HOP DRYING IN BELT DRYER USING COOLING CHAMBERS

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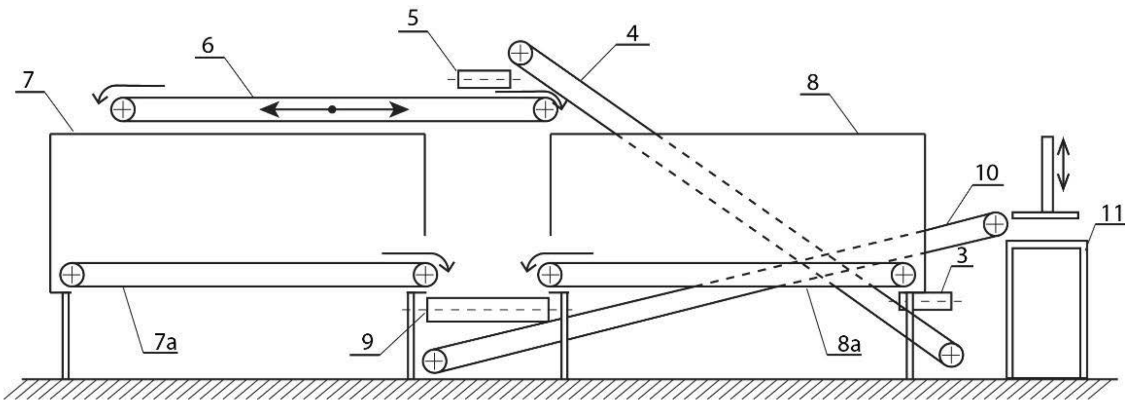
Abstract
When drying hop cones, sufficient drying of strigs is the bottleneck. Bracts are then dried up to such a level which makes pressing the hops impossible. That is the reason why hops are conditioned after over-drying to reach an optimum moisture content of 10 to 12 %. This process does not benefit hops, therefore we suggested to substitute the conditioning chamber for two cooling chambers, in which the moisture of bracts and strigs can be equilibrated. This equilibrium is essential for baling. The advantage of this drying method is energy saving and improvement in the quality of the hop product. On the basis of the patented design and a utility model, the apparatus was assembled at the belt dryer PCHB 750 of Agrospol Velká Bystřice Ltd. Comparing the operation with conditioning and the option of the cooling chambers, the gas savings amounted to 2,356 CZK.t^{-1} of dry hops and the electricity savings amounted to 831 CZK.t^{-1} of dry hops. Assuming the reduction of the harvest period by approximately 39 %, the other cost items will be reflected in the overall saving.

