Effect of number , thickness of the blades and feed rate on the capacity and power consumption of the hammer mill

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Abstract

The research aims to manufacture of hammer mill with the least number of parts, suitable thickness of blades, lowest energy cost and suitable capacity. A experiment was conducted with three factors(Number , thickness of blade and feed rate) the first with three levels 2, 3 and 4 blade , the second with three levels 6, 9, 12 mm with a weight of 98 grams for each and the third feed rate are levels of 90 and 180 $kg.h^{-1}$. The results showed a significant effect of number(A) , thickness of blade(B) and feed rate(C) on the production capacity and specific energy consumption. A significant effect of the combination of A with B and A with C on the production capacity and specific energy consumption. the superiority of the number of the four blades with lowest of thickness . Hammer mills can be designed with the lowest blade thickness, when using a large number of blades, in order to reduce the cost of materials used in manufacturing, as well as reduce the cost of the energy requirements of the production unit.

Key word: Hammer mill, blade of miller , mill capacity.

Introduction

There is an increasing demand at the present time to purchase small hammer millers for domestic use or to prepare fodder in small poultry projects. Since these machines have limited productivity, it is better to have a low cost of purchase, maintenance and operation. The smaller the moving parts in the machine and its size (such as the rotating blades), the lower the energy consumption and the maintenance cost. Studies have been carried out with the aim of reducing operating costs. Oluwole et.al (2019) tested a small milling machine powered by a small petrol engine, where the speed of the grinder can be controlled with the stability of the drive train (weight of the rotating parts).

Nwadinobi (2017) also carefully studied power needs, spindle selection and motor power. Increasing the grinding speed can eliminate the effect of the rotor weight and the force required to grind the grains, as the speed is a major factor in the kinetic energy, as well as the possibility of reaching a high grinding capacity of the grinder when using the high speed as the opportunity to use larger sieve openings (Ibrahim et. Al, 2019)). Reducing the thickness of the blades reduces their weight, size, and hence the required motion energy. Vigneault.et al., (1992) found that the efficiency of the machine increased when using a smaller blade thickness. In large grinders of large width, they usually allow the use of a large number of blades to increase the production capacity and the degree of smoothing, but in a small grinder with limited width, the larger number of blades may not be necessary, especially when there is sufficient machine speed and an appropriate feeding rate. This is what we intend to test in this research as The research aims to:

Manufacture of hammer mill grinding machine with the least number of blades, suitable thickness of blade, lowest operating cost and suitable capacity.

Materials and research method

The grinder was manufactured in the workshop of the machinery department with the specifications shown in Table 1 for the purpose of conducting the experiment using it, where a factor experiment was conducted with three factors, the first number of blades with three levels 2, 3 and 4 blade and the second blade thickness with three levels 6, 9, 12 mm with a weight of 98 grams for each blade was made Holes to reduce the weight of the blades that weigh more than 98 (with the largest thickness) and the third feed rate are levels of 90 and 180 kg / hour. Each treatment was repeated 3 times. The experiment was conducted according to a complete random design and the results were analyzed by the ssps.22 program to find the effect of the studied factors on the production capacity, specific energy consumption, and the average diameter of the milled particles, and compared the averages under the significant level of $p < 0.05$.

Table 1 : Specifications of the hammer mill.

No.	Parts	Measurement	No.	Parts	Measurement
1	Number of blades	Variables	8	Total grinder height	
2	Blade weight	*98 ±2 gm	9	Ground grain exit height off the floor	70 cm
3	Screen Opening	6 mm	10	Power engine (Electrical Motor-single phase)	2HP(1.5 KW) , 220 V , 9.3 A
4	Total screen area	12800 mm^2 (16cmx8cm)	11	Engine pulley-diameter	10 cm
5	Miller - case diameter	30 cm	12	Engine velocity	2830 RPM
6	Miller - effective diameter	27 cm	13	Grinder pulley-diameter	8 cm
7	Hammer disk-diameter	10 cm	14	Grinder velocity	2264 RPM

