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Some engineering factors affecting the performance of wheat grain grinding

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ABSTRACT

The major goal of this research is to investigate some engineering factors affecting the performance of wheat grinding for obtaining whole flour. To achieve this goal, the effect of grinding disc shape, clearance, and moisture content of wheat grain on the performance of grinding were studied. The results showed that: The specific energy requirements and extraction ratio increased with increasing the moisture content, whereas the productivity of whole wheat flour increased with increasing the moisture content from 14 – 16 % then decreased with increasing the moisture content from 16 – 20 % for all types of tested grinding discs. Also, the specific energy consumption and extraction ratio decreased with increasing the tested grinding clearance from 0.1 – 0.4 mm, whereas the machine productivity increased with increasing the clearance from 0.1 to 0.4 mm for all types of tested grinding discs. Under the tested moisture content range and grinding clearance, the results showed that the original grinding disc was better than other two local discs, the original disc (D1) had low values of specific energy requirements, and it had high values of productivity and extraction ratio followed by local disc (D2) with four curved blades. The highest values of machine productivity were 4.61 and 4.33 Kg/h with specific energy requirements of 0.089 and 0.092 kWh/kg and extraction ratio of 71 and 57 % at using original disc (D1) and local disc (D2) which has four curved blades respectively when the moisture content was 16% and grinding clearance was 0.1 mm.

1. Introduction

Wheat is one of the most important grain crops, a basic nutritional raw material for people and a major energy source all over the world (Lupu et al., 2016). The global cultivated wheat area is about 219 million hectares and production volume of wheat grain is 808 million tons while, the cultivated area in the Arab Republic of Egypt is about 1.43 million hectares with a productivity of 9.7 million tons (FAOSTAT, 2022). However, Egypt is the world's largest wheat-importing nation, with only less than half of the national consumption being met by domestic production which is primarily produced from big desert frames and millions of smallholders along the River Nile and in the Nile delta (Abdalla et al., 2022).

Over the last few decades, there has been a significant increase in the demand for whole wheat flour (Seal et al., 2016). Whole wheat flour products provide significant nutritional benefits over refined flour products (Gómez et al., 2020). Consuming more whole wheat flour or grain lowers the risk of cardiovascular disease, type 2 diabetes, and certain malignancies additionally improves intestinal health (Seal et al., 2016). Whole wheat grain contains the following nutritional composition: 78–80% carbohydrates, 8–18% protein, 9–15% dietary fiber, 1%–2% fats, and 1%–3% minerals (Miller Jones et al., 2015). Wheat can be used for food (67%), feed (20%), and seed (7%) (El-Porai et al., 2013). Wheat

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grain consists of three main parts: endosperm (82.7-83.7%), peripheral layers (pericarp + intermediate layer + aleurone) (13.1-14.3%), and germ (3-3.2% dry weight) (Barron et al., 2007).

Wheat flour is derived from two main types of wheat grains; Flours obtained from bread wheat varieties (*Triticum aestivum L.*) are widely used of bread and other bakery products elaboration, whereas durum wheat flours (*Triticum turgidum ssp. durum L.*) have technological properties that makes them suitable for high-quality pasta production (Igrejas and Branlard, 2020; Ciudad-Mulero et al., 2021). Protein content in in hard wheat is higher (12-16%) than in soft wheat (8-10%) according to [USDA/NASS (2001) C.F. El-Porai et al. (2013)].

There are various stages for wheat grain grinding including cleaning, conditioning, grinding, and sifting (Dziki, 2023). The most crucial step in the processing of wheat is grinding (Ahmed et al., 2015; Davara et al., 2018). Also, the grinding process is one of the most energy consuming processes during the flour and feed production, and the main factors that affect the energy consumption during grinding process are machine parameters and physical properties of grains (BUDĂCAN et al., 2013; Dziki, 2008). Grinding is a common technique for reducing food's size because it produces food powders that are easy to use as intermediate or final products and are chemically and microbiologically stable (Jung et al., 2018). The process of wheat grinding requires the usage of a variety of equipment such as plate, hammer, stone and roller mills (Prabhasankar and Haridas Rao, 2001). Also, mills that use attrition or shear forces for size reduction play an important role in fine grinding. Since much of grinding is carried out in the food industry, it produce very small particle sizes and this type of mill is widely used (Bayram and Öner, 2007). The single disc mill, double disc mill, and Buhr mill are three of the main designs of the disc attrition mills (Barbosa-Cánovas et al., 2005).

Before grinding, the moisture level of food materials is a very important factor, since it determines the materials' physical properties and the powder properties, such as flowability after grinding, the moisture content of food materials is closely related to its energy requirement for grinding (Jung et al., 2018). Apart from the equipment employed, the process of grinding is influenced by grain moisture and its mechanical properties which are mostly determined by the cultivar factor. In all cases an increase of grain moisture increases the specific energy requirements of grinding (Ahmed et al., 2015). The design of grinding disc, clearance, rotational speed, and the feeding rate all influence grinding efficiency.

