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STUDY AND EVALUATION OF THE PROCESS OF GRINDING THE YELLOW MAIZE GRAINS BY USING CHAINS FOR LOCALLY DEVELOPED HAMMER MILL

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Abstract

The aim of the research to improve the process of grinding the yellow corn grain, A research was conducted in the mechanical workshop that belongs to the Department of Machines and Equipment-College of Agricultural Engineering Sciences-University of Baghdad (October 2018). The output of the hammer is better than that produced by conventional hammers A mechanical grain grinder was comprised of a hopper for grains, a round case of grindingthatcontains a disk, which isused for attaching the hammers, and a sieve surrounding that disk. The conventional hammers were replaced with metal chains in order to test the efficiency of grains hammering. The grinder was tested using two types of chains,in order to conduct a comparison between those chains and the hammers. Threesieves of perforates diameter of 4, 6 and 8 mm were used in three replications. The complete randomised design (CRD) was used, and the treatments means were tested according to the least significant differences (L.S.D). The results showed that replacing the conventional hammers with the chain hammers led to a significant effect on the grains grinding. Furthermore, increasing the grinding perforates diameter led to a significant effectalso on the grains grinding. The best results derived out of the experiment, such as consumed electricity, highest capacity, lowest capacity and temperature increasing were recorded with the chain (B)and the sieve 8mm, whereas the least average of particles measurements along with its standard deviation was recorded with the chain (A) and the sieve perforates of 4 mm. Thus, it's applicable to adopt the hammering mechanism of chains as an alternative of the conventional hammers.

Key words : Grains grinding, hammer grinder, ground particles, mechanical grinding.

Introduction

Maize, or *Zea mays* L, is considered as thethird most important seeds–yield, that comes right after Wheat and Rice,in terms of the planted area moreover production across the world (LITA, 2009). It's a primary substance in the feeding of poultry and cattle,moreover, many of industries important as raw material (Akande *et al*., 2006). Sutowski *et al*. (2017) mentioned that boosting the quality of work is among the important goals of modern production systems. The force required for milling, consumed electricity and temperature of substance must be known in order to guarantee the consistency of work. Kumar and Vettivel (2014) stated that grinding requires a high energy for every volume of the particles that causes increasing in the temperature of grinding zone as a consequence of the force used and friction. The challenge in manufacturing these machines lays in maintaining a high quality along with an increase in production and reduce costs. Kim *et al.* (2018) refered to that theoretically grain grinding increases the superficial area of fodder that leads to an increase in the digestion ability, which improves using the grains as fodder along with an increase in animal capacity. Grinding the grains in a minute manner leads to somedeficiencies like creating dusts and harmsto the animal stomachsuch as ulcer, finally the animal decreases the consumption of fodder. Ahmed *et al*. (2006) mentioned that the sieves openings and grains type are considered among the important factors that

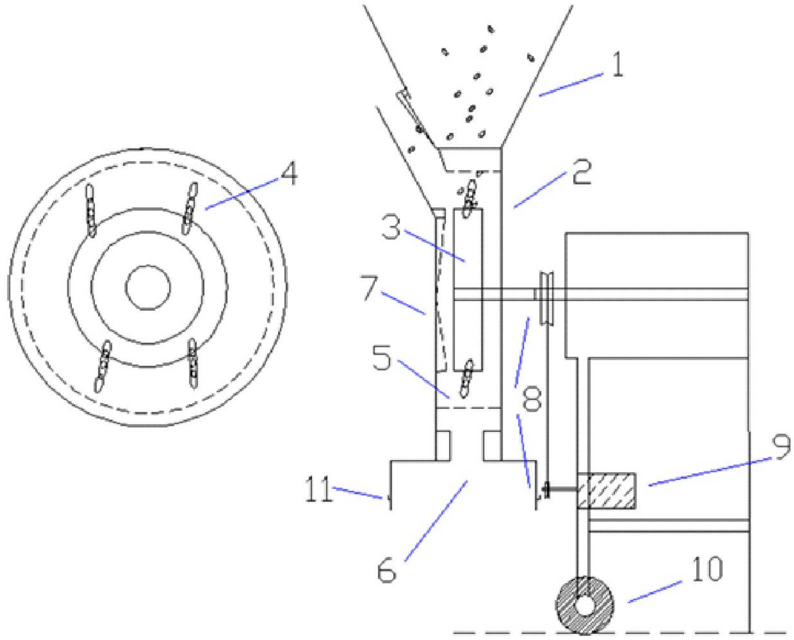

Fig. 1 : The manufactured and developed grinder machine.