Key words: *hop cone; drying; conditioning; moisture.*

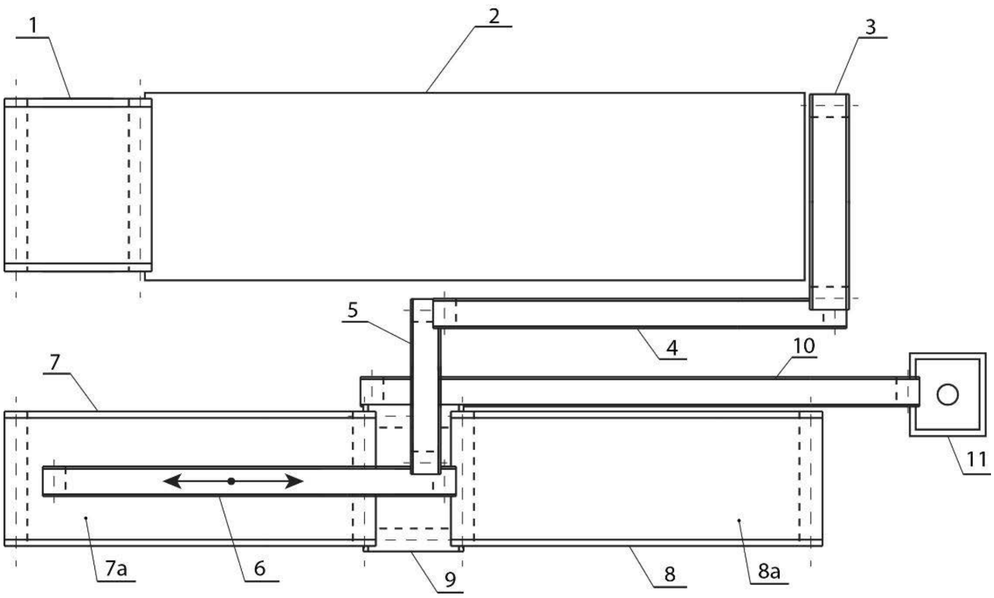
INTRODUCTION

In conventional belt dryers hops are dried down to a moisture content of 8 up to 6 %. They are over-dried by reason of the need for adequate drying of the hop cone strig (*Heřmánek et al., 2018*; *Hofmann et al., 2013*). On the other hand, bracts are then dried to such an extent that baling these hops is impossible. Therefore, after drying, hops are 'conditioned'. After conditioning, the hops have an optimum moisture content of approximately 10 to 12 %. It is obvious that neither over-drying nor subsequent moistening does not benefit the hops (*Henderson & Miller, 1972*; *Rybáček et al., 1980*). With the current setting of belt dryers the optimum moisture content is achieved already by the end of the second belt, yet the strig moisture content being considerably higher (*Mitter & Cocuzza, 2013*; *Srivastava et al., 2006*). Drying on the third belt, where the hops are over-dried, takes up to 1/3 of energy requirements for drying, therefore a design has been created in which the over-drying and subsequent moistening in a conditioning chamber is substituted by a system of two cooling chambers where the hop cones will be left for approximately 4 to 8 hr. or longer if necessary. During this time the moisture levels of bracts and strigs will reach an equilibrium value. This equilibrium is essential for the final baling as the increased moisture in the cone strigs might cause the hops to deteriorate. The designed technological process responds to the requirement for an increase in the efficiency of gentle hop drying in belt dryers, for a reduction of drying costs, and for an increase in the quality of the final product (*Chyský, 1977).*



3-transverse conveyor, 4-longitudinal conveyor, 5-conveyor to the cooling chambers, 6-reverse sliding conveyor, 7,8-cooling chambers, 7a,8a-floor discharge conveyors, 9-transverse discharge conveyor, 10-conveyor to the press, 11-square bale press

Fig. 1 Side view of the cooling chambers and system of conveyors



1-filling conveyor, 2-belt dryer, 3- transverse conveyor, 4- longitudinal conveyor, 5- conveyor to the cooling chambers, 6-reverse sliding conveyor, 7,8-cooling chambers, 7a,8a- floor discharge conveyors, 9- transverse discharge conveyor, 10-conveyor to the press, 11- square bale press

Fig. 2 Top view of the deployment of the belt dryer, cooling chambers and system of conveyors

In the proposed technology (Fig. 1 and 2) the dried hop cones are conveyed from the belt dryer (2) with the conditioning switched off into the cooling chambers where the moisture content of the bracts and strigs evens out spontaneously, and the resulting moisture of the dried hop cones rises by 2 up to 4 % to 10 up to 12 % . Chamber filling and emptying system is separated in a way that the first cooling chamber (7) is filled by dried hops which gradually cool down here, and from the other chamber (8) the hops are conveyed (10), during the filling of the first chamber after being cooled down, i.e. after the moisture levels have reached an equilibrium value of 10 to 12 %, to the square bale press (11) where they are baled. Each cooling chamber capacity is 125 m^3 (12.5 x 4.0 x 2.5 m), which corresponds to the belt dryer performance.
The aim of the research, which is presented by the article, is to compare the drying curves with the existing technology of hop drying and using cooling chambers.
Based on the conceptual patented designs and a utility model, in 2018 the apparatus was assembled at the PCHB 750 belt dryer of Agrospol Velká Bystřice Ltd. The proposed technology of the cooling chambers is assembled as follow-up equipment, i.e. a floor plan extension is necessary as well as roofing of the whole space, with regard to the dimensions of the cooling chambers. The assembly was put into operation in the harvest season of 2018.

