ANALYSIS OF HOP MATTER SEPARATION WITH INCREASED ROLLER CONVEYOR THROUGHPUT

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Abstract

This paper focuses on a roller conveyor, which forms a part of separating machine line and is located after the secondary picker. The roller conveyor serves here as a roller sieve.

Before the 2015 harvest season started, rollers with new structure had been designed and manufactured. These rollers were to enhance the share of admixtures that had been separated out. In the season of 2015, several laboratory measurements were carried out in order to verify the function of these rollers.

This paper presents results of the measurement verifying the function of rollers at enhanced throughput of the roller conveyor. The throughput was enhanced from the standard 450 $kg.h^{-1}$ to 900 $kg.h^{-1}$in order to simulate a situation when the material entering the roller conveyor is not evenly layered. The aim was to determine the dependency of hop matter falling through on the gap size between rollers and on the roller rotation frequency.

Key words: separation line, hop matter, roller conveyor, curve of falling through.

INTRODUCTION

Hops are nowadays used principally as one of the basic ingredients in hop brewing. Ninety-eight percent of the world hop production is grown for exactly this purpose (CARTER ET AL., 2000). Their use for other purposes is not mentioned in the world statistics. However, their importance in pharmaceutics is well-known, as besides the basic substances adding the basic sensory characteristics to produced beer (bitterness, aroma and full flavour), hops also contain a number of other substances of medical importance (JURKOVÁ ET AL., 2011; VRZALOVÁ&FRIC, 1994). For instance, flavonoids contained in hop cones appear promising as antioxidants and antivirals, particularly against the HIV virus (WANG ET AL., 2004).

This paper deals with separating the hop matter which is harvested from low trellises. In this growing system, hop bines climb (twine) spontaneously up a special plastic network that is a substantial part of the low trellis system. This way eliminates a complicated hiring of labour for the most difficult operations, such as hanging and sticking of hop strings and hop-bine training (ŠTRANC ET AL., 2012; ŠTRANC ET AL., 2010).

Majority of the traditional hop varieties cannot be grown on low trellises, for then they reach only 40 to 60% of the yield they would achieve on classic trellises (SEIGNER ET AL., 2008). The new "dwarf" varieties bred for low trellises should, according to breeders and economists, reach at least 80% of the yield reached by the varieties grown on classic trellises (DARBY, 1999).

In the Czech Republic, hop growing on low trellises is now in the experimental stage and the current acreage of low-trellis hop-fields counts for only less than 50 ha (EAGRI, 2014).

For this growing technology different machinery is needed. The hops from low trellis are harvested by means of a mobile harvester, pulled by tractor. The hop matter brought from the mobile harvester is then submitted to separation on a mechanical line which is adjusted in a way compared to the classic mechanical picking line. The process of separation shall ensure that hop cones are separated from stems and leaves (JECH ET AL., 2011).

This paper is focused on the part of separating machine which is located after the secondary picker, namely the roller conveyor with infinitely adjustable pitch of each roller. Its importance lies in separating hop cones from stems and leaves. The main function of the roller conveyor is to separate the hop matter into small-sized fraction formed by hop cones, leaves and fragments of size smaller than the size of the gap between individual rollers, and into large-sized fraction such as stems, clumps, big leaves which cannot fall through the rollers (NEUBAUER ET AL., 1989).

The right operation of the roller conveyor depends on several parameters. They are the rotation frequency of the rollers, roller profile, and the gap between individual rollers. To be able to determine the precise significance of these parameters, a model of such a roller conveyor was made in 2014, which is a scale copy of the real roller conveyor used in the separation line employed for separation of hops grown on low trellis (KRUPIČKA & RYBKA, 2014).

Previous measurements from the 2015 harvest season showed the advantages of rollers with tooth profile which had been designed and manufactured in the same year. The measurements confirmed our assumption that more leaves and small-sized admixtures are separated out into the waste with a shrinking gap.

A frequent problem that has not been sufficiently solved yet with the separation line prototype is uneven feeding of hop matter from the line feeder. For that reason larger clusters of hop matter sometimes get onto the roller conveyor.