After the undesired matter is sorted out the end after cleaning and preconditioning the wheat (soaking in water in order to increase moisture content) it is ready for grinding, the modern wheat grinding plant is normally a complex system; many varied the production rate according to the techniques and capacity for production line. The statement operation of the mill needs a lot of time for training to have experience to correctly handle the various processing machines into producing high-quality flour with highest possible yield (Fouda et al., 2017). Additionally, Grinding is often done in large mills (governmental and private) where wheat grains go through several stages before grinding process (such as transport, storage, cleaning, conditioning... etc.) which may lead to loss in the quantities of wheat grains, furthermore, the process of grinding wheat grains in large quantities in government and private mills requires packing and transport operations, which may sometimes lead to a loss of flour and an increase in its production costs. Approximately 25 million tons of wheat is lost during the postharvest stages (including storage and post-production). About 46 percent of this loss is observed in developing countries (Baloch, 1999). In addition to the need for storage, which can sometimes lead to spoilage of the flour, which affects human health. To obtain freshly full milled flour which has high nutritional value at any time, there was an urgent need for small grinding machines that suit the needs of the Egyptian family, especially small farmers, these machines are not available locally and are imported from abroad at high prices, with the passage of time and repeated use of the machine, the problem of wearing of grinding discs appears, which are not available locally. Therefore, the focus was on finding solutions to this problem by developing and manufacturing simple grinding discs from local materials to replace imported discs, in addition to its use in the local manufacturing of wheat grain grinding machines. So, the main objective of this study was as follows:

Study of some engineering factors (such as shape of grinding disc, grinding clearance, and moisture content of wheat grain) affecting the performance of wheat grain grinding to contribute in the developing and local manufacturing of wheat grain grinding machines that suit the needs of the Egyptian family (home usage), in addition to study the operating and grinding costs.

2. Materials and methods

This study was conducted at the Department of Agricultural Machinery and Power Engineering -Faculty of Agricultural Engineering, Al-Azhar University, Cairo, Egypt and ACU (Ahram Canadian University) Laboratory in Egypt through years of 2022 - 2023.

2.1. Materials

2.1.1. Type of wheat grains

The wheat grains used in this study were a mixture of the three following types; two types of Egyptian wheat (*Egassed 22* and *Giza 11*) and imported French wheat to enhance the properties of the produced flour.

2.1.2. Grinding machine

A Perten laboratory mill 3303 as shown in Fig. 1 was used for wheat grain grinding, this Lab mill is a disc type mill and consists of the following parts: base of machine, power transmission, feeding system, grinding chamber, final product outlet. The overall length, width, and height were 28, 15, and 48 cm while the total mass of grinding machine was 16 kg.

The power transmitted from an electric motor [220 -230 V, single phase, 1.6 A, 50 Hz, and rotational speed of 2800 rpm] to the grinding disc by using direct transmission. Grinding chamber contains a pair of herringbone discs with a diameter of 75 mm, one of them is fixed and installed on the internal wall of the grinding chamber, while the other is movable and installed on the engine shaft as shown in Fig. 2. Three types of moving discs were used; original disc (D1) and two discs were manufactured locally; disc with four curved blades (D2) and disc with four straight blades (D3) as shown in Fig. 3. The clearance was adjusted using a lever to control the distance between the two grinding discs in six levels of 0.1 mm each, and the clearance was calibrated using a feeler gauge.

Fig. 1. Perten 3303 laboratory mill, reprinted from; https://www.yumpu.com/en/document/read/52958056/laboratory-mill-3303

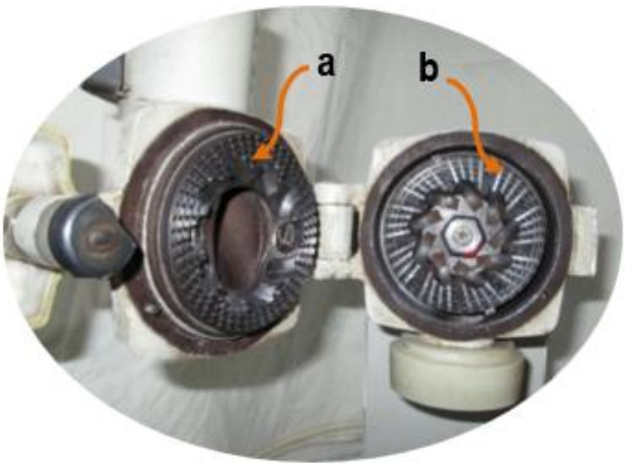
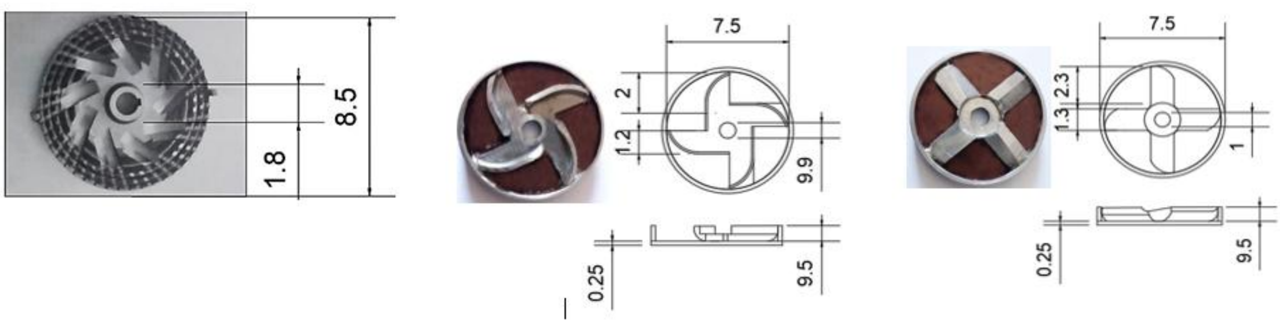