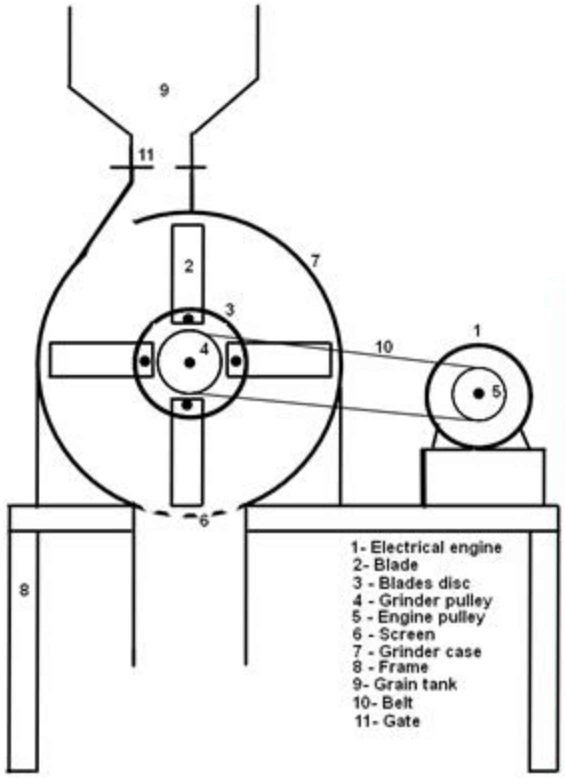

Figure 1-A Description of the parts of the grain

Figure 1 –B Blades dimension 100 mm Length x 25.4 mm width with different of thickness 6 , 9 and 12 mm

Mill Production Capacity:

The crushed grains (product) were collected and weighed with an electronic scale after running the mill for one minute, using an electronic timing regulator linked with the mill motor to stop it after the end of the running time. The production capacity was calculated in units of gram / minute using the following equation:(Basim,2013)

Production Capacity (g / min) = $\frac{weight\ of\ grains\ after\ grinding}{time}$ …(1)

Specific consumption of electrical energy:

The require milling power was estimated by using the following equation. The method (El Shal, et.al. 2010) was used with the modification that the mill motor used in the current research is a single-phase type.

Total consumed power (kw) = $\frac{I.V\ \eta\ \cos\ \theta}{1000}$ ....(2)

Where:
I= line current strength in Amperes.
V = Potential strength (voltage) being equal to 390V.
Cos θ = power factor (being equal to 0.84).
η = Mechanical efficiency assumed (95%).
The specific energy requirement (kw. h/kg) was calculated by using the following equation:

$$\text{The specific energy requirement (kW. h/kg)} = \frac{The\ consumed\ power\ (kW)}{Actual\ milling\ capacity\ (kg\ /h)} \quad \ldots(3)$$

Results and discussion

Effect of blade number on the capacity and Specific energy consumption

Using the variance analysis test, we found a significant effect of the number of blades on the production capacity under the probability level P <0.05 and using the $LSD_{1.73}$ least significant difference test, we found that the number of the four blades outperformed the numbers 2 and 3, as the four blades recorded a production capacity of 49.87 kg / h compared to 44.92 and 44.84 for the two blades. 2 and 3, respectively, and thus the direction of the relationship tends to increase the capacitance with the increase in the number of blades (Figure 2) and this is consistent with (Oluwole, 2019). On the other hand, there was a significant effect of the number of blades on the specific energy consumption, and the four blades recorded the lowest specific energy consumption due to the increase in productivity in the same period of time for operating blades 2 and 3, as it recorded 0.034kw.h / kg compared to 0.037 for each of blades 2 and 3(Figure 3).