The aim of this measurement was to determine the quantity of admixtures and cones separated out using these new rollers with tooth profile at double material throughput on the roller conveyor. Double throughput means double amount of material, thus simulating the already mentioned hop matter clusters.

MATERIALS AND METHODS

Roller conveyor model

The model (Fig. 1) has 9 rollers in total and they are 600 mm long. The first roller is rigidly attached to the frame, the remaining 8 rollers have adjustable pitch allowing to change the between them. The space underneath the rollers had been divided by means of KAPA boards to be able to determine the amount of hop matter fallen through the gaps. The hop supply was provided by a belt conveyor 600 mm wide and 1000 mm long.

Fig. 1. – Model of roller conveyor

For the purpose of the measurement new rollers were used, with a diameter of 89 mm and tooth profile of their metal welded collars (Fig. 2). On a tube there are 14 welded collars 39 mm apart. A welded collar has 30 teeth and an outer diameter of 125 mm. Owing to an enlarged tube diameter and a welded collar height of 17.5 mm the gap between rollers can be set to 20 mm. This profile of metal welded collars is more efficient in catching leaves and small twigs and moving them further upon the rollers.

Fig. 2. – Laboratory roller conveyor with rollers fitted with tooth profile welded collars

Methodology of the measurement

The 2015 harvest season measurements used again the hop variety Sládek, harvested from low trellises. To prevent the hops from changing their characteristics during their separation, fresh hop matter was brought from the hop grower every single measurement day. The hop matter sample was selected so that the percentage representation of individual components (hop cones, leaves) remained unchanged.

The sample corresponding to the standard throughput of the model roller conveyor, which is 450 kg.h^{-1}, weighs 450 g. For the purpose of this measurement the sample weight was doubled to a value of 900 g (Fig. 3). This way simulated the doubled amount of material conveyed by the roller conveyor. The other parameters remained unchanged – the peripheral speed of the conveyor belt 0.27 m.s^{-1} and the basic rotation frequency of the rollers 0.67 s^{-1}. These values correspond to the real ones and had been set by means of frequency converters.

Fig. 3. – A hop matter sample evenly spread over the conveyor belt

The sample contained 336 g of cones and 564 g of leaves. The average hop cone size was determined out of a sample comprising of 100 pieces. The average value of the hop cone length was 28.3 mm and the average value of the cone diameter was 16.6 mm.

The measurement was conducted in such a way that the hop matter sample was mixed and evenly spread over the conveyor belt. Then the roller drive was switched on, followed by the belt conveyor drive. The hop matter was being continuously separated on the roller conveyor and thanks to KAPA boards, installed underneath each roller, was falling through into 7 containers. The individual components of the hop matter that fell in between rollers were weighed accurate to 1 g.

The dependency of hop matter falling through on the gap size between rollers at doubled throughput was determined for these three gaps – 20, 24 and 28 mm. Also the dependency of hop matter falling through on the roller rotation frequency was examined with all the gap sizes between rollers.

RESULTS AND DISCUSSION

Comparison of three different gaps between rollers and the basic rotation frequency

Based on the measured data a curve of hop matter falling through was established for three gap sizes between rollers (20, 24 and 28 mm) and is depicted in the graph of Fig. 4. The graph clearly shows that at the smallest gap setting of 20 mm the hop matter falls through more evenly. This is noticeable particularly with the first two gaps between rollers. It is favourable in terms of separation, since the amount of neither the hop matter nor admixtures fallen through the first gap was so great.