Fig. 2. Grinding chamber. a) fixed disc and b) moving disc.



Original disc (D1) Local disc (D2) Local disc (D3)

Fig. 3. Tested grinding discs.

2.1.3. Measuring instruments

1) Electric oven: The electric oven was used to determine the moisture content of wheat grains, the specifications of oven were as follow; VENTICELL55 type, 230V, 50/60 Hz, 1250W, and Max temperature up to 250° C.

2) Digital balance was used to weigh the individual samples of wheat grains, measurement ranged from (0-7 kg) with accuracy of 0.01 g.

3) A digital AVO meter was used to measure the consumed current, with accuracy of 0.001, range of the measurement AC/DC voltage up to 600V and AC/DC current up to 10 A.

2.2. Methods

2.2.1. Cleaning of wheat grains

Wheat grains were subjected to cleaning process to remove any further impurities (immature grain, broken, foreign materials, etc.) before the beginning of grinding experiments according to El-Sabaei (2017). Wheat grains was cleaned by using a sieve (2 mm x 2 mm).

2.2.2. *Moisture* content of wheat

The moisture content [M_C, (%, wb)] of wheat grain were determined by drying method in a hot air oven at 105° C for 24 hours according to Mousa (2020). This test was repeated three times.

2.2.3. Conditioning of wheat grains

To achieve the desired moisture content of wheat grains sample, the amount of added water was well mixed with grains and left for 24 h. The following equation was used to calculate the mass of added water according to Tavakoli et al. (2009).

$$m_w = \frac{m_i(M_{fm} - M_{im})}{1 - M_{fm}} \quad ...[1]$$

where;

m_w: is the mass of added water to the wheat grains specimen (g).

m_i: is the initial mass of used wheat grains specimen, (g).

M_{fm}: is the final moisture content of specimen, (%, wb).

M_{fm}: is the initial moisture content of specimen, (%, wb).

2.2.4. Variables of study

The following variables were studied to evaluate the performance of grinding process:

- Shape of grinding disc: three types of moving disc; Original disc (D1), local disc (D2), and local disc (D3).
- Grinding clearance: four clearances of 0.1, 0.2, 0.3, and 0.4 mm.
- Moisture content of wheat grains: four levels of 14, 16,18, and 20 (%, wb).

All grinding experiments were conducted at constant rotational speed (2800 rpm) and constant feeding rate (8.31 kg/h), also; experiments of this study were replicated three times.

2.2.5. Performance indicators

2.2.5.1. Machine productivity

Machine productivity was calculated using the following equation:

$$\text{Productivity} = \frac{\text{mass of milled wheat grains, (kg)}}{\text{time of milling, (h)}} \quad ...[2]$$

2.2.5.2. Specific energy requirement

The specific energy requirements (kWh/kg) were calculated according to Mousa (2018) using the following equation:

$$\text{Specific energy requirements} = \frac{\text{Power, (kW)}}{\text{Productivity, (kg/h)}} \quad ...[3]$$

The power consumption (kW) was determined by using the following equation:

$$\text{Power} = \frac{I \times V \times \cos\emptyset \times \eta_m}{1000} \quad ...[4]$$

where:

I: is the consumed current, (amperes).

V: is the voltage difference (220 Volt).

$\cos\emptyset$: is the power factor assumed 0.85 and

η_m: is the mechanical efficiency of motor assumed (85%).

2.2.5.3. Extraction ratio

Extraction rate is the amount of white flour that extracted from a given weight of clean and conditioned wheat. The extraction process was done by knowing the total weight of the ground wheat grains, then knowing the weight of the amount of flour extracted from the sifting process and dividing the two quantities to find out the extraction rate. The particle size index of each sample was determined by sieving through standard sieve NO. 40 GG (475 μm). The extraction ratio was calculated according to El-Porai et al. (2013) using the following equation:

$$\text{Extraction rate, (\%)} = \frac{\text{mass of flour, (g)}}{\text{mass of crude wheat, (g)}} \times 100 \quad ...[5]$$

2.2.5.4. Cost analysis

The total cost was determined according to kepner (1982); Hunt (1983) as follows:

$$\text{Total operating cost (LE/}h) = \text{Fixed cost (LE/h)} + \text{Variable cost (LE/h)} \quad \text{... [6]}$$

A. Fixed costs

1. Deprecation of the machine

Deprecation of the machine was calculated from the following equation:

$$D = (P - S) / L \quad \text{... [7]}$$

where:

D: is the machine deprecation, (LE/year)
P: is the purchase price, (LE)
S: is the salvage or selling price (LE, 0 %)
L: is the time between buying and selling year.

