ANALYSIS OF THE TECHNOLOGICAL PROCESS OF HOP DRYING IN BELT DRYERS

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Abstract
Current problems of the present technology of hop growing include complex innovation in the drying process in existing belt dryers. An emphasis is put on increasing the drying efficiency and innovating the current conditioning. The presented output needs to be preceded by an analysis of the existing drying state. The operating measurement was carried out in three belt dryers and included a measurement of the temperature and moisture content parameters of the drying medium as well as the qualitative parameters of the hops being dried. The drying parameters were monitored by means of continuously recording data- loggers and a laboratory analysis of the samples (hop moisture, alpha bitter acids, hop storage index). The drying process revealed that the hops are virtually dry (10 ± 2.0 % of moisture content) already at the end of the second belt, or possibly at the beginning of the third belt (Stekník). The hop drying in Velká Bystřice proved that hops are considerably over-dried (moisture content of 4 to 8 %) and are subsequently adjusted through conditioning to the final moisture content of 8-10 %. Over-drying leads to a substantial shattering of hop cones, a factor which renders the manipulation with hops for further processing more difficult, leading to larger losses in the lupulin content.

Key words: hops, belt dryer, temperature, moisture content.

INTRODUCTION

The most common method of hop preservation is drying, during which the water content in hop cones reduces from former approx.75 % of moisture content to 8 or up to 10%. Drying is carried out immediately after the hop harvest mostly in belt dryers that are operated continuously (3 belts). Hot air is the drying medium here which is heated by burning natural gas or light heating oil. The maximum drying temperature ranges between 55°C to 60°C and is practically stable for the entire duration of drying. Hops are exposed to this temperature for 6 to 8 hours (HENDERSON, MILLER, 1972; HENDERSON, 1973).

The stability of alpha bitter acids as a key substance in hops from the point of view of brewing technology is sufficient at drying temperatures not exceeding 60°C (DOE, MENARY, 1979). However, for some heat-labile substances the drying temperatures ranging from 50 to 60°C in the final stage of drying are too high. At such temperatures irreversible transformation and losses occur. An example of these substances is hop essential oils that are contained in hops in the amount of 0.5 – 3.5 % depending on variety (HOFMANN ET AL., 2013). The pilot studies proved that 15 to 25 % of the total content of essential oils present in hops before drying decrease under the current drying conditions (KIENINGER, FORSTER, 1973). Besides the loss in amount, also the sensory profile alters as a consequence of decrease in more volatile components. Regarding special aroma hop varieties, so-called "flavour hops", in which the content and composition of essential oils are key quality parameters, such losses lead to a decline in the product quality.

The currently used belt dryers are out-dated, implemented in the 70s and 80s of the last century. The overall capacity of drying technologies is now 9500 tons of dry hops, which represents a capacity that is higher by 38 %, the total production being approx. 6000 tons of dry hops. It follows that there is no need to build new dryers for hops but to focus on modernisation and automation of the drying process as a whole in the existing drying technologies.

One of the tasks referring to the currently solved NAZV research project of the Czech Ministry of Agriculture is therefore the complex innovation in the drying process in existing belt dryers. The expected economic benefit should be brought by saving the heating medium as well as electricity, deriving from shortening of the drying time, increasing of the facility capacity and shortening of the harvesting time (RYBÁČEK, 1991). The object of the given research is to pass on to hop-processing plants inter alia a drying process that had gone through a complex innovation, with particular emphasis on increasing the efficiency of drying and on innovating the conditioning system

(HANOUSEK ET AL., 2008). Related to that is a design and implementation of belt dryer adjustments, including automation of the operations and continuous measuring of stability and control of the drying process. The object of this paper is an analysis of the current state of hop drying, conditioning and stabilization, which precedes in terms of content the innovation in the entire process of hop drying.

MATERIALS AND METHODS

The operating measurement was carried out in belt dryers being parts of the plants of the co-researchers:

- The Research Farm in Stekník, Hop Research Institute Co., Ltd., Žatec - PSCH 325 belt dryer,
- Agrospol Velká Bystřice Ltd. - PSCH 750 belt dryer and PSCH 900 belt dryer.

