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FACTORS AFFECTING ENERGY CONSUMPTION IN HAMMER MILLS

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Abstract

The use of hammer mills is widespread, since the size of granular or fibrous materials can be reduced, the simplicity of the structures and the fineness of the milled product can be easily controlled. However, in these mills, the grinding activity, which is an important indicator of energy utilization efficiency, is lower than in other mills. In this study, the effects of technological (physico-mechanical properties, fineness grade, particle size distribution etc.), mechanical (hammer annulus velocity, rotor dynamic characteristics, air flow in crusher unit etc.) and constructive (dimensions of crusher unit, hammer shape, the size of the gap between the unit walls and the hammer edges, the feeding technique of the crusher unit, the technique of unloading the product, the screen area, the impact plate etc.) have been investigated how such factors affect energy consumption in hammer mills.

***Key words**: hammer mill, specific energy consumption.*

INTRODUCTION

The machinery used in breaking and grinding of granular products, in accordance with the breaking efficiency, is called mill. Nowadays, it is necessary to mechanically apply a force in grinding of grains and other forage plants (Güzel, 1999). The purpose of grinding is to increase the specific surface area of the material by reducing the size of the material. With the help of this process which is frequently required in the product processing technique, besides many benefits, the product is transformed from crude to finished product. On the other hand, an increase in the surface area occurs when the size of the product is reduced and the volume decreases. The benefits it provides are: the mix ability of the material is facilitated to obtain more homogeneous mixtures, the coating property of the material is increased, the growth period in the surface area of the material accelerates the drying period, the dissolution and absorption rates increase. Crushing and grinding in the direction of the stated aims should be carried out carefully in the production of mixed feeds, since it is an important process affecting the quality of the feed (Yıldız et al., 2008). In the production of feed, crushing and grinding operations can be carried out with disks, cylindrical rollers and hammer mills (Figure 1.)

Figure 1. General types of hammer mills

However, hammer mills are more widely used because of their high capacity of work, their low repair and maintenance costs and their ability to process mixtures of materials consisting of granules of different sizes (Yıldız, 2002).

MATERIALS AND METHODS

Hammer mills are rough grinding mills with hard and soft shredding operations. The hammer-shaped pushing elements, which are fixedly or movably connected about a shaft, are subjected to a high-speed crushing product. The granules are disintegrated as they pass through the sieve surrounding the mill body (Figure 2).

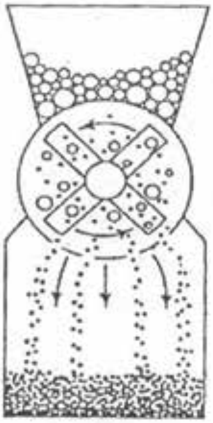

Figure 2. Schematic view of the material milled by the hammer mill

The shredding device consists of hammers that are freely connected at their ends on a rotating shaft (Güzel, 1999). Among these hammers, those with a rectangular shape and a thickness between 4.5 mm and 10 mm are more common. Although their construction is simple, they have a long lifespan. The hammerheads can be made wider to function as a pneumatic conveyer to transport the processed material to a certain distance. Hammers with notched edges are more effective in crushing-grinding. Crushing and grinding with hammer mills has an important effect not only on hammers but also on sieves that enclose crushing unit at the same time. The sieve surrounding the crushing unit is positioned according to the positions of the hammers, the numbers and the feeding situation of the product. Sieve hole shapes can be round, oblong and angular (Figure 3). The sieve hole diameter and shape is an important factor determining the processing precision and mill capacity. Sieves are made of steel sheet with a thickness of 2-3 mm. Sieves made of thick sheet are more durable and long lasting.

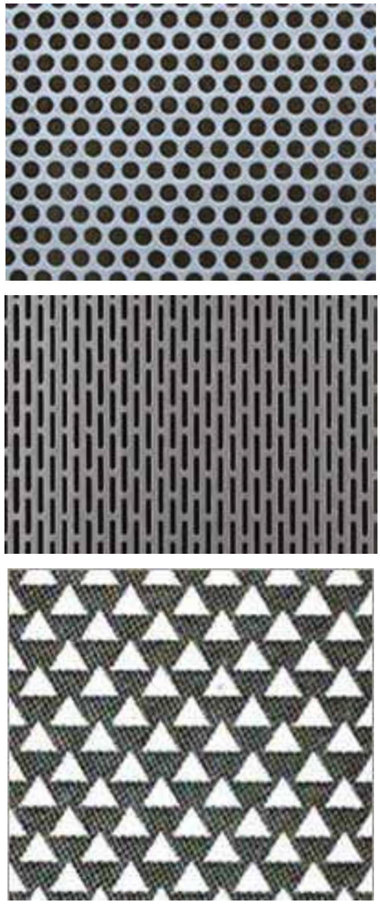

Figure 3. Some examples of sieve hole shapes

However, as the processed material becomes difficult to pass through the sieve holes, the dusting rate will increase (Yıldız, 2002).
The penetration of the granular material into the crushing unit is provided by the feeding gap. The feeding gap can be tangential or axial to the breaking unit (Yıldız et al., 2008).