2. ***Interest rate***

Interest rate was considered as a percentage of the machine purchase price per year, it was considered 12 %.

3. Taxes, insurance and shelter

The cost of taxes insurance and shelter was considered 5% of the machine purchase price per year.

B. Variable costs

1. Repairs and maintenance (R+M)

For the machinery is about 5.77% of the machine purchase price.

2. ***Electric cost***

The price of electrical energy was 0.5 LE/kWh according to the year 2023.

3. ***Lubricant cost***

Lubricant cost was taken as 15% of the electric cost

4. ***Labor cost***

The Labor wage was ignored in our study because the purpose of this research is for home usage (small scale), Furthermore, wheat grinding procedure will be done as needed.

$$\text{Grinding cost, (LE/kg)} = \frac{\text{Operating cost, (LE/h)}}{\text{Productivity, (kg/h)}} \quad \text{... [8]}$$

Spread sheet tools such as Microsoft Excel and SPSS (V., 26) were used for statistical analysis of the study's data.

3. Results and discussions

3.1. Machine productivity

Fig. 4 showed that the machine productivity increased with increasing the moisture contents from 14 to 16 (%, wb), then decreased with increasing the moisture contents from 16 to 20 (%, wb) for all tested clearances and grinding discs. Also, the results indicated that the machine productivity increased with increasing the clearance (Khairy et al., 2016 confirmed this) from 0.1 to 0.4 mm for all tested moisture levels and shapes of grinding discs.

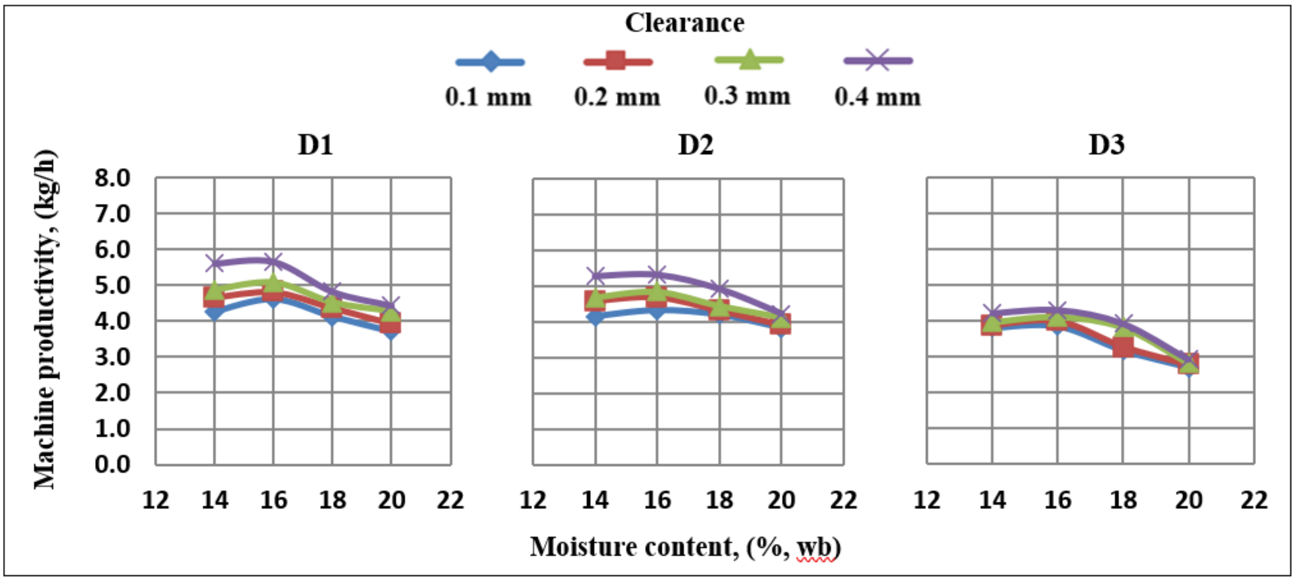


Fig. 4. Effect of tested moisture content and clearance on grinding machine productivity using different types of grinding disc.

As expected, increasing the grinding clearance from 0.1 to 0.4 mm led to an increase of the productivity of whole grinding flour from [(4.27 to 5.61), (4.61 to 5.66), (4.13 to 4.82) and (3.72 to 4.43 kg/h)], [(4.15 to 5.27), (4.33 to 5.31), (4.20 to 4.91) and (3.82 to 4.21 kg/h)] and [(3.81 to 4.21), (3.86 to 4.30), (3.17 to 3.92) and (2.69 to 2.93 kg/h)] when using original grinding disc (D1), local disc (D2) and local disc (D3) at moisture contents 14, 16, 18 and 20 (%, wb) respectively. Also, the results revealed that the highest value of machine productivity was 5.66 kg/h at clearance of 0.4 mm and moisture contents of 16 (%, wb) when using original grinding disc (D1), while the lowest value of machine productivity was 2.69 kg/h at clearance of 0.1 mm and moisture content of 20 (%, w.b) when using local disc (D3).

