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Comparison of power consumption of a two-roll mill and a disc mill

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Abstract. Grinding or milling is often used process, for example in the production of feed, grinding of malt in beer production, grinding of cereals on flour, etc. In order to optimize the energy intensity of the whole production process, it is necessary to know the energy consumption of individual processes. The grinding of malt influences the mashing process, the drawing-off and the boiling yield. Correct grain grinding makes the endosperm available for enzyme and physicochemical reactions during wort production. Husks affect the drawing-off process. Two-, four- or six-roll mills, in some cases a hammer mill or disc mill, are most commonly used for grinding of malt. Power consumption was monitored when light, Munich, caramel and coloring malt were grinding. A two-roll mill and a disc mill with engine speeds of 1,500 rpm and 2,800 rpm were used for grinding. The gap between the mill rollers and the mill disks was set to 0.4 mm. The fineness of the grinding was evaluated for all types of malt on all used equipment. The energy intensity of the grinding was correlated on 1.0 kg of malt and then compared.

Key words: malt, grinder, dispersant, electrical power, mechanical power.

INTRODUCTION

At present, the process of production or processing also tracks the energy intensity of processes, as it is one of the ways to reduce production costs (Kunze, 2010; Chládek et al., 2013).

Traditional procedures may not always be the least energy consuming, and it may sometimes be appropriate to adjust the production process with respect to energy consumption while maintaining the other requirements.

Beer production is demanding energy consumption. Throughout the manufacturing process, there are a number of energy-intensive technological processes - malting, malting, boiling, cooling and more. The energy intensity of breweries depends on their size, equipment level and the introduction of austerity measures. As has been said, one of the processes that consume energy is malting.

Malt grinding is a mechanical and seemingly simple process that fundamentally influences the process of mashing, drawing-off and the brewing yield. Mechanical breakdown of malt grain is necessary to make extractive substances available and accelerate their dissolution.

Malt grain consists of husks and endosperm. The endosperm is composed mainly of starch, glycids and proteins. Correct grain grinding makes the endosperm available for enzymatic and physical-chemical reactions in the wort production. Husks affect the process of drawing-off. The requirements on fineness of grinding vary depending on the process of drawing-off used, which is influenced by the type of beer produced.

For filtration vat, the grist should have the most thoroughly grinded, at least damaged husks, a low proportion of coarse semolina and a high proportion of fine semolina. These requirements are most often met by malt mills (roller mills) which contain two, four or six milling rollers (Kosař & Procházka 2000; Basařová, 2010).

The grist for mash filter should have, on the contrary, well-milled husks. For grinding for mash filter is usually preferred hammer mill or a disc mill (Chládek, 2007; Vaculík et al., 2013).

In this work, the energy intensity of grinding on a two-roll mill and disc mill is monitored. It builds on the previous work, where a sieve analysis of the malt grist was carried out for these grinding devices.

MATERIAL AND METHODS

The energy consumption of grinding of different types of malt when using different devices was measured. It was used two-roller mill KVM 130/150 (Fig. 1), made by KVM Uničov, Czech Republic, with maximum performance 250.0 kg hour^{-1} and two electric motors, each with input 2.05 kW. Grinding gap width was set to 0.4 mm. Roll speed was 250 rpm.

The second device was disc mill Skiold SK 2500 (Fig. 2), made by Skiold Sæby, Denmark. To this disc mill is connected a drive dynamometer type DS 546-4/V made by Mezservis Vsetín, Czech Republic, with output 26.0 kW. Gap width between the grinding discs was set to 0.4 mm. Disc mill was used with 1,500 rpm and 2,800 rpm.

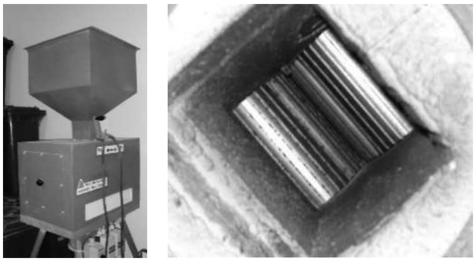

Figure 1. Two-roll mill KVM 130/150.

