the hop moisture content. The advantage of data loggers, compared to rigidly fixed sensors in a dryer, is that they pass through the dryer together with the hops, continuously sensing the whole drying process (*Krofta, 2008; Mitter & Cocuzza, 2013*).

Laboratory analysis of the samples

The laboratory analyses monitored the moisture content of all hop samples, which was subsequently compared to the drying medium relative humidity measured by means of data loggers. The samples had been taken at the end of the first dryer belt. The moisture content in the hops was determined by the Mettler-Toledo HE53 moisture analyser (Fig. 5). The measurements were carried out 3 times repeatedly and the resulting values were averaged (*Forster & Gahr, 2013; Henderson & Miller, 1972*).

Fig. 5 Mettler-Toledo HE43 moisture analyser

RESULTS AND DISCUSSION

Tab. 1 shows the parameters of the drying process determined this way. The values from individual data loggers placed in the middle and on the edges of the belt differed minimally, thus confirming a presumption about drying process being even over the whole width of the dryer. The measurement results are further shown below in the graphs of Fig. 6 and Fig. 7.

Tab. 1 Parameters of the drying process

Date of measurement: 27. - 29. 8. 2018	Site: Rakochmel, Co., Ltd. in Kolešovice PCHB 750 belt dryer							Variety: Saaz
Sampling point	1st belt							
Rotor	Switched off				Switched on			
Measurement number	1	2	3	Mean	1	2	3	Mean
Sampling time [h:min]	13:20	12:45	13:01		16:20	16:00	16:01	
Drying air temperature [ºC]	40.6	41.0	41.5	41.03	40.8	41.0	40.7	40.83
Drying air relative humidity [%]	40.2	41.6	42.8	41.53	33.2	34.8	33.2	33.73
Hop moisture content [%]	48.4	53.7	57.0	53.03	46.9	50.4	48.6	48.63

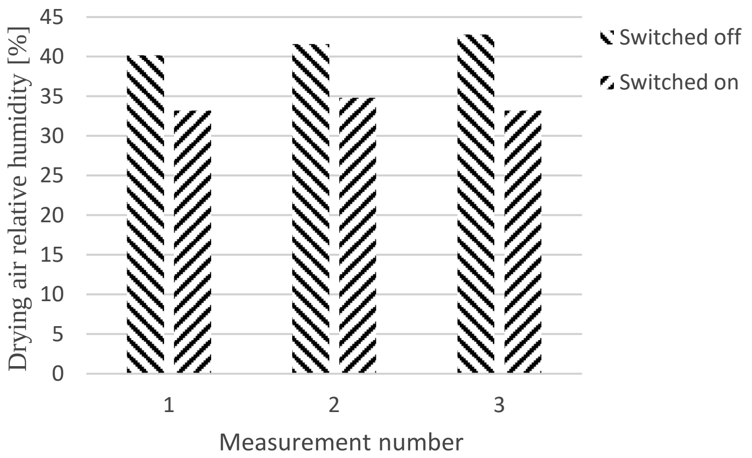

Fig. 6 Drying air relative humidity measured by data loggers on the first belt with the rotor switched on and off

In his comprehensive study, *J. Münsterer (2020)*, who deals with a detailed study of hop drying in chamber and belt dryers, points out the prevention of hop failure in the first third of the first belt. It summarizes the results of many experiments showing that the intensity of drying in the first third of the first belt has the greatest effect on performance and quality retention. However, it does not mention the installation of such a device.