Duncan Multiple-Range Test (DMRT) in Table (1) showed that; the mean values of machine productivity were not significantly for the original grinding disc D1 and local disc D2 while decreased significantly using the local disc D3. Also, Duncan's Test indicated that; the mean values of productivity increased significantly with increasing the grinding clearance from 0.10 to 0.40 mm. Whereas, the mean values of machine productivity increased significantly with increasing the moisture content from 14 to 16 % then decreased significantly with increasing the moisture content up to 20 %.

Table 1

Effect of shape of disc, clearance and moisture content on the productivity, Duncan's Test at 5% level.

Performance indicator	Variables of study			
Productivity, (kg/h)	Shape of grinding disc			
	D1	D2	D3	
	4.539 a	4.512 a	3.595 b	
	Grinding clearance, (mm)			
	0.10	0.20	0.30	0.40
	3.904 a	4.048 b	4.297 c	4.613 d
	Moisture content, (%, wb)			
	14	16	18	20
	4.498 b	4.598 a	4.136 c	3.632 d

According to the previously mentioned results for grinding process of wheat grain in this study; it is clear that the optimum machine productivity was obtained by using the original grinding disc D1 and local disc D2, clearance of 0.4 mm and moisture content of 16 (%, wb).

3.2. Specific energy requirements

Fig. 5 showed that the specific energy requirements increased with increasing the moisture content of wheat grains from 14 to 20 (%, w.b) for all tested grinding clearances, shapes of grinding discs used Ahmed et al. (2015) corroborated this, also., similar trend was observed by another researcher BUDĂCAN et al. (2013) they caried out their experiments on two different grain types: maize and wheat, two different moisture content levels were employed for each grain type (11.1% and 17.6% for maize, and 13.4% and 18.8% for wheat, respectively) their results indicated that the specific grinding energy increased with increasing the grain moisture content for both maize and wheat. This result could be attributed to the fact that dry wheat grains are fragile, easy to mill, and require less energy for the grinding process. In addition, the plasticity of the nucleus and bran increases with the increase of the moisture content of wheat grains, because of this, grinding of wheat grains requires more energy when increasing the moisture content (Warechowska et al., 2016). Also, the results indicated that the specific energy requirements decreased with increasing the tested clearance from 0.1 to 0.4 mm (Werby et al. (2014); Khairy et al. (2016) confirmed this) for all tested moisture levels and shapes of grinding discs.

Increasing the moisture content from 14 to 20 (%, wb) led to an increase in the specific energy required for grinding process from [(0.082 to 0.116), (0.073 to 0.107), (0.068 to 0.094) and (0.057 to 0.088 kWh/kg)], [(0.087 to 0.115), (0.077 to 0.110), (0.073 to 0.104) and (0.061 to 0.100 kWh/kg)] and [(0.097 to 0.175), (0.088 to 0.166), (0.081 to 0.163) and (0.071 to 0.150 kWh/kg)] when using original grinding disc (D1), local disc (D2) and local disc (D3) at tested clearances 0.1, 0.2, 0.3 and 0.4 mm respectively. Also, the results indicated that the highest value of specific energy consumption was 0.175 kWh/kg at moisture content of 20 % and clearance of 0.1 mm using local grinding disc (D3) while the lowest value of specific energy consumption was 0.057 kWh/kg at moisture content of 14 (%, wb) and clearance of 0.4 mm using original grinding disc (D1).

Duncan's Test in Table 2 indicated that the mean values of specific energy requirements were not significantly for the two local grinding discs (D2 and D3) while decreased significantly using the original disc D1. Also, Duncan's Test showed that the mean values of specific energy requirements increased significantly with decreasing the grinding clearance from 0.10 to 0.40 mm. Whereas, the mean values of specific energy requirements increased significantly with increasing the moisture content from 14 to 20 %.

According to the previously indicated results for the grinding procedure of wheat grains used, we noticed that, the largest clearance (0.4 mm) and the lowest moisture content (14%) when using the original grinding disc (D1) had lowest specific energy requirements, while, the minimum clearance (0.1 mm) and the highest moisture content (20 %, w.b) with using the two local grinding disc (D2 and D3) had highest specific energy requirements.