MATERIALS AND METHODS

The implementation of the new technological process using cooling chambers was preceded by repeated in-process measurements of the dependence of hop cone moisture content, and of bracts and strigs moisture contents separately on the drying time (drying curve) when drying the Saaz variety (*Heřmánek et al., 2016*; *Rybka et al., 2017*). The samples had been taken from each inspection window (Fig. 3) of the dryer (1-9), conditioning (10-11) and conditioning outlet (12). The moisture contents of the whole hops, bracts and strigs were determined by means of the Mettler-Toledo HE43 moisture analyser (*Jech et al., 2011*).
The drying curve shape led us to recommend setting the drying process in a way so that the drying kept going on still on the third belt, not over-drying the hops, with the conditioning switched off, thus the cones reached a moisture content of approximately 9-10 % at the outlet. With the current belt dryers their technological process can be influenced, in that context, by an increased belt speed, or possibly by a change in the dried hop layer height, or even by a highly complicated adjustment of the drying air distribution. Almost all of the adjustments lead to an increase in the hop passage through the dryer and

to a reduction of the drying time. The option covering an increased belt speed was then implemented in such a way so that the hop cone moisture content at the 9th inspection window was approximately 10 %. Following the hops at the dryer outlet, they were continuously loaded into one or the other cooling chamber in which the moisture content of the bracts and strigs evened out spontaneously to a required resulting hop cone moisture, and their temperature stabilized to ambient temperature. The hops were then conveyed to be baled and dispatched.

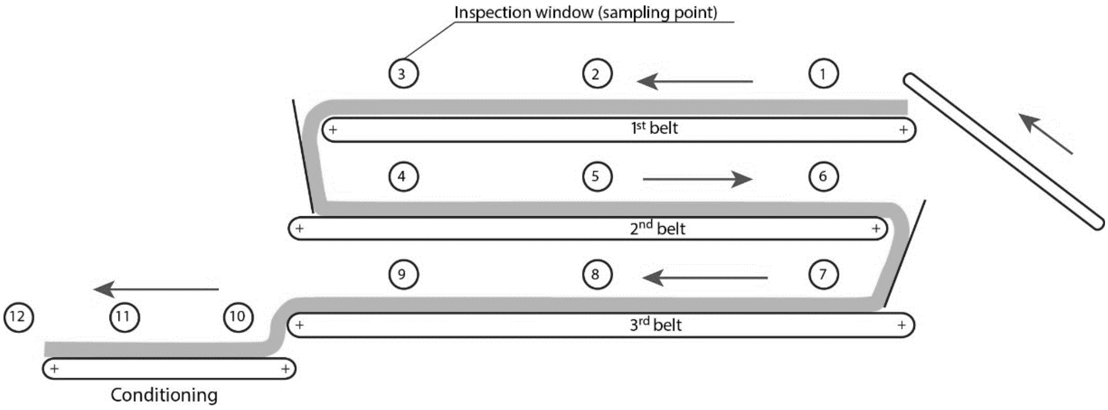


Fig. 3 Scheme of the belt dryer measured area with marked sampling points

RESULTS AND DISCUSSION

1. Dependence of the moisture content of hop cones, bracts and strigs on the drying time (drying curve).

At the beginning of the 2018 harvest season, the drying curve was determined for the Saaz semi-early red-bine hops variety. Several measurements were carried out the results of which did not vary significantly. Fig. 4 shows an example of a drying curve from one of the measurements. The graph makes it possible to assess the relationship between the moisture contents of the whole cones, bracts and strigs. Tab. 1 presents the belt speed and cumulative time of measurement. The drying curve character is defined by the moisture levels at individual inspection windows detected by the moisture analyser for the cones, bracts and strigs (*Kumhála et al.,* 2016; Rybka *et al., 2016*). In order to ensure full drying of the strigs, hops are then over-dried. The product is subsequently moistened by conditioning up to the acceptable moisture level. It is apparent that the strig moisture content declined gradually compared to the bract moisture. Since the ratio by mass of the bracts and strigs was approximately 9:1, in determining the moisture content of cones a value approaching the moisture content of bracts was obtained. The strigs by passing the conditioning were logically gaining a higher moisture more slowly compared to the whole cones the moisture content of which is practically identical to that of the bracts.
The drying curve in Fig. 4 clearly shows that during normal drying the hop cones are considerably over-dried. Already at the beginning of the third belt (inspection window n. 7) the hops are sufficiently dried and even the hop cone strig has a moisture content of 8 to 10 %. Thus, any further drying leads to energy losses, cost increases and to degradation of the hop cone quality. The drying curve illustrates that at least 200 min out of the total drying time is needless drying. The presented dependence resulted in recommendation to set the drying process in a way so that the drying kept going on still on the third belt, not over-drying the hops, with the conditioning switched off, thus the cones reached a moisture content of approximately 9-10 % at the outlet and were subsequently stored in the cooling chambers.