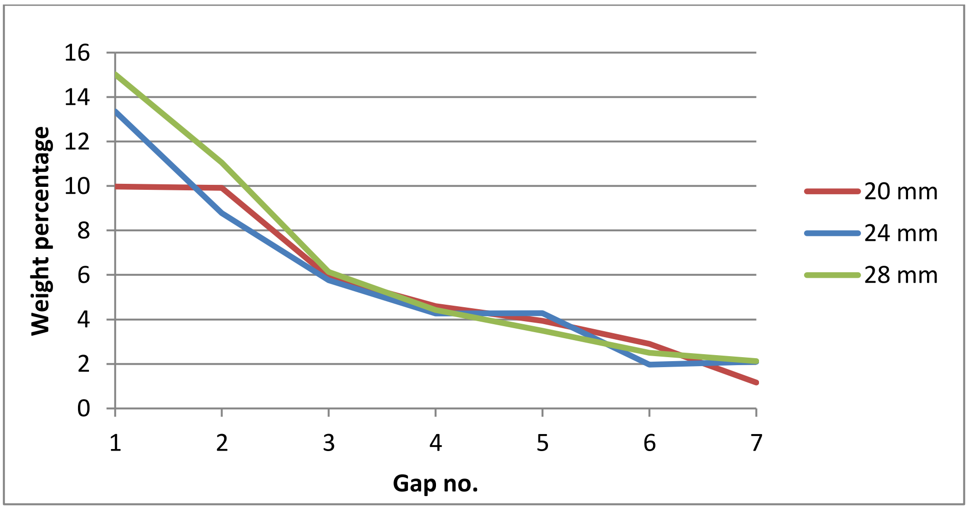

Fig. 4. – Weight percentage of the hop matter fallen through the separate gaps with rollers of 89 mm in diameter and rotation frequency of 0.67 s^{-1}

As regards the leaves and cones in the waste, the best results in terms of separation were measured with the gap setting of 20 and 24 mm (Fig. 5). The values measured for these two gaps were almost identical. Approximately 91% of all leaves were conveyed into the waste. With the gap set to 28 mm they were 86%. The following graph in Fig. 6 illustrates a comparison with the standard throughput of 450 $kg.h^{-1}$ measured in the previous measurements. It can be seen that at doubled throughput by approx. 20% more admixtures are conveyed into the waste. With the gap of 20 mm it is by about 10% more admixtures. These results are logical because the hop matter sample is not quite ideally separated between nine rollers.

The measured values correspond to theoretical assumptions of the relationship for the calculating the quantity of small-sized fraction *Qs*, which fall through on the length of the roller track *l* per unit of time (NEUBAUER AT AL., 1989).

$$Q_p = \left(\frac{1}{Q_2} + \frac{G_o}{{Q_2}^2} * \frac{1}{\beta * l}\right)^{-1} \quad (1)$$

Where:

Q_2 - the quantity of small-sized fraction coming to the track per unit time [kg.h^{-1}]

G_o - the quantity of large-sized fraction coming to the track per unit time [kg.h^{-1}]

β - coefficient of intensity of sieving which depends on the height of the layer of the incoming material and it is in the range $0 < \beta \leq 1$

The relationship shows that an increase in weight of small-sized and large-sized fraction, but maintaining the same length of tracks, fall through less the quantity of small-sized fraction *Qp*. For this reason is in the waste found relatively large percentage of hop cones (NEUBAUER AT AL., 1989).

Theory of grain separation is the similar when it is separated straw from grain. With the increased flow of material through the walker is not sufficiently material separated and arises losses, when the grain goes to waste (SRIVASTAVA ET AL., 2006).