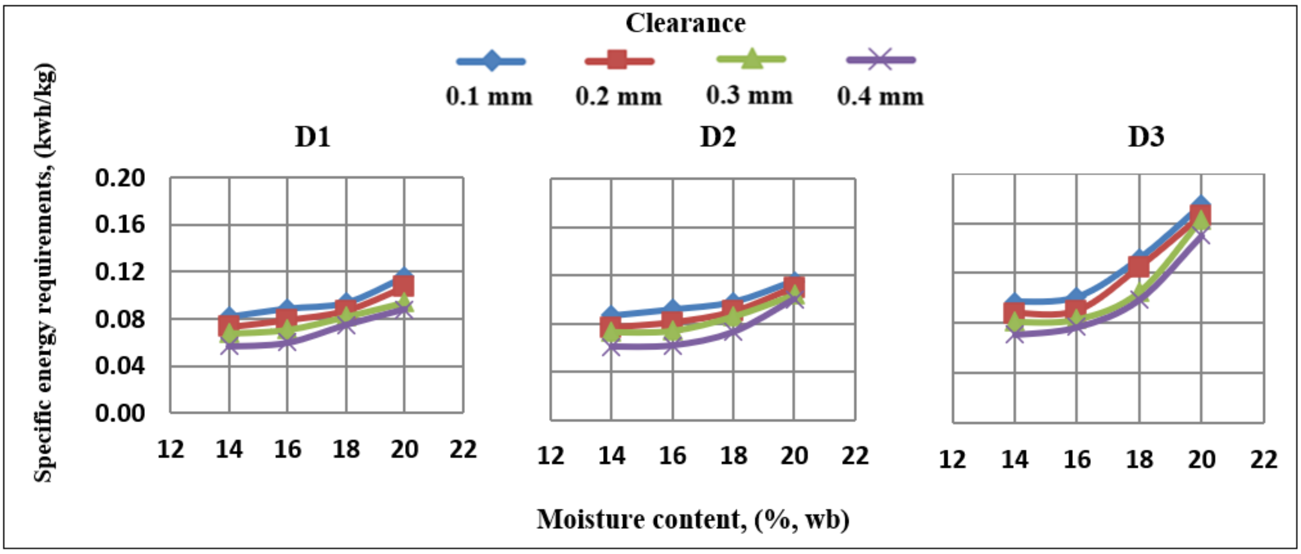


Fig. 5. Effect of tested moisture content and clearance on specific energy requirements using different types of grinding disc.

Table 2

Effect of shape of disc, clearance and moisture content on the specific energy requirements, Duncan's Test at 5% level.

Performance indicator	Variables of study			
Specific energy requirements, (kWh/kg)	Shape of grinding disc			
	D1	D2	D3	
	0.372 [a]	0.382 [b]	0.387 [b]	
	Grinding clearance, (mm)			
	0.10	0.20	0.30	0.40
	0.402 [a]	0.386 [b]	0.374 [c]	0.359 [d]
	Moisture content, (%, wb)			
	14	16	18	20
	0.337 [a]	0.366 [b]	0.388 [c]	0.431 [d]

3.3. Extraction ratio

Fig. 6 indicated that the extraction ratio increased by increasing the moisture contents of wheat grains from 14 to 20 (%, w.b) for all tested grinding clearances and shapes of grinding discs used. Also, the results showed that the extraction ratio of wheat flour increased by decreasing the tested grinding clearance from 0.4 to 0.1 mm for all tested moisture contents and shapes of grinding discs used.

Decreasing the tested grinding clearance from 0.4 to 0.1 mm resulted in an increase in the extraction ratio of wheat flour from [(45 to 70), (46 to 71), (48 to 73) and (52 to 73 %)], [(39 to 54), (42 to 57), (43 to 58) and (44 to 60 %)] and [(27 to 35), (30 to 37), (31 to 38) and (31 to 38 %, w/w)] when using original grinding disc (D1), local disc (D2) and local disc (D3) at tested moisture contents 14, 16, 18 and 20 (%) respectively. Also, the results revealed that the maximum value of extraction ratio was 74 % at moisture content of 20 (%) and clearance of 0.1 mm using original grinding disc (D1) while the lowest value of extraction ratio was 27 % at moisture content of 14 (%) and clearance of 0.4 mm using local grinding disc (D3).

Duncan's Test in Table 3 indicated that the mean values of extraction ratio were significantly for all tested grinding discs D1, D2, and D3. Also, Duncan's Test showed that the mean values of extraction ratio increased significantly with decreasing the tested grinding clearance from 0.40 to 0.10 mm. Whereas, the mean values of extraction ratio increased significantly with increasing the moisture content from 14 to 18 %.

Table 3

Effect of shape of disc, clearance and moisture content on the extraction ratio, Duncan's Test at 5% level.