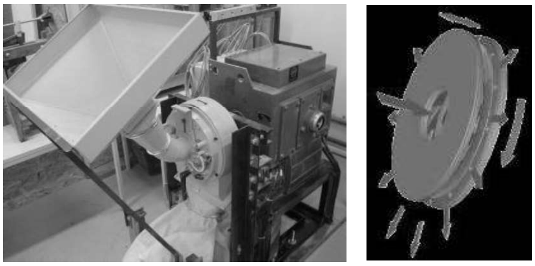

Figure 2. Disc mill Skiold SK 2500.

Both grinding devices, on which the measurement was made, are part of he laboratories that fall under the Department of Technological Equipment of Buildings of Faculty of Engineering at the Czech University of Life Sciences Prague.

Dry grinding of malt was made on both devices and four kinds of malt were processed (Table 1).

Table 1. Basic properties of malt

Malt type	Producer	Malt colour (EBC)	Humidity (%)
Light barley malt (pilsner type)	Soufflet, Hodonice, Czech Republic	3–4	5.1
Barley malt called Munich	Heinz Weyermann, Bamberg, Germany	15	4.8
Barley malt called colouring	Heinz Weyermann, Bamberg, Germany	1,100–1,300	4.1
Barley malt called caramel	Heinz Weyermann, Bamberg, Germany	150–200	4.5

Two-roll mill

Samples of malt weighing 3.0 kg were used for individual measurements. The Nanovip Plus network analyzer was used to measure the values.

The first measurement took place idling speed and then was open a flap blocking the supply of malt between the cylinders. Values were recorded at two second intervals. From the measured values of current, voltage and power factor, the electrical power is calculated using the following formula (Pokorný, 2003; Feynman et al., 2011).

$$P_e = U \cdot I \cdot \cos\varphi \quad (1)$$

where P_e – electrical power (W); U – voltage (V); I – current (A); $\cos\varphi$ – power factor (-).

Disc mill

Samples of 3.0 kg malt were used for individual measurements. A computer with original software from MEZ Vsetín was used to measure the values. Due to the fact that the device allows changing the engine speed, two values were chosen for the given measurements, namely 1,500 rpm and 2,800 rpm.

The first measurement took place idling speed and then was open a flap blocking the supply of malt between the discs.

From the measured speed and torque values, the mechanical power is calculated using the following formula (Čadil, 1976; Feynman et al., 2011).

$$P_m = M \cdot 2\pi \cdot \frac{n}{60} \quad (2)$$

where P_m – mechanical power (W); M – torque (N.m); n – speed (rpm).

RESULTS AND DISCUSSION

All obtained samples of malt grist were categorized on Pfungstadt sifter. Using a roller mill, the obtained grist was the coarsest for all types of malt, the finest grist was obtained using a dispersant at 2,800 rpm (Vaculík et al., 2010; Smejtková et al., 2016).

The course of power in dependence on time for individual devices and malt samples is shown in the Figs 3–6.

Fig. 3 illustrates the energy consumption over time when grinding a light malt using a two-roll mill, disc mill 1.500 rpm and disc mill 2.800 rpm. The highest values of energy consumption were achieved for the disc mill 2.800 rpm, but grinding took off the shortest time.

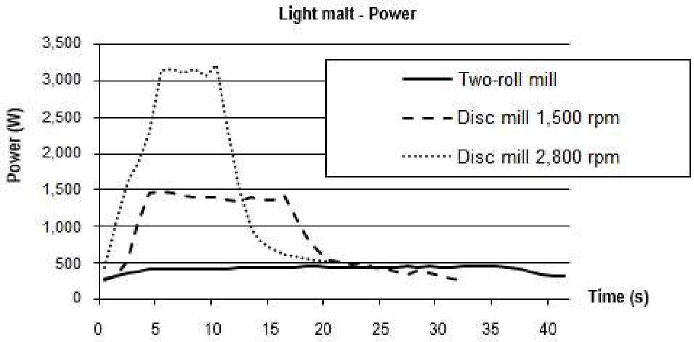

Figure 3. The course of power when grinding light malt.