affect on the machine capacity and its consumed electricity, whereby using sieves with small openings leads to an increase in the ground substances-fineness, which requires more electricity to rotate inside the internal grinder case before getting out of the sieves openings and the capacity decreases in turn alternatively. The average of the measured ground-particle valueswas affected by the diameters of the used sieves openings. Al-Namah (1990) stated that there are different types of grains-grinder machines,through an exertingeffect on grains,in order to obtain a certain degree of fineness. Among these methods is hitting the grains with rotating metallic hammers affecting them through their rotating motionthat leads to shattering them into small particles, depending on the hit force of the hammer on the grain. According to that, the present study of the subject is to develop a mechanism of hammering with usinga common hammertheory.The study aims to develop and test a locally manufactured grinder machine and decrease the consumed electricity by using a lighter hammers along with maintaining the same grinding quality or even better than the common hammers.

Materials and Methods

A research was conducted in the mechanical workshop that belongs to the Department of Machines and Equipment, College of Agricultural Engineering Sciences, University of Baghdadm October 2018. A grain grinder was manufactured in a local Engineering workshop in Baghdad, the grain grinderis comprised of a grain Hooper (1), a circulated shape-grinder case is located downward (2), in which the Hammers Disks are placed inside (3) and the hammers are placed on the circumferencesof the disk (4) at it's four sides,the hammers duplicated for each one. Eight Metallic hammers were manufactured that is used in the conventional hammering;moreover the grinder was equipped by two types of Chain type ofhammers of eight pieces for each type. The hammers can be placed andremoved off therims of the disk plate through fixing screws. The sieve surrounds the inner side of the hammer'sdisk-cover that could be replaced and cleaned easily whenever is needed. The outlet of the threshed grains (6) is located downward that is finished in a round shape provided with fins that enables the fixing of collecting bags. The hammer diskis covered from the front (7) that is connected to the grinder cover by a hinge. This cover is comprised of a grain hopperfrom the top that descends the grains downward.The grinder door / cover is padded with a sponge to prevent the dust from getting outside while grinding. The grinder is provided with electricity through pulleys and belts (8) from an electric engine (9) of 1.5 HP and rotational velocity of 1420 RPM. Thegrinder can be moved through wheels (10) undershanks that is attached to the grinder frame, as illustrated in fig. 1.

All the measurements of the manufactured grinderare listed in table 1.

Mechanism of Grinder test

A test was conducted for the locally manufactured grinder using 30 kg of corngrains bought from a silo in

Baghdad.Randomised samples were taken to measure the humidity content of the corn, before grinding, by an average of 4.1% on the basis of corn wet weight according to Pfost (1976). The temperature of the corn was measured before grinding by using a temperature sensor equipped with a probe. Thetemperature was 32.25-33.9°C. The velocity of grinding was measured by using a laser anemometer. The following variables were controlled in order to conduct the test:

1. Diameter of grinder's sieve in three levels 4, 6 and 8 mm

2. Grinder hammer type in three levels, chain A, chain B, and conventional hammers

And by three replications, hence the total experimental units become 27 units. The experimental treatments were analyzed using complete randomised design (CRD). The significance of the treatments effect was tested according to least significance differences (L.S.D), at the probability of ($p< 0.005$). The program (SAS, 2012) was used for the statistical analysis of the data collected. Effects of the indicators were measured as follows:

1. The consumed electricity (KW)

The consumed electricity was measured using a Digital Clamp-meter of Chinese made. Duringthe grinding operation, the electricity consumed by the engine was measured according to the equation used by Kurt and Gieck (1979) as follows:

$$EC = \sqrt{3}*I*V*\eta*\cos\theta/1000$$

Where,

EC = The consumed electricity (KW).

I = The consumed current (Ampere).

η= Mechanical efficiency (estimated by 0.95) according to (Metwally, 2010).