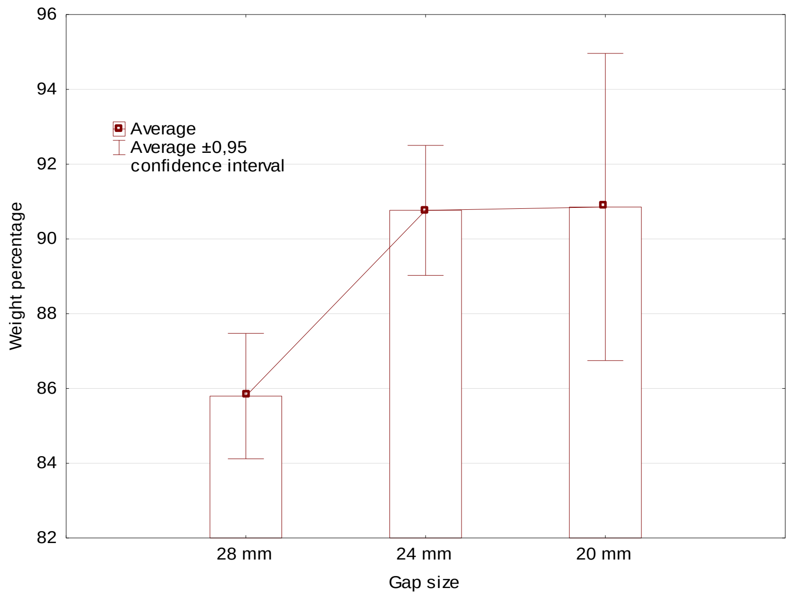

Fig. 5. – Weight percentage of leaves and small-sized admixtures in the waste with rollers of 89 mm in diameter and rotation frequency of 0.67 s^{-1}

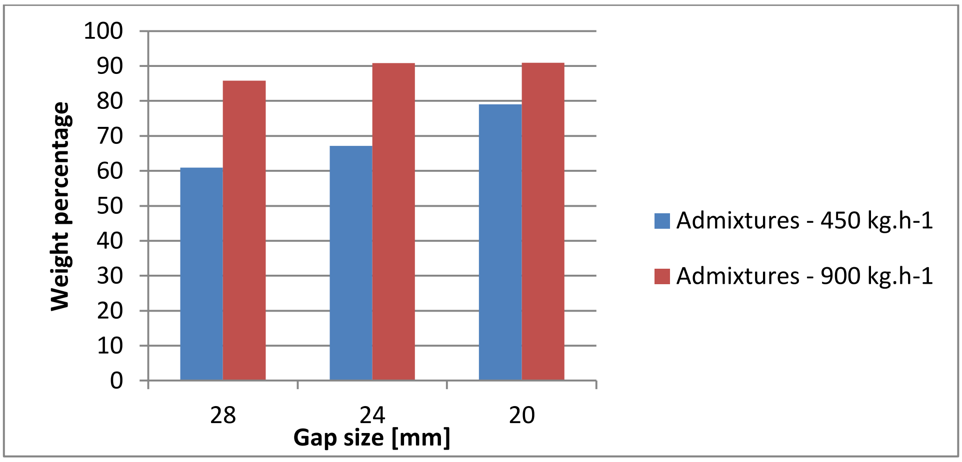

Fig. 6. – Weight percentage of leaves and small-sized admixtures in the waste with rollers of 89 mm in diameter, rotation frequency of 0.67 s^{-1} and two versions of throughput

Insufficient separation was reflected in the quantity of cones that were found in the waste. The graph of the following figure (Fig. 7) illustrates how many hop cones were conveyed into the waste. It shows that with decreasing gap between rollers more cones get into the waste. With the gap setting of 28 mm it is 3.7%, and with the smallest gap sized 20 mm it is even 12.8%. In terms of losses these values are absolutely unacceptable.

The following graph in Fig. 8 again compares the standard throughput of 450 kg.h^{-1}. Here it can be seen that at the standard throughput of 450 kg.h^{-1}cone losses are minimal. With the gap of 28 mm they are zero. With the gap set to 24 mm only 0.2% of cones were found in the waste. With the smallest gap of 20 mm the results were a little worse, on average 1.6% of cones get into the waste.