2. Inclusion of the cooling chambers in the technology of hop drying.

In 2018, the issued design was implemented inside the enlarged facility of the picking line and belt dryer of Agrospol Velká Bystřice Ltd. where two cooling chambers were built, interconnected by a system of conveyors following up the PCHB 750 belt dryer outlet (*Rybka et al., 2018*). The entire new technology was subsequently validated. The drying belt speed increased (Tab. 1) in such a way so that the hop cone moisture content at the 9th inspection window was approx. 10 %. Owing to the ratio of the times of passage between the first and ninth inspection window at the initial and the new belt speed, the drying time was reduced by approx. 39 %. Fig. 5 depicts the drying curve of the progress of drying without conditioning and with the subsequent use of cooling chambers. The graph in Fig. 5 clearly shows that upon leaving the belt dryer the moisture content of the strig is relatively high, however, it gradually evens out with the moisture content of the bracts inside the cooling chambers (Fig. 6).

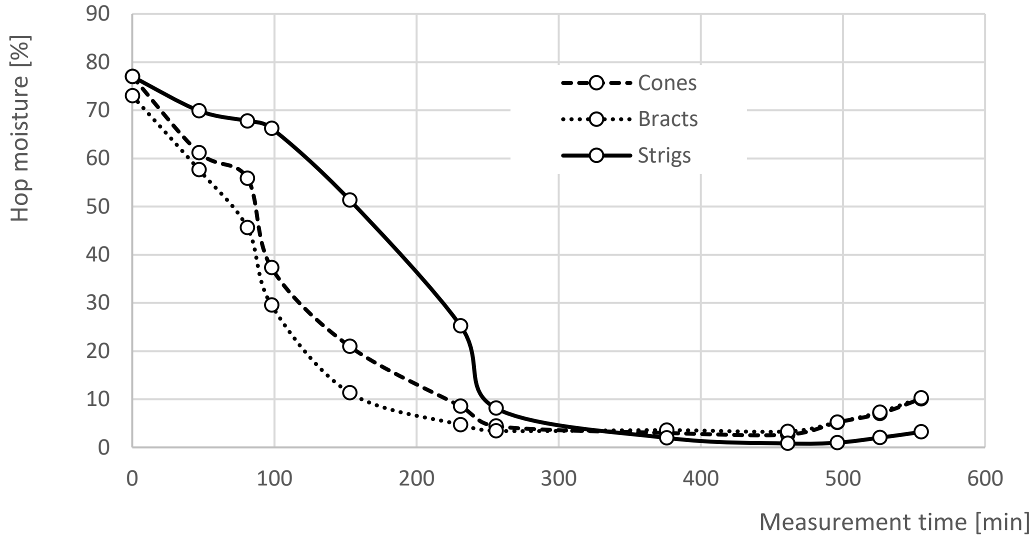


Fig. 4 Dependence of the moisture contents of cones, bracts and strigs on the drying time (points = inspection windows)

Tab. 1 Parameters of hop drying in belt dryer with and without conditioning

Drying with conditioning													
Sampling point		1st belt			2nd belt			3rd belt			Conditioning		
Inspection window		1	2	3	4	5	6	7	8	9	10	11	Outlet 12
Belt speed	$m.s^{-1}$	0.0031			0.0019			0.0012					
Measurement time	min	0	47	81	98	153	231	256	376	461	496	526	555
Drying without conditioning													
Belt speed	$m.s^{-1}$	0.0055			0.0034			0.0019					
Measurement time	min	0	33	56	66	96	139	151	221	279			