Performance indicator	Variables of study			
Extraction ratio, (%)	Shape of grinding disc			
	D1	D2	D3	
	60.29 [a]	49.44 [b]	34.10 [c]	
	Grinding clearance, (mm)			
	0.10	0.20	0.30	0.40
	55.89 [a]	51.31 [b]	44.67 [c]	39.92 [d]
	Moisture content, (%, wb)			
	14	16	18	20
	45.17 [a]	47.67 [b]	49.25 [c]	49.69 [c]

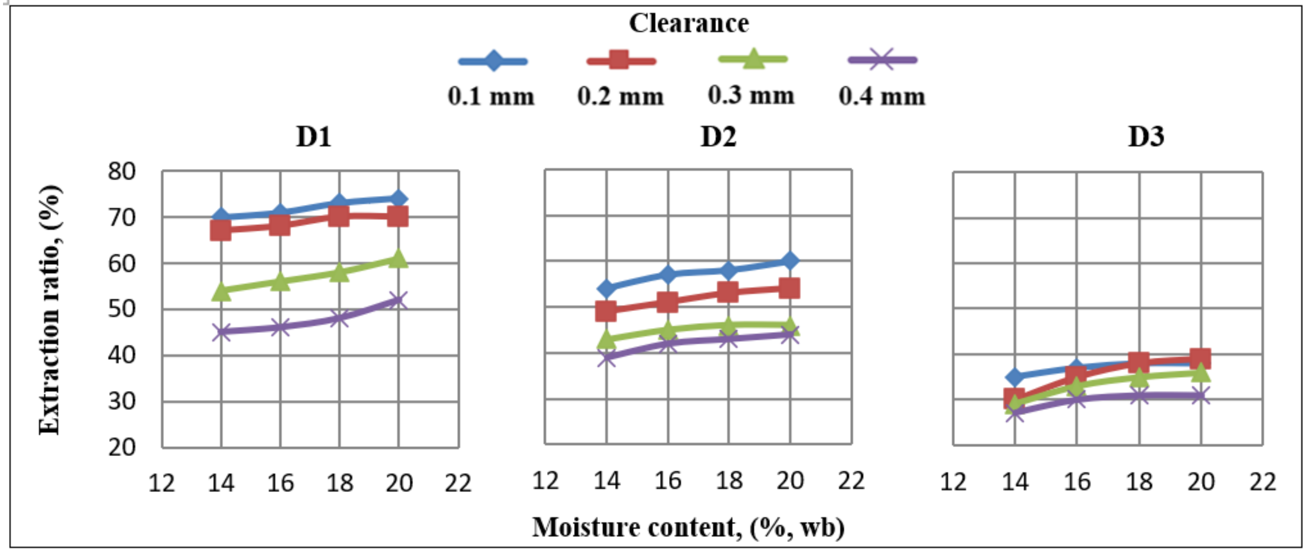


Fig. 6. Effect of tested moisture content and clearance on extraction ratio using different types of grinding disc.

According to the previously indicated results, we can summarize that, the highest values of flour extraction percentage were obtained with the original grinding disc (D1) at clearance of 0.1 mm and moisture content of (18 – 20 %), whereas; the smallest values of flour extraction percentage were obtained with the local grinding disc (D3) at clearance of 0.4 mm and moisture content of 14 %.

Based on the previously reported results for performance indicator (Productivity, specific energy requirements and extraction ratio), we can recommend the optimum operating conditions for the grinding process of wheat grains used in this study as follow; It is preferred to use the original grinding disc (D1) in the grinding process, but, if any problem occurs for the original grinding disc, such as; corrosion, unavailability, difficulty in manufacturing ... etc., it is preferable to use the local grinding disc (D2) which has four curved blades, because of its simplicity of manufacturing from local materials and its low price compared to the original grinding disc. Also, the results showed that the maximum values of machine productivity occurred at the moisture content of 16 % for all tested clearances. Also, the results indicated that the highest values of extraction ratio occurred at clearance of 0.1 mm for all tested moisture content.

3.4. Operating costs

The total hourly operating cost of the grinding machine were 24.8 and 21.6 LE/h whereas, the grinding cost (LE/kg) was calculated with dividing the total hourly operating cost on the productivity of machine at optimum operating conditions; moisture content of 16 (%, w.b) and grinding clearance of 0.1 mm, at these conditions, the average values of wheat grinding cost were 5.40 and 5.00 LE/kg using original grinding disc (D1) and local disc (D2) respectively.

4. Conclusions

- The specific energy requirements and extraction ratio increased with increasing the moisture content, whereas the productivity of whole wheat flour increased with increasing the moisture content from 14 – 16 % then decreased with increasing the moisture content from 16 – 20 % for all types of tested grinding discs.
- Also, the specific energy consumption and extraction ratio decreased with increasing the tested grinding clearance from 0.1 – 0.4 mm, whereas the machine productivity increased with increasing the clearance from 0.1 to 0.4 mm for all types of tested grinding discs.
- Under the tested moisture content range and grinding clearance, the results showed that the original grinding disc was better than other two local discs, the original disc (D1) had low values of specific energy requirements, and it had high values of productivity and extraction ratio followed by local disc (D2) with four curved blades.
- The highest values of machine productivity were 4.61 and 4.33 Kg/h with specific energy requirements of 0.089 and 0.092 kWh/kg and extraction ratio of 71 and 57 % at using original disc (D1) and local disc (D2) which has four curved blades respectively when the moisture content was 16% and grinding clearance was 0.1 mm.