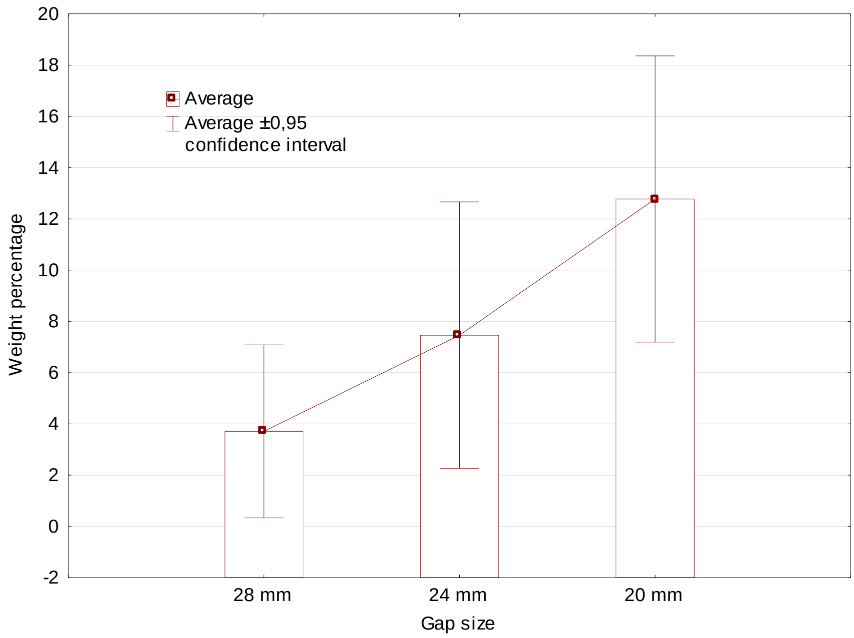

Fig. 7. – Weight percentage of hop cones in the waste with rollers of 89 mm in diameter and rotation frequency of 0.67 s^{-1}

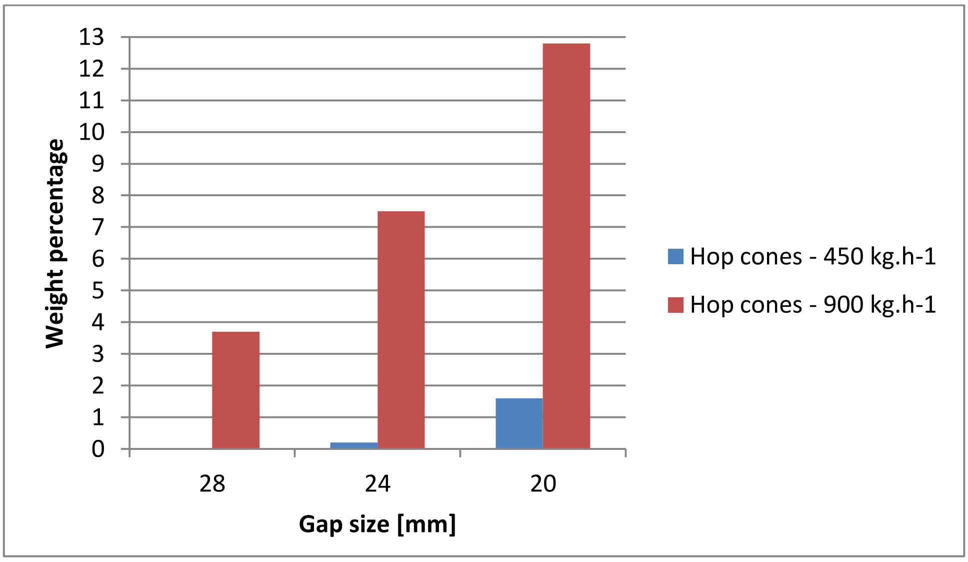

Fig. 8. – Weight percentage of hop cones in the waste with rollers of 89 mm in diameter, rotation frequency of 0.67 s^{-1} and two versions of throughput

Dependency of hop matter falling through on the gap size and rotation frequency of rollers

The processed measured data revealed that the rotation frequency of rollers have no significant effect on separation of leaves or cones. Our assumption that an increased rotation frequency of rollers would cause a higher percentage of leaves and small-sized admixtures to leave for the waste, was not confirmed. The following graph in Fig. 9 illustrates the weight percentage of leaves and small-sized admixtures in the waste for the gap of 24 mm and three rotation frequencies of rollers. With an increased rotation frequency of rollers a slight decline in the amount of leaves separated out in the waste can be observed, although from a statistical point of view no dependency can be derived from the measured data.

The graph in Fig. 10 presents the weight percentage of hop cones in the waste for the gap of 24 mm and three rotation frequencies of rollers. Here the difference is really minimal and again no dependency can be derived.