Fig. 4 illustrates the energy consumption over time when grinding Munich malt. Compared to the light malt grinding, the disc mill 2.800 rpm has a lower power consumption, but the highest between used equipment.

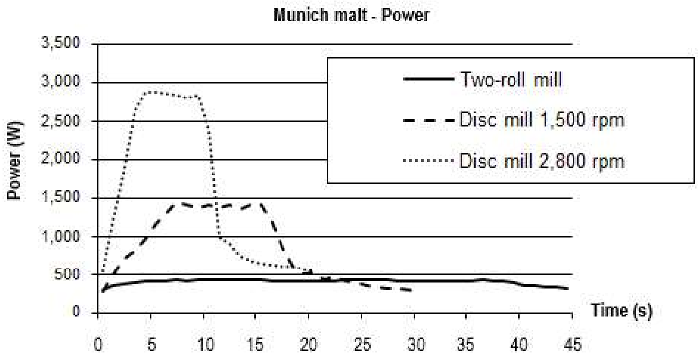

Figure 4. The course of power when grinding Munich malt.

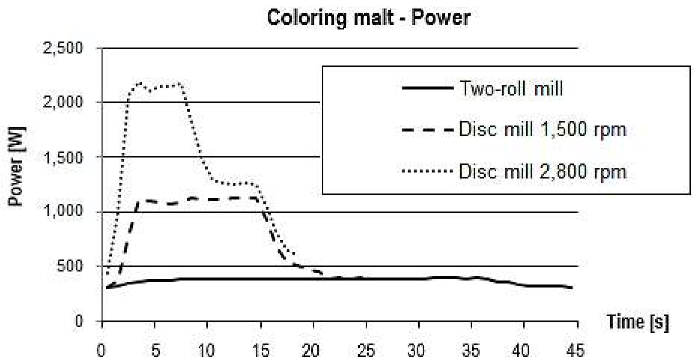

Figure 5. The course of power when grinding colouring malt.

Fig. 5 illustrates the energy consumption over time when grinding coloring malt. Energy consumption is the lowest when grinding coloring malt, especially when using a disc mill 2,800 rpm. This is because the coloring malt is very fragile.

Fig. 6 illustrates the energy consumption over time when grinding caramel malt. Compared to the previous measurement, the energy consumption increased while using the disc mill 1,500 rpm.

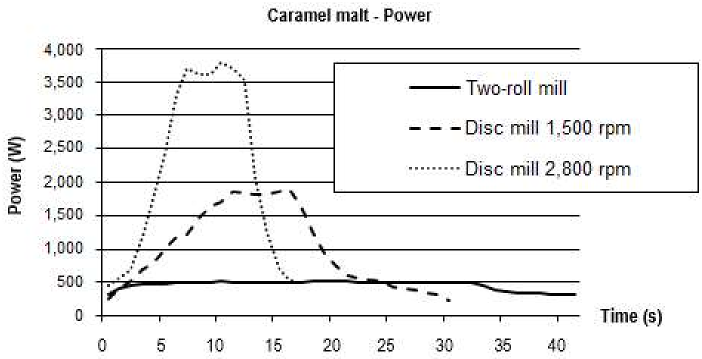

Figure 6. The course of power when grinding caramel malt.

The results obtained correspond to those of other authors (Boehm et al., 2015; Salonitis, 2015). Also, when using similar grinding equipment and grinding other materials, the results are comparable (Chohan et al., 2009; Mohd Rozalli et al., 2015).

In the Fig. 7 is shown energy consumption per 1.0 kg of malt for all used devices. From average power needed to grinding, power idling speed was subtracted. This value was multiplied by the time needed to grinding of each sample and related to 1.0 kg of sample.