The measured parameters were the temperature and moisture parameters of the drying medium, and the qualitative parameters of the hops being dried – temperature, moisture content, drying time (JECH ET AL., 2011). Given the large extent of the measured values, only selected results constitute the content of this paper. Further results are available at the authors.

The monitored parameters were being determined in two ways:

- through measuring by means of inserted data-loggers,
- through a laboratory analysis of the samples.

To measure continuously the air temperature and relative humidity inside a layer of the hops being dried, VOLTCRAFT DL-121-TH data-loggers were employed which allow for setting the frequency of data storage (SRIVASTAVA ET AL., 2006). In our case this frequency was set to 5 minutes. The data-logger internal memory is able to store 32000 of measured data, which is absolutely sufficient. The data-logger was integrated together with the sensor in a plastic case and powered via an inserted battery. The plastic case was fitted with a USB connector at one of its ends, via which the stored data were imported into the computer.

To protect them against mechanical damage in the course of passing through the dryer and against being soiled by lupulin, we fixed the data-loggers into polyurethane material and inserted them into two stainless half-spherical sieves. This guaranteed their sufficient protection, the sieves did not impede the air permeation and there were no mistakes in measuring (Fig. 1).

In the dryer, three data-loggers were placed through the first check window on the first (upper) belt, two of them approx. 0.5 m far from the left and right dryer wall and one in the middle (Fig. 2).

The advantage of data-loggers compared to fixed sensors in a dryer is that they pass together with hops through the dryer, continuously recording the entire drying process. The following graphs are based on the average values received from the employed data-loggers.

Fig. 1. – Inserting a data-logger into a protective sieve

Hop samples were being taken throughout the process of drying, following a pre-determined schedule, and then were submitted to a laboratory analysis. The analysis allowed for identification of the hop storage index HSI, the content of alpha bitter acids, and the hop sample moisture content was also determined.

The first sample was always fresh green hops taken immediately after picking. Other samples were taken at check window points (Fig. 3) by individual belts, three samples from each belt. Last samples were taken prior to and after the conditioning, and one more sample prior to baling.

Fig. 2. – Deployment of data-loggers to dryer width

In Stekník as well as in Velká Bystřice the monitored hops were mainly of the Saaz hop variety. The hop moisture content was determined in the laboratory dryer of the Hop Research Institute Co., Ltd, Žatec with forced air circulation according to the EBC 7.2 method. The HSI hop storage index was determined using the EBC 7.13 conventional spectrophotometric method from a toluene hop extract. The content of alpha bitter acids was measured by liquid chromatography according to the HPLC EBC 7.7 method (KROFTA, 2008; WEIHRAUCH ET AL., 2010). Tables and graphs were created reflecting the results of the hop sample laboratory analyses.

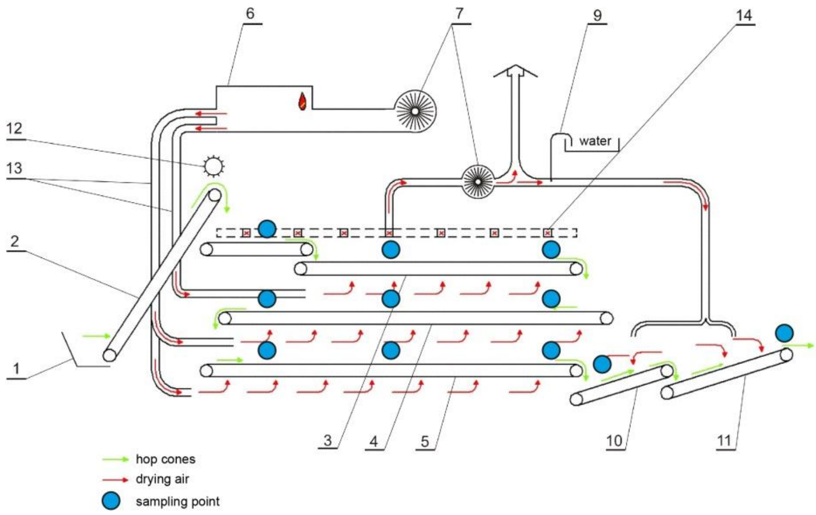

Fig. 3. – Scheme of the belt dryer with indicated sampling points

1 - hopper, 2 - inclined wire mesh conveyor, 3(4,5) - upper (middle, lower) drying wire mesh conveyor, 6 – hot-air aggregate, 7,8 - fan, 9 – water management, 10(11) - first (second) wire mesh conveyor of the conditioning chamber, 12 – straightening roll, 13 - distribution air pipes, 14 - suction openings