V =The Voltage (Volt).

$\cos\theta$ = Electricity factor (estimated by 0.84).

2. Capacity (Kg/h)

The capacity was measured using an Electric/ Digital scale along with a Timer for time confirmation. Whereby, the ground substance wascollected, according to a fixed time for each experimental unit for weight cognition. Thecapacity was measured according to the following equation mentioned by Eldesoukey *et al*. (2007).

$$C = W / T$$

Where,

C = Capacity (Kg/h).

W = Weight of sample (Kg).

T = Time of grinding (h).

3. Temperature Rising (^{O}C)

Temperature rising was measured just after the ground grains come out of the grinder, using a thermal sensor equipped with a probe. After subtraction from the grains temperature before grinding, the following equation mentioned by (Ahmed, 2001) was used to calculate the temperature rising:

$$T.R = T2 - T1$$

Where:

T.R = Temperature rising (°C).

T2 = Temperature of the ground grains after grinding (°C).

T1 = Temperature of the ground grains before grinding (°C).

4. Average particle-size (mm)

The average particle size was measured by weighing samples of the ground product of (100 gm), using an electric/Digital scale. Then, screening with a collection of sieves was organised in a descending order, starting with the big perforates to the small one, then into a container, in which the remaining particles that pass through the sieves are being collected in it. Average of the particles was measured according to the following equation used by Istavn (1980)

$$\overline{X} = \sum_{i}^{k} Xi.Fi$$

Where,

$\overline{X}$ = Average of particle sizes

Xi = Average of particle sizes in the sieve i (mathematical average for the upper and lower sieve).

i = The serial number of the sieve .

k = Number of the sieves.

Fi = Proportion of the weight given in the sieve i.

5. Standard Deviation

Standard Deviation was calculated after weighing the ground product as samples of 100gm using an electric/ Digital scale, then conducting screening to it according to the measuring method of particles average sizes. Hence, the Standard Deviation for the particles wascalculated according to the equation used by(Istavan, 1980).

$$\overset{-k}{\underset{i}{S.D}} = \sqrt{\Sigma|xi - x|^2 . fi}$$

Where,

S.D = Standard deviation.

Results and Discussion

1. The Consumed Electricity (KW)

Table 2 shows the effect of hammering tool type and the sieve'sperforatesdiameter on the consumed electricity. Changing the hammering tool affected significantly the consumed electricity. The highest consumed electricity was 2.63 KW through using the conventional hammering. The least consumed electricity was 1.89 KW through using the chain (B). That's maybe due to the fact that the conventional hammer weighs for chain (A) (0.79) gm, while the used chains weighs (0.42) gm for chain (B) and composed of 8 hammers,meaning additional weights/loads on the engine, which leads to extra electricity consumption. As for the chains adopted in the study, the contrary happens. Also, table 2 depicts that changing the grinding sieves had a significant influence on the electricityconsumption,whereby the highest electricitywas 2.98KW with the sieve 4 mm and the electricity consumption decreased with the sieves 6 and 8 mm, which were 1.86 and 1.76 KW, respectively, those results goes with Ahmed (2006). The interaction between hammering tool and sieve perforates diameter had a significant effect on the electricityconsumption. The highest consumed electricity was 3.74 KW with the conventional hammer and sieve perforates 4mm, whereas the least consumed electricity was 1.54 KW along with using chain A and sieve diameter 8mm.

2. Capacity (Kg/h)

Table 3 revealsthe effect of hammering type tool and sieve'sperforatesdiameter on capacity. The type of hammering toolhad asignificant effect on the capacity, indicated by 7.74 and 8.30 Kg/h for the conventional hammering and chain (B), respectively. The least capacity was 4.99 Kg/h by hammering with chain A. That's may be owing to the fact that chain (B) and the conventional hammering are heavier than chain (A), which leads to a greater hammering/grinding that results in crumbling/ fragmenting of the ground grains. Also, table 3 manifests that changing the sieve had a significant influence on the capacity, whereby increasing the sieve'sperforates diameter from 4 to 6 then to 8 mm, the capacity increased from 5.02 to 7.61 and to 8.40 Kg/h, respectively, that's due to the duration of ground grains exit is lesser with increasing the diameter of sieve perforates which leads

Table 1 : Specifications of the locally developed grain miller.