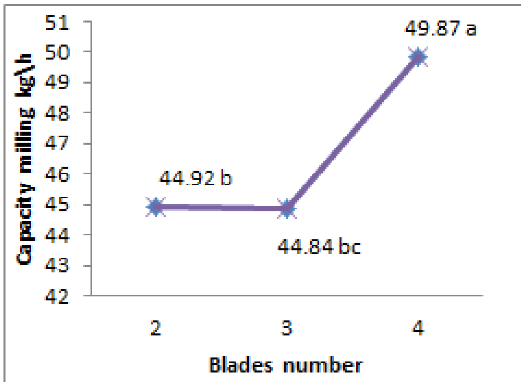

Figure 2 Effect of blade number on capacity

L.S.D 1.73 , The difference indicate a significant differences between the averages of the treatments

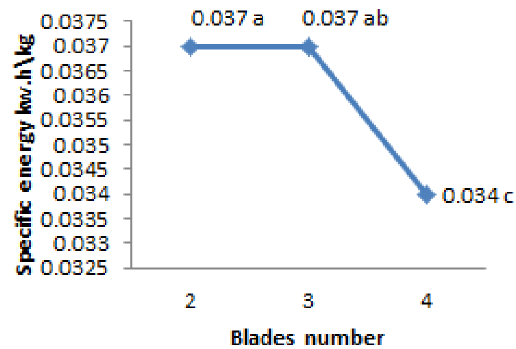

Figure 3 Effect of blade number on specific energy consumption

L.S.D 0.002 , The difference indicate a significant differences between the averages of the treatments on

Effect of blade thickness on the capacity and Specific energy consumption

From figure 4, we notice the inverse relationship between blade thickness and production capacity, as the statistical analysis recorded a significant effect of blade thickness on capacity. According to $LSD_{1.73}$ test, the thickness of the blade exceeds 6 mm over 9 mm, then 12 mm, as the production capacity was 48.6 kg / h compared to 46.51 and 44.52 for the thickness 9 and 12 mm, respectively. The thickness of 6 mm also recorded the lowest specific energy consumption compared to other thickness levels according to The $LSD_{0.002}$ test scored 0.038 against 0.037 and 0.034, as we can see from Figure 5. This is what he also found (El Shal , 2010) and (Richard, 1960).

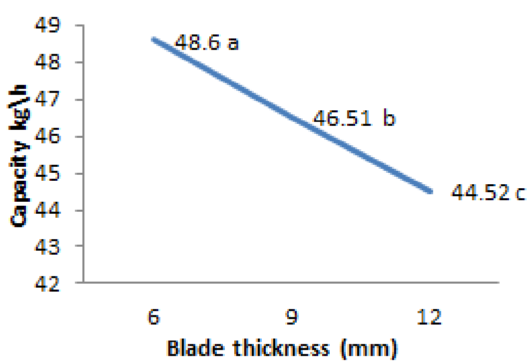

Figure 4 Effect of blade thickness on capacity

L.S.D 1.73 , The difference indicate a significant differences between the averages of the treatments

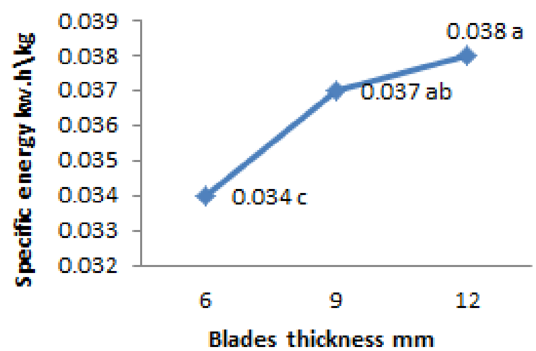

Figure 5 Effect of blade thickness on

L.S.D 0.002 , The difference indicate a significant differences between the averages of the treatments

Effect of feed rate on the capacity and Specific energy consumption

The analysis of variance tests found a significant effect under the probability level p <0.05 of the feed rate on the production capacity and specific energy consumption. From Figure 6, we notice that the feeding rate of the 180 kg / h exceeded the 90 kg / h, as it recorded a production capacity of 58.35 kg / h compared to 34.74 kg / h, respectively. While in Figure 7, we notice the low energy consumption when using the 180kg / h feed rate, as it was recorded at 0.027 kw. h / kg compared to the 90 kg / h feed rate, which was 0.045 kw. h / kg.