RESULTSAND DISCUSSION

The Research Farm in Stekník of the Hop Research Institute Co., Ltd., Žatec

The graph in Fig. 4 clearly shows that the whole drying process is recorded when measured continuously. Around the 90th minute the temperature dropped and the relative humidity increased due to the dryer failure and following forced interruption of operation.

Fig. 5 presents an example of one measurement carried out with samples from a laboratory dryer. Besides hop moisture content, the graph also depicts the hop storage index HSI progresses. The graph in Fig. 6 confirms the previously stated progress of the hop moisture content dependency on hop passage through the dryer. A conclusion can be drawn that hops are dried to approx. 10% of moisture content already at the end of the second belt. The laboratory analyses also indicate that only minimum changes occur both in alpha bitter acids and the HSI after the hops have passed through the belt dryer.

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Data-loggers enabled measuring of the Saaz hop variety in both dryers. This measurement was very problematic, for due to a low yield the drying continuity was often interrupted and the belt dryers were put out of operation many times.

In both dryers the ambient environment was measured only on the third belt and in conditioning. The resulting values are to be found in Fig. 6 and 7. Both measurements confirmed that hops are already dried on the third belt and are unnecessarily over-dried, which means wasting of energy expended to heat the drying air.

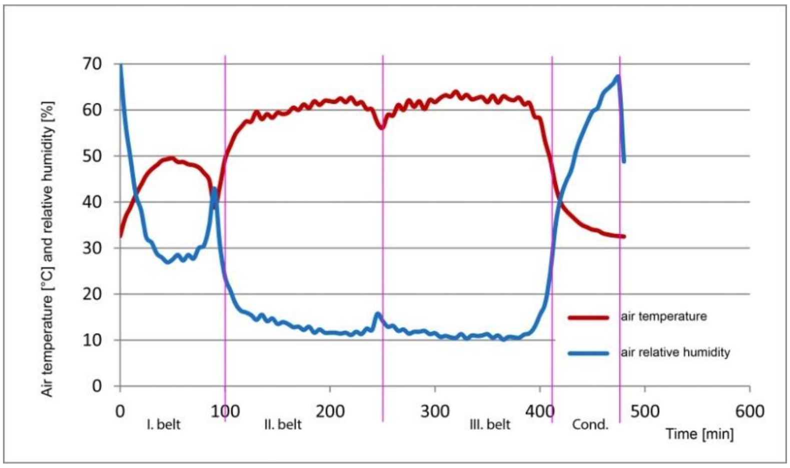

Fig. 4. – Air temperature and relative humidity of the Saaz hop variety measured by means of data-loggers

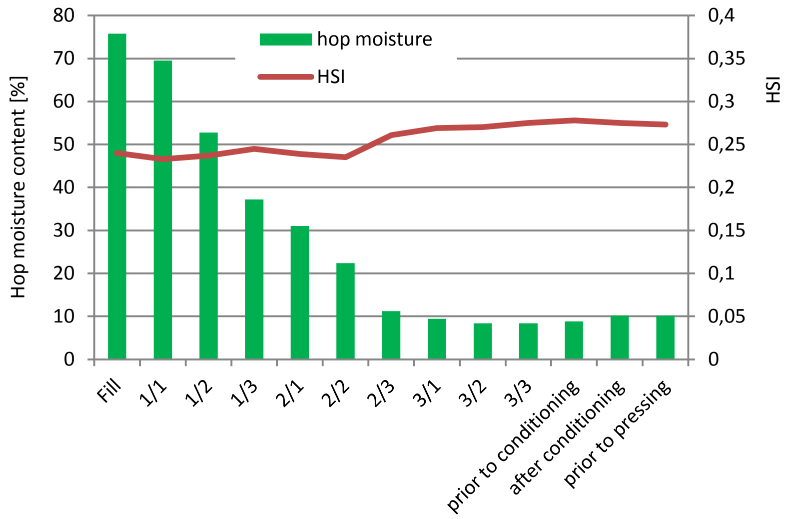

Fig. 5. – Progress of the hop moisture content and HSI with samples of the Saaz hop variety(1/1 – 1st belt and 1st window…)