Recommendations

- Attention to cleaning of wheat grains of impurities and foreign matter before carrying out the grinding process, in addition to performing the conditioning of grains at the appropriate amount and time to reach the optimum moisture content (16%) to easy separation of endosperm from the bran, also, the local disc with four curved blades can be used to grind wheat grain with a clearance of 0.1mm to produce whole grinding flour.

- Further research and development of wheat grain grinding discs is still required to achieve super fine grinding and ultra-fine grinding to obtain full grinding flour with high nutritional value.
- Working on manufacturing small grinding machines suitable for Egyptian family to promote the local manufacturing and reduce dependence on imports from other countries. Future studies should also be conducted to reduce the power consumed in the grinding process.

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بعض العوامل الهندسية المؤثرة على آداء طحن حبوب القمح

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الملخص العربي

يهدف هذا البحث الي دراسة بعض العوامل الهندسية المؤثرة على آداء عملية طحن حبوب القمح للمساهمة في التطوير والتصنيع المحلي لآلات طحن حبوب القمح التي تناسب احتياجات الاسرة المصرية ... اشتملت آلة الطحن المستخدمة على المكونات الأساسية التالية: محرك كهربائي بقدرة ٠,٤ كيلووات، غرفة الطحن المزودة بقرصين أحدهما ثابت والاخر متحرك بالإضافة الى نظام للتحكم في خلوص الطحن، مدخل مزود ببوابة للتحكم في معدل التغذية ومخرج للمنتج النهائي. تم تطوير وتصنيع قرصين طحن من خامات محلية لاختبارهم في طحن حبوب القمح ومقارنتهم بقرص الطحن الأصلي، قرص محلي بشفرات منحنية وآخر بشفرات مستقيمة.

تم دراسة تأثير المتغيرات التالية على آداء طحن حبوب قمح خليط من الأصناف (إجاسيد ٢٢، جيزة ١١، قمح فرنسي).

- شكل قرص: القرص الأصلي، قرص بشفرات منحنية وقرص بشفرات مستقيمة.
- خلوص الطحن: ٠,١، ٠,٢، ٠,٣ و٠,٤ مم.
- المحتوى الرطوبي لحبوب القمح: ١٤، ١٦، ١٨ و٢٠٪ على أساس رطب.

وكانت أهم النتائج المتحصل عليها كالتالي:

- أظهرت النتائج أن متطلبات القدرة النوعية، ونسبة استخلاص الدقيق ازدادت بزيادة المحتوى الرطوبي في حين أن انتاجية الآلة ازدادت بزيادة الرطوبة من ١٤-١٦٪ ثم انخفضت بزيادة الرطوبة من ١٦-٢٠٪ وذلك لجميع أنواع اقراص الطحن المختبرة.
- بينت النتائج أن متطلبات القدرة النوعية، ونسبة استخلاص الدقيق انخفضت بزيادة خلوص الطحن من ٠,١-٠,٤ مم في حين أن انتاجية الآلة ازدادت بزيادة الخلوص المختبر من ٠,١ - ٠,٤ مم وذلك لجميع اقراص الطحن المختبرة.
- تحت مدي المحتوى الرطوبي وخلوص الطحن المختبر تبين تفوق قرص الطحن الأصلي على القرصين المحليين ... حيث كانت أقل قيمة لمتطلبات القدرة النوعية وأعلى انتاجية وأعلى نسبة استخلاص للقرص الأصلي يلية القرص المحلي ذو الشفرات المنحنية ويلية القرص ذو الشفرات المستقيمة.
- أظهرت النتائج أن أعلى إنتاجية للآلة كانت ٤,٦١ و٤,٣٣ كجم/ساعة بقدرة نوعية مستهلكة ٠,٠٨٩ و٠,٠٩٢ كيلووات ساعة /كجم ونسبة استخلاص ٧١ و٥٧ % عند استخدام قرص الطحن الاصلي والقرص المحلي ذو الشفرات المنحنية على التوالي عندما كان المحتوى الرطوبي ١٦٪ وخلوص الطحن ٠,١ مم.

التوصيات:

الاهتمام بتنظيف حبوب القمح من الشوائب والمواد الغريبة الموجودة به قبل تنفيذ إجراء الطحن ... بالإضافة الى اجراء عملية الترطيب بالقدر والوقت المناسبين للوصول الى رطوبة الطحن الأمثل (١٦٪) لسهولة فصل الإندوسبرم عن القشرة الخارجية وإمكانية استخدم قرص الطحن المحلي ذو الشفرات المنحنية في طحن حبوب القمح بخلوص ٠,١ مم لإنتاج دقيق الطحن الكامل - ومع ذلك لاتزال هناك حاجة الى مزيد من الدراسة والتطوير لأقراص طحن حبوب القمح من أجل الوصول الى الطحن المتناهي الدقة للحصول على طحين الدقيق الكامل ذو القيمة الغذائية المرتفعة. والعمل على تصنيع آلات طحن صغيرة تناسب الأسرة المصرية من أجل تعزيز التصنيع المحلي. كما ينبغي إجراء دراسات مستقبلية من أجل خفض الطاقة المستهلكة في عملية طحن حبوب القمح.