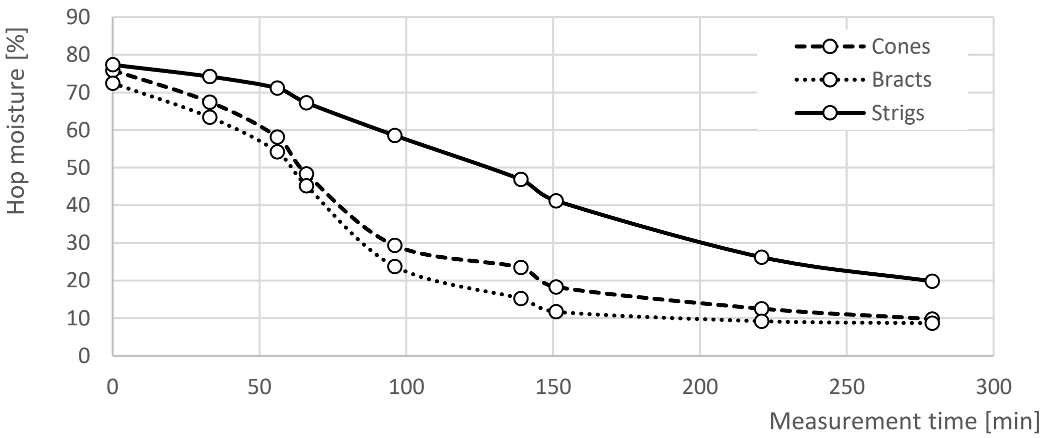


Fig. 5 Dependence of the moisture contents of cones, bracts and strigs on the drying time with the use of cooling chambers

Following the accelerated drying process, we monitored the progress of changes in the moisture contents of cones, bracts and strigs inside the cooling chambers. The graph in Fig. 6 illustrates the gradual mutual transmission of moisture for the cones, bracts and strigs, and their approximation. Our assumption that during the cooling process the moisture content of cones increases by approx. 1 % under the influence of the external atmospheric environment has been fulfilled. The hop cone moisture content at the outlet prior to baling complies with the requirements specified by hop purchasers.

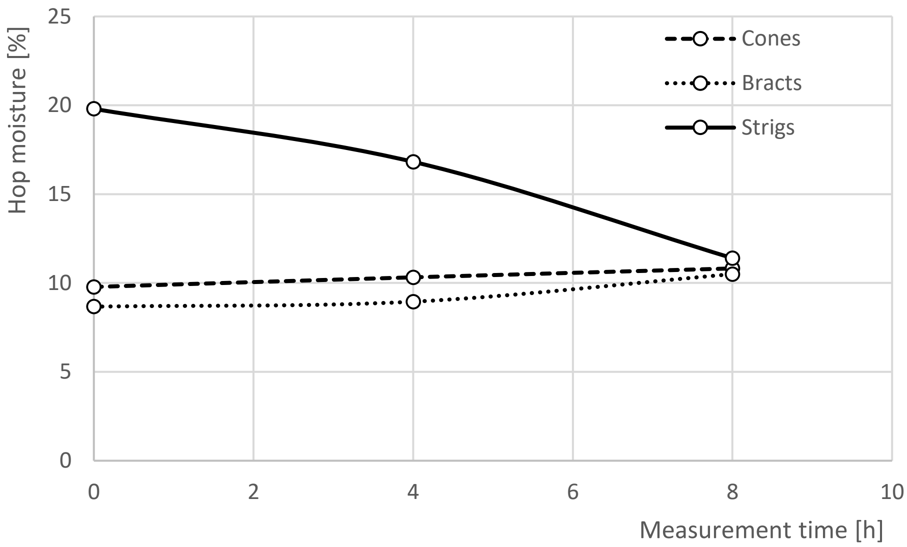


Fig. 6 Dependence of the moisture contents of cones, bracts and strigs on the storage time inside the cooling chambers

CONCLUSIONS

The economic output concerning the inclusion of cooling chambers in the hop drying technology is directly related to the reduced drying time in the belt dryer. This reduction of drying time and elimination of over-drying has significant effects on the increase in the quality of hop cones, reduction of losses in the heat-labile substances, as well as on the final assessment of the hop product (*Krofta, 2008*). Due to our long-standing monitoring of the day-to-day operation it was found out that the inclusion of cooling chambers in the process of hop drying will bring about savings in gas of 2,356 CZK.t^{-1} of dry hops, and savings in electricity of 831 CZK.t^{-1} of dry hops. As a consequence of the anticipated reduction of the harvest period by approx. 39 %, other cost items will be reflected in these savings, such as e.g. salary of the workers participating in the harvest, their use for other activities, savings in the fuel for tractors and in the electrical power for other operations related to the harvest, etc. There are no negative effects that would influence the environmental quality.

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