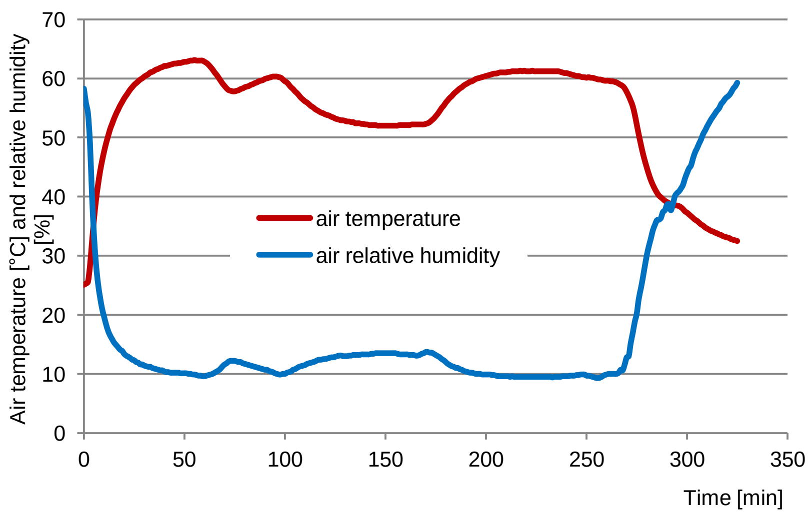

Fig. 6. – Air temperature and relative humidity with the Saaz hop variety measured by means of data-loggers in the PSCH 750 belt dryer

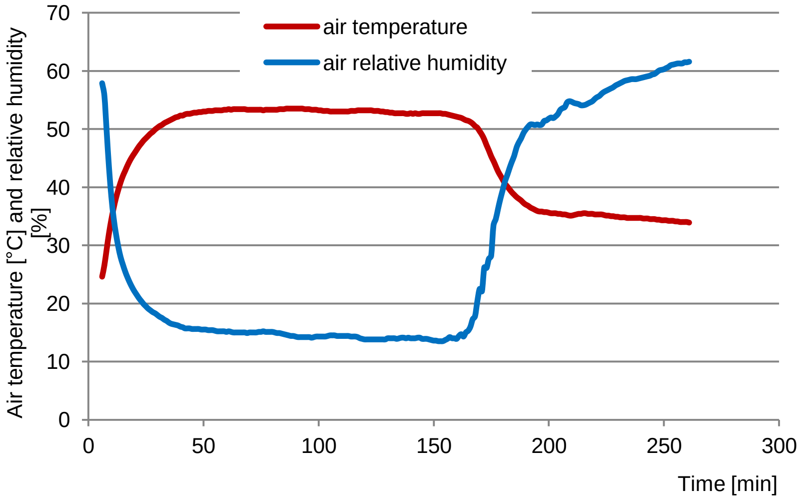

Fig. 7. – Air temperature and relative humidity with the Saaz hop variety measured by means of data-loggers in the PSCH 900 belt dryer

In the plant of Agrospol Velká Bystřice Ltd. samples were taken in both belt dryers when drying the Saaz hop variety.

Examples from the individual measurements are given in Fig. 8 and 9. Besides hop moisture contents, the graphs also illustrate the hop storage index HSI progresses.

The graphs in Fig. 8 and 9 (Velká Bystřice) show similar progress to the graph in Fig. 5 (Stekník), which suggests the same sub-conclusion.