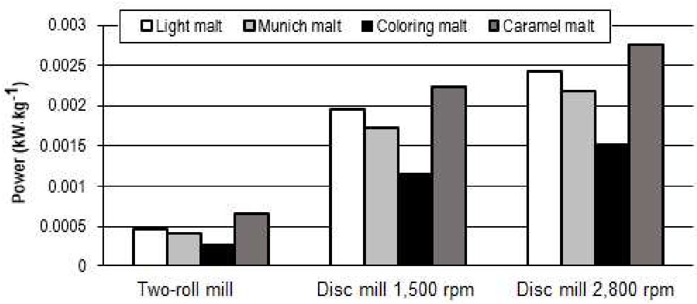

Figure 7. Energy consumption per 1 kg of malt.

Idling speed, for the two-roll grinder is electrical power 321 W, for the disc mill 1,500 rpm is mechanical power 220 W and for the disc mill 2,800 rpm is mechanical power 425 W.

The most energy consumption of the compared devices has the disc mill with 2,800 rpm for all types of malt. The least demanding is the two-roll grinder. Of the used malt, the highest demand on energy consumption of grinding has caramel malt, followed by light malt, Munich malt and the least demanding coloring malt.

Used grinding devices also differed in the speed of grinding. Fig. 8 shows a comparison of the time needed to grinding of 1.0 kg of malt. For the disc mill, the time required for grinding is decreasing as the number of revolutions increases.

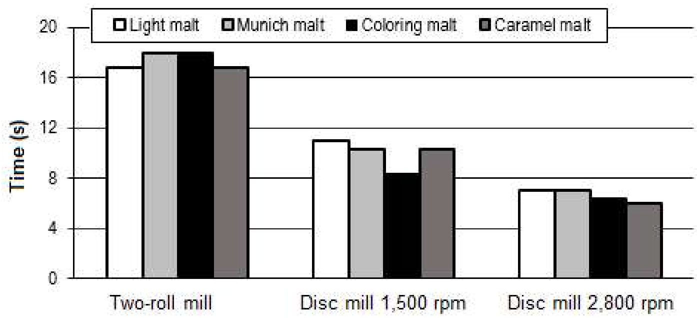

Figure 8. Grinding time of 1 kg of malt.

From these values, we can approximately determine the capacity of individual grinding devices for each type of malt (Table 2).

Table 2. Capacity of the grinding device

	Efficiency		
Malt	Two-roll mill (kg $hour^{-1}$)	Disc mill (1,500 rpm) (kg $hour^{-1}$)	Disc mill (2,800 rpm) (kg $hour^{-1}$)
Light malt	214	327	514
Munich malt	200	349	514
Coloring malt	200	434	571
Caramel malt	214	349	600

CONCLUSION

The paper presents the results of the measurement of the required power of a two-roll mill and a disc mill 1,500 rpm and 2,800 rpm for the grinding of light, Munich, caramel and coloring malt.

The rotational speed of the disc mill influences the fineness of grinding, energy consumption and grinding time. The higher the speed, the shorter the grinding time and the finer the grist, but the higher the energy consumption. Regardless of the speed used, the disc mill has a higher energy consumption than a two-roll mill, but the grinding time is shorter and the malt finer.

Regardless of the use of the grinding device, the highest energy consumption is used to grind caramel malt, followed by light malt, Munich malt, and the least demanding is coloring malt.

Due to the short period of grinding of small malt samples, the performance values expressed in kg h^{-1} should be considered as indicative only. A small inaccuracy in the measurement is a larger deviation when referring to time 1.0 hour.

For a two-roll mill, the performance in grinding different types of malt is not much different and is significantly lower compared to the disc mill. For the disc mill 1,500 rpm, the highest performance was achieved when the coloring malt was grinded.

Disc mill 2,800 rpm has the highest performance of the monitored devices, the performance of grinding of caramel malt is higher than that of other malt.

The subject of the next measurement will be the monitoring of the energy consumption of the four-roll and six-roll grinders and the comparison of the obtained results with the results of this work. Based on the evaluation of all measured quantities, it will be possible to select a suitable type of grinder, taking into account its energy consumption.

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