RESULTS AND DISCUSSIONS

a. *Effective factors on energy consumption*

Reducing the grain size in the processing of grain products for food and feed purposes is the most important and most energy-consuming process (Dziki, 2008).
The following two points need to be taken into account in terms of energy consumption; the first one is that the grain size should be selected accordingly and avoided unnecessary

excessively fine grinding. The second one is that the mills to be used during the grinding process must be sensitive to the selection of the constructive and operating parameters.

The grain size should be large enough to ensure that the feed is optimally assessed by the animal.

The materials that are made into small granules can be better digested in the organism. Because, as the granules become smaller, the area that digestive enzymes will act is broadened and the nutrients are digested in a shorter time.

However, it is not desirable to reduce the grain too much. Because of the over shrinking particles in the digestive system increases the rate of transit and the time they are affected with the relevant enzymes is shortened. This affects the digestion process negatively.

The performance of animals consuming mixed feeds of different grain sizes may vary. It is suggested that the broilers consume different grain sizes during different ages. Nir and Şenköylü (2000) suggest that broilers consume different grain size feeds at different ages. As a matter of fact, according to the age of the animals in the broiler feed, have been reported to vary between 900-1100 µm for 1-7 cut ages, 1100-1300 µm for 7-21 cut ages and 1300-1500 µm for> 21 cut ages respectively.

Goodband (2002) reported that the optimum grain size for wheat in pig feed was varied between 800-900 µm, and that there was no benefit of grain size below 1000 µm in the broiler feed.

Similarly, another study conducted by Dmitrewski (1982) found that average grain size should be above 3000 µm for cattle and above 1000 µm for pig and broiler chickens, and that excessively fine grind is harmful to the digestive tract, has been reported to increase consumption.

Grinding efficiency is; (mechanical properties of the milled product, fineness grade, particle size distribution etc.), mechanical (hammer circumferential speed, rotor dynamic characteristics, air flow in the crusher unit etc.) and constructive features (dimensions of the crusher unit, the size of the gap between the hammer edges, the feeding technique of the crusher unit, the method of emptying the milled product, the sieve area, the impact plate, etc.).

b. *The effect of technological features on energy consumption*

Factors such as fineness grade, shape, humidity, hardness, density, strength, porosity, abrasiveness and stickiness affect the energy consumption of the product grinded in hammer mills. Some studies have reported that the mechanical properties of the material contained in the technological factors are significantly influenced by the moisture content and the increase of the moisture content of the wheat increases the specific energy consumption (Glenn, Johnston 1992; Mabille et al., 2001; Islam, Matzen, 1988). Some studies have reported that the mechanical properties of the material contained in the technological factors are significantly influenced by the moisture content and the increase of the moisture content of the wheat increases the specific energy consumption (Glenn, Johnston, 1992; Mabille et al., 2001; Islam, Matzen, 1988). In general, it has been reported that, in grinding applications, the increase in fineness due to the reduction in particle size has also been associated with decreasing the grinding efficiency (Dmitrewski, 1982; Stamboliadis, 2007). In addition, in a study by Dziki (2008), it was reported that wheat grinding increased the grinding efficiency of hammer mills when used with crushing application, which can change the mechanical properties of the grains. In the same study, the specific energy consumption of the broken wheat varieties varied between 72.3-146.7 kj kg^{-1} for the Turnia variety and 67.0-114.4 kJ kg^{-1} for the Slade variety depending on the moisture content and the specific energy consumption after the crushing application was found to be in the range of 47.6-100.5 kJ kg^{-1} for the Turnia variety and 44.6-85.3 kJ kg^{-1} for the Slade type respectively. The specific energy required for the milling of barley and oats (elastic crust) is greater than the milling of wheat, rye and corn. On the other hand, due to the decrease in moisture content and the increase in grinding activity, the specific energy requirement seems to increase (Ayık, 1997).