S. no.	Parts	Measurements
1	Grains: Length *width *Height	30*30*30 cm
2	Grinder - case diameter	45 cm
3	Grinder - effective diameter	29.5 cm
4	Hammer disk- diameter	16 cm
5	Total grinder height	154 cm
6	Ground grain exit height off the floor	62.5cm
7	Engine pulley- diameter	14cm
8	Grinder pulley- diameter	7cm
9	Grinder velocity	3000 rpm

Table 2 : The effect of hammering tool type and sieve's perforates diameter on the consumed electricity (KW).

Hammering tool type	Sieve's perforates diameter (mm)			Mean of tool effect
	4	6	8	
Chain (A)	3.07 ab	1.67 c	1.54 c	2.09 AB
Chain (B)	2.15 bc	1.79 c	1.75 c	1.89 B
Hammering	3.74 a	2.14bc	2.01 c	2.63 A
Mean of perforates effect	2.98AB	1.86B	1.76 A	
Least significance effect p>0.05				
Hammering tool type : 0.59	Sieve perforates: 0.59		Interaction : 1.03	

* The difference in the letters in each column indicate a significant differences between the averages of the treatments on a level of (p<0.05).

Table 3 : The effect of hammering tool type and sieve's perforates diameter on the capacity(Kg/h).

Hammering tool type	Sieve's perforates diameter (mm)			Mean of tool effect
	4	6	8	
Chain (A)	4.68 b	4.76 b	5.53 b	4.99 B
Chain (B)	5.37 b	9.06 a	10.49 a	8.30 A
Hammering	5.02 b	9.03 a	9.19 a	7.74 A
Mean of perforates effect	5.02 B	7.61A	8.40A	
Least significance effect p>0.05				
Hammering tool type : 1.80	Sieve perforates:1.80		Interaction : 2.14	

Table 4 : The effect of hammering tool type and sieve's perforates diameter on the grinding temperature increasing (°C).

Hammering tool type	Sieve's perforates diameter (mm)			Mean of tool effect
	4	6	8	
Chain (A)	2.33 bc	2.15bc	1.98 c	2.15 B
Chain (B)	1.91 c	0.98 d	0.83 d	1.24 C
Hammering	3.25 a	2.88 ab	2.16bc	2.76 A
Mean of perforates effect	2.49 B	2.00 B	1.65A	
Least significance effect p>0.05				
Hammering tool type : 0.46	Sieve perforates : 0.46		Interaction : 0.81	

Table 5 : The effect of hammering tool type and sieve's perforates diameter on the average particle size (mm).

Hammering tool type	Sieve's perforates diameter (mm)			Mean of tool effect
	4	6	8	
Chain(A)	1.345 e	1.511 de	1.784 dc	1.546 C
Chain (B)	1.539 cde	2.163 b	2.714 a	2.138 B
Hammering	1.378 e	1.834 c	2.259 b	1.824 B
Mean of perforates effect	1.420 C	1.836 B	2.252 A	
Least significance effect p<0.05				
Hammering tool type : 0.172	Sieve perforates:0.172		Interaction:0.298	

Table 6 : The effect of hammering tool type along with sieve's perforates diameter on the standard deviation.

Hammering tool type	Sieve's perforates diameter (mm)			Mean of tool effect
	4	6	8	
Chain (A)	2.860 e	3.714 d	4.416 c	3.663 B
Chain (B)	2.860 e	4.815 b	5.220 a	4.298 A
Hammering	2.736 e	3.640 d	4.922 ab	3.766B
Mean of perforates effect	2.818 C	4.056 B	4.853 A	
Least significance effect p<0.05				
Hammering tool type : 0.230	Sieve perforates:0.230		Interaction:0.399	

to a decreasing in the time of grinding/milling, in other word, the capacity increases (Rudnitiski, 1990 and Ahmed *et al.*, 2006). The interaction among the studied factors had a significant effect on the capacity, the highest capacity was 10.49 Kg/h with chain B and sieve 8 mm, and the least capacity was 4.68 Kg/h with chain (A) and sieve's perforates diameter of 4 mm.