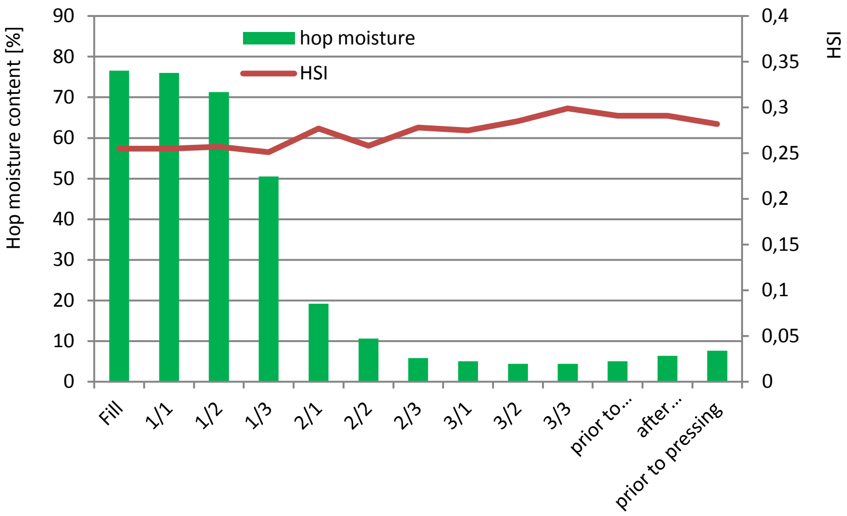

Fig. 8. – Progress in the hop moisture content and HSI with the Saaz hop variety samples in the PSCH 750 belt dryer

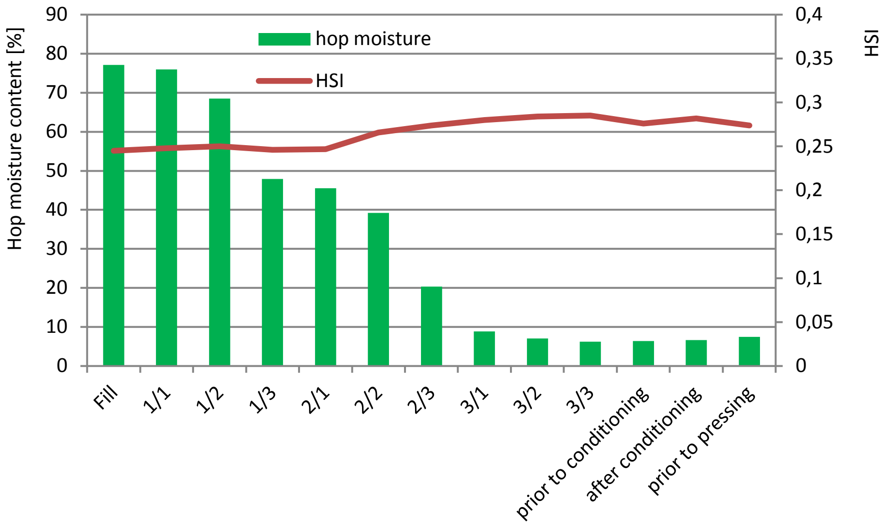

Fig. 9. – Progress in the hop moisture content and HSI with the Saaz hop variety samples in the PSCH 900 belt dryer

CONCLUSIONS

The progress of drying in the operating belt dryers showed that hops are practically dry (10 ± 2.0 % of moisture content) already at the end of the second belt, or possibly at the beginning of the third belt (Stekník). Hop drying in the belt dryers in Velká Bystřice proved that hops are considerably over-dried (4 to 8 % of moisture content) and are subsequently adjusted to the final moisture content of 8-10 %. According to the company staff this state is intentional, working as prevention against the occurrence of nests of moist hops, which occurs on irregular basis when drying hops with high initial moisture content. The causes of such state (nest occurrence) should be examined in greater detail in the next project solution. Over-drying results in extensive hop cone shattering, rendering the manipulation with hops for further processing more difficult and leading to larger losses in the lupulin content.

The reports from travels to important hop-growing areas in the USA, Germany and China provided by hop experts showed that in these countries hops have been dried and processed in a similar way, therefore we may assume similar outputs from the measurement. Foreign research centres do not deal with the given issues, which is the reason why there are no comparable results available for possible discussion.

As indicated in the above, there is great room for improvement in the whole drying process, both in terms of energy and the quality of the final hop product. A complex innovation in the hop drying process in the current belt dryers is very much needed and logically we may assume savings for heating medium and electric energy, resulting from shortening the drying time, increasing the capacity of the facility, and shortening the harvest time. In case of the concept of low-temperature drying no energetic savings can be expected, but the main economic benefit will lie in increasing quality of the product which the hop growers will realise at higher prices.

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