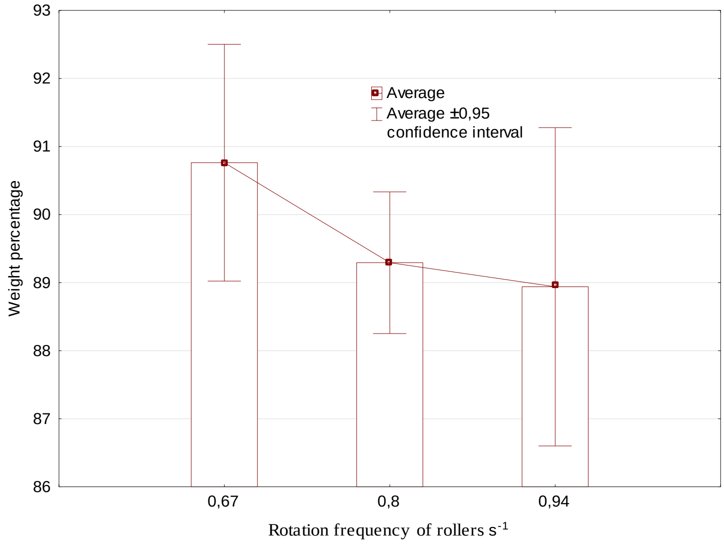

Fig. 9. – Weight percentage of leaves and small-sized admixtures in the waste with rollers of 89 mm in diameter, gap of 24 mm and three rotation frequencies

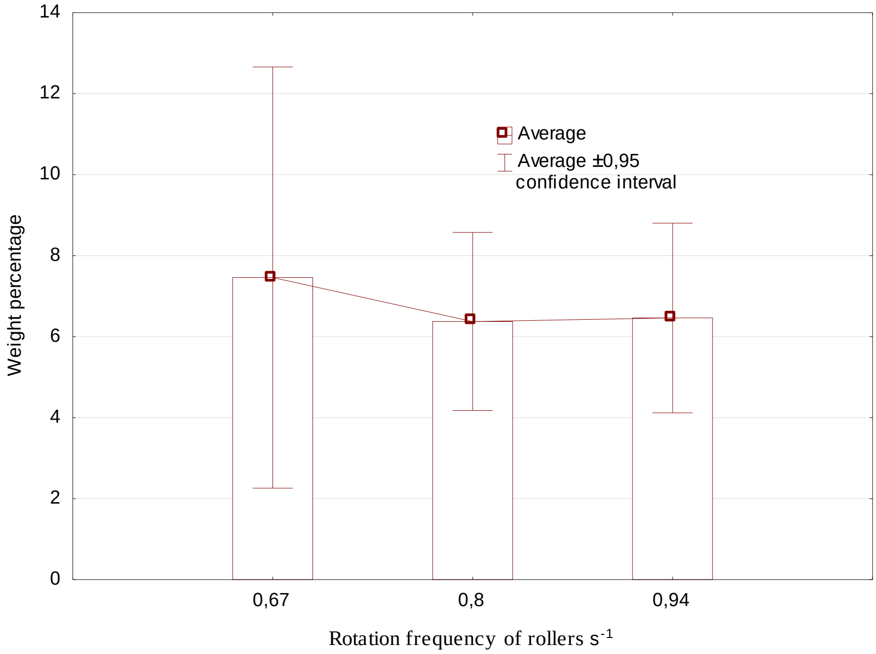

Fig. 10. – Weight percentage of hop cones in the waste with rollers of 89 mm in diameter, gap of 24 mm and three rotation frequencies

CONCLUSIONS

These measurements, the same way as the previous ones in 2015, were carried out with a hop matter sample that contained only hop cones and leaves. The amount of these two components had been precisely defined. The measurements simulated an increased material throughput on the roller conveyor. They confirmed the assumption that decreasing gap between rollers results in a larger amount of admixtures that are conveyed to the waste. Compared to the common throughput, by approx. 10 to 20% of leaves more were separated out into the waste. Hop cone losses of 3.7 to 12.8% according to the gap setting are unacceptable. It can be seen that hop matter is not sufficiently separated on a conveyor consisting of nine rollers with the gap size of 20 to 28 mm between them. To achieve a real inclusion of these rollers into the separating line, the number of rollers would need to be increased.

No statistically significant differences were found when comparing different rotation frequencies of the rollers.

ACKNOWLEDGEMENTS

Processed with the support of TA CR within the TA03021046 project solution.

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