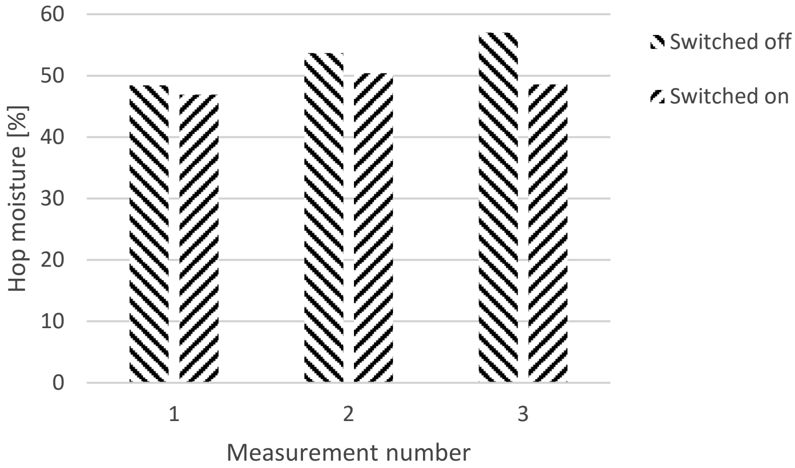

Fig. 7 Hop moisture at the end of the first belt with the rotor switched on and off

The average moisture content of hops with the rotor being switched off was 53.03 % at the end of the first belt, and 48.63 % with the rotor being switched on. If we consider the value of 53.03 to be 100 %, then the drying process will intensify by 8.30 % with the rotor switched on.
Further observations of the rotor switched on or off emerged from the company's four-year monitoring of the ELFO (Extra light fuel oil) consumption for heating the drying air (Tab. 2). The average consumption between 2011 and 2014 related to the harvest season was 486.5 $l.t^{-1}$ of dried hops without the rotor installed, and 415.5 $l.t^{-1}$ of dried hops with the rotor installed between 2015 and 2018 related to the harvest season, which implies significant fuel savings of 14.59 % when using a rotor.

Tab. 2 ELFO consumption for each year of the measurement

	Year of measurement	ELFO consumption [l]	Dried hops [t]	Average consumption [$l.t^{-1}$]
Without rotor installed	2011	21949	42.48	517
	2012	12300	30.90	398
	2013	22200	43.87	506
	2014	24100	45.90	525
With rotor installed	2015	13600	32.94	413
	2016	29369	69.47	423
	2017	28444	63.30	449
	2018	22756	60.30	377

CONCLUSIONS

The experiments carried out in the PCHB 750 hop belt dryer of Rakochmel, Co., Ltd. in Kolešovice comparing the drying process with its rotor switched on and off above the first belt show that by involving the rotor in the technological process a hop layer becomes more air-permeable and it also has a positive impact on reducing the drying air relative humidity at almost identical temperature. Tab. 1 and the graphs in Fig. 6 and Fig. 7 depict the measurement results in the harvest season of 2018. The graph in Fig. 6 shows the average measurement data obtained by means of three data loggers. The graph in

Fig. 7 shows the hop cone moisture content detected by means of Mettler-Toledo HE43 moisture analyser. Both graphs clearly illustrate a decrease in both moisture contents when the rotor was switched on. The hop moisture decreased by 8.30 % with the rotor switched on. The variability of results, however, may be influenced by the variable moisture of the hops entering the dryer. In case of these measurements this moisture content was relatively steadied (75±2 %), but not necessarily always. Therefore, it will be appropriate to carry out repeated measurements in the following harvesting seasons. However, the inclusion of a rotor had a significant positive impact on the long-term monitoring of fuel consumption. Between 2011 and 2014, the total fuel consumption without using the rotor was 80,549 l of ELFO for drying 163.15 t of hops. This implies that the average consumption of ELFO was 493.7 $l.t^{-1}$ of dried hops. Between 2015 and 2018, the total fuel consumption using the rotor was 94,169 l ELFO for drying 226.01 t of hops, giving the average consumption of ELFO 416.7 $l.t^{-1}$ of dried hops. Four years of the rotor operation generate fuel savings of 15.6 %.

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Corresponding author:

Asc. Prof. Ing. Adolf Rybka, CSc., Department of Agricultural Machines, Faculty of Engineering, Czech University of Life Sciences Prague, Kamýcká 129, Praha 6, Prague, 16521, Czech Republic, phone: +420 22438 3121, e-mail: rybka@tf.czu.cz