c. *The effect of mechanical properties on energy consumption*

Mechanical properties of hammer mills; such as hammer circumferential velocity, hammer shape, feed rate and technique, type of crusher unit, size and shape of crusher unit, hammer-sieve range, grinding product evacuation technique, effective hole area / total sieve area ratio of used sieves, sieve surface properties and geometry, depends on the operational and constructive parameters of the crusher unit. It has been reported that the hammer circumferential velocity changes at an optimum range of 60-80 ms-1 in terms of grinding efficiency and that the specific energy consumption increases significantly at hammer peripheral speeds above these values, due to the increase in ventilation resistance in the crusher unit (Dmitrewski, 1982). It also suggested that hammer mill dimensions are important for energy consumption and that for high-capacity mills D (rotor diameter) / L (rotor width) = 1.5-1.7 and for low-capacity mills D / L = 4-7. In addition, it has been reported that the most useful hammer shape is that the thickness is between 1.5 and 10 mm, the indentations are flat rectangular plates, and the reduction in hammer thickness reduces the specific energy consumption by up to 15% (Dmitrewski, 1982).

d. ***The effect of constructive properties on energy comsumption***

The sieves included in the constructive factors are the most important factor affecting the grinding efficiency of the hammer mills. The sieve hole diameter determines the fineness and grinding capacity of the material being milled. The increase in grinding capacity for a given fineness grade is a key factor in increasing the grinding efficiency (Fang et al., 1997; Koch, 1996). Therefore, in order to increase the grinding capacity, the ratio of "hole area / total sieve area" should be kept as high as the sieve strength permits (Figure 4).

Figure 4. Increase in effective sieve surface

These ratio values, also referred to as the sieve area utilization factor, vary between 8% and 35%, depending on the size of the sieve holes (Dmitrewski, 1982). In agricultural applications, round-hole sieves are generally used, while sieves with pocket-shaped (grater type) holes are used in industrial heavy-duty machines for feed production (Figure 5).

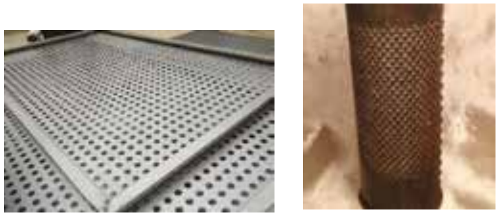

Figure 5. Round hole sieve and Pocket shapes holes

Due to the sharp edges, the porthole sieves increase the grinding capacity as well as increase the crushing effect. However, the negative aspect of these sieves is that they wear very quickly. The round-hole sieves can be drilled conically to increase the grinding capacity.

It has also been noted that placing steel bars 7 mm or 9 mm high on the sieve parallel to the rotor shaft results in an average reduction in energy consumption of up to 15% (Dmitrewski, 1982), by increasing both the grinding capacity and the disintegration effect.

In a study by Beyhan, in 2008, the values of specific energy consumption after grinding with round and oblong hole sieves, different hammer circumferential speed and sieve hole sizes were examined.

For round-hole and oblong-hole sieves, the specific energy consumption values are found as in Table 1.

As the distance between the hammer and the surface of the sieve increases, the grinding capacity decreases and the specific energy consumption increases; it has been reported that in the case of feeding tangentially to the circular wall of the crusher unit, the grinding capacity is increased and accordingly the specific energy consumption is reduced (Dmitrewski, 1982).

Table 1. Specific energy consumption values for sieve types

Sieve Type	Shd (mm)	Sec ($kWht^{-1}$)	Clarification
Rounded hole	2.5	9.38-10.36	Increase with a curvilinear change
	4.5	5.84-9.42	
	6.5	2.45-4.00	
	Hw (mm)		
Oblong hole	1.5	9.40-5.64	Decrease with a curvilinear change
	2.0	6.85-4.70	
	2.5	3.61-3.46	

Sec: Specific energy consumption values obtained after increasing the specific surface area given to the material; **Shd:** Sieve hole diameter; **Hw:** Hole width.

CONCLUSIONS

The grinding efficiency in hammer mills varies depending on the properties of the material to be grinded and the characteristics of the hammer:

- ✓ The material to be grinded; factors such as fineness grade, shape, moisture content, hardness, density, strength, porosity, abrasiveness and stickiness are effective in energy consumption;
- ✓ On the other hand, such as hammer circumferential velocity, hammer shape, feed rate and technique, type of crusher unit, size and shape of crusher unit, hammer-sieve range, grinding product discharge technique, hole area / total screen area ratio of used sieves, sieve surface and geometry, the construction of the crusher unit and the operating parameters significantly affect energy consumption.

Undoubtedly, the work on this subject should not only focus on determining the energy that should be given to the system but also concentrate on the applications that will bring down this energy the most. For example, in recent years, increasing the grinding efficiency by reducing the surface energies by modifying the surface properties of the grains by adding surface active materials to the grinding systems is one of the more popular research topics.

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