3. Grinding Temperature Increasing (°C)

Table 4 clarifies the effect of hammering tool type and sieve's perforates diameter on the grinding temperature increasing. Interchangeably, it was observed that changing the grinding tool of conventional hammer had a significant effect on the temperature increasing, reached 2.76°C, on the other, hand the least recorded grinding temperature increasing was 1.24°C with chain(B). That's owing to the fact that the chain (B) recorded a higher capacity per unit of time, which led to a decreasing in the grinding temperature, knowing that the conventional hammer is thicker and heavier, which led to grinding temperature increasing. This is in consistent with Kumar and Vettivel (2014). It can be observed from table 4 that increasing the perforates diameter from 4 to 6 then to 8 mm led to grinding temperature increasing from 2.49 to 2.00 then to 1.65°C, respectively, this is normal, whereby the capacity increases with perforates diameter increasing, which leads to decrease the time of staying the grains inside the grinding tank and this leads in turn to decrease the temperature of ground product, this is in consistent with Kumar and Vettivel (2014). The interaction between hammering tool and sieve's perforates diameter in grinding temperature increasing had an influence, in terms of least temperature recorded was 0.83°C with chain (B) and sieve 8 mm, but the highest was 3.25°C with the conventional hammering and hole diameter of 4mm.

4. Average particle size (mm)

From table 5, the effect of hammering tool and sieve's perforates diameter on the average particles diameter can be observed. Furthermore, the hammering tool has a significant effect on the particle average size. Whereby, chain B recoded the least particle average size of 1.546 mm, along with a marginal difference in comparison with the conventional hammering tool of an average of 1.824 mm despite of being a significant influence. Whereas, the highest average of particle size (less fineness) was of 2.138 mm, recorded with chain (B). That's may be due to the fact that the chain (A) is lighter in terms of weight, hence conducting more elasticity and more consistency. Nevertheless, increasing the grinding perforates diameter from 4 to 6 then 8 mm led to a significant increasing in the average particle size from1.420 to 1.836 then to 2.252 mm, respectively, that's owing to the fact that the smaller sieve tends to keep the grains a longer time until becomes able to pass through the perforates, hence the fineness decreases. The contrary happens in terms of the larger sieve perforates, this is in consistency with Istavan (1980) and Abbas and Raghda (2013). The interaction among the factorseffected significantly on the average particle size, the highest particle average was 2.714 mm with chain B along with sieve 8 mm, while the least average of particle size was 1.345 mm with chain (A) along with sieve 4 mm.

5. Standard Deviation

Table 6 displays the effect of hammering type along with sieves' perforates diameteron the standard deviation. Whereby, the chain (A) recorded a significant least value of standard deviation by a mean of 3.663, then the conventional hammer comes next by a mean of 3.766. Whereas, the chain (B) differed significantly from them, by a mean of 4.298.That's maybe due to the fact that the chain (A) recorded the least average of particle measurements (higher fineness), that led to a decreasing in standarddeviation, this is in consistency with Ahmed (2001). It's also observed that increasing the diameter of sieve perforates from 4 to 6 then to 8 mm led to an increasing in the particles standard deviationfrom 2.818 to 4.056 then to 4.853, respectively, that's maybe due to the fact that the bigger sieve perforatesdiameter led to exit of bigger grain particles with the rest of the ground substances including the fine particles,without being ground perfectly, this is in consistency with Ahmed (2001) and Abbass and Raghd (2013). Also, table 6 illustrates the interaction between hammering tool with sieve's perforatesdiameter had a significant influence on the standard deviation of the particles, whereby the least standard deviation was 2.736 with the conventional hammer and sieve 4mm, whereas the highest standard deviation was 5.220 with the chain (B) and the sieve's perforates diameter 8mm.

Conclusion

1. Changing the conventional hammers with chains had a significant effect on the grinder indicators and the measured ground particles.

2. When increasing the sieves diameter from 4 to 6 then to 8 mm, chains had a significant infkuence on the all the studied indicators.

3. The best consumed electricity along with the best capacity and the less temperature increasing were found with the chain hammers and the sieve diameter of 8mm.

4. The least average particle size and outliers/ standard deviations were recorded with the chain hammers and the sieve diameter of 4mm.

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