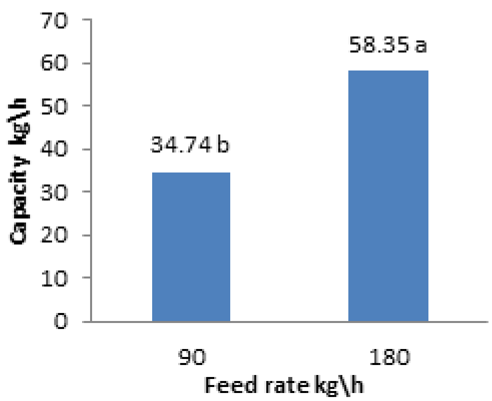

Figure 6 Effect of feed rate on capacity

L.S.D 1.73 , The difference indicate a significant differences between the averages of

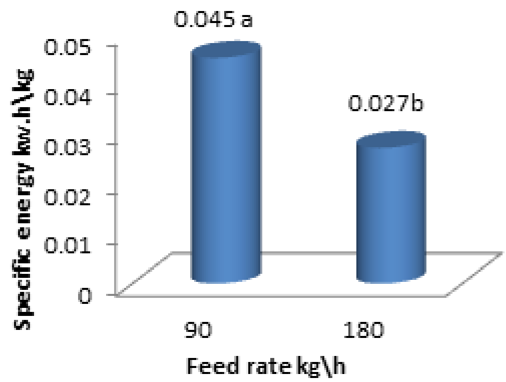

Figure 7 Effect of feed rate on specific energy consumption

L.S.D 0.002 , The difference indicate a significant differences between the averages of

The effect of combinations between the number of blades and the thickness of the blades on capacity and specific energy consumption

Tables 2 and 3 show the correspondences between the number and thickness of the blades on the capacity and energy consumption respectively. The analysis of the results showed a significant effect of this reconciliation on the studied characteristics, and the LSD test showed the superiority of the number of the four blades with thickness of 6 and 9 mm over the rest of the parameters in production capacity, which recorded 52.51 to 54.67 kg / h. As for the specific energy consumption, the lowest values recorded were when treating the four blades with thicknesses 6, 9 and 12 mm, as these combinations outperformed the rest of the treatments, and the highest values were when the treatments were of the number of blades 2 and 3 with thickness 6, as 0.040 kw.h / kg each.

Table 2 The effect of combinations between the number of blades and the thickness of the blades on capacity

Blade thickness (B) / Blade number (A)	6 mm	9 mm	12 mm
2	45.36 de	42.80 defg	46.60 cd
3	48.29 c	42.07 defghl	44.16 def
4	52.15 ab	54.67 a	42.80 defgh
LSD $_{AB}$ 2.99 The difference indicate a significant differences between the averages of the treatments on a level of ($p<0.05$)			

Table 3 The effect of combinations between the number of blades and the thickness of Specific energy consumption

Blade thickness (B) / Blade number (A)	6 mm	9 mm	12 mm
2	0.036 abc	0.040 a	0.035 bcd
3	0.035 bcd	0.040 a	0.037 ab
4	0.030 e	0.030 e	0.030 e
LSD $_{AB}$ 0.004 The difference indicate a significant differences between the averages of the treatments on a level of ($p<0.05$)			

The effect of combinations between the number of blades and the feed rate on capacity and specific energy consumption

The results showed a significant effect of the combination of the number of blades and the feeding rate on the production capacity and specific energy consumption. Table 4 shows the superiority of the four blades at a feeding rate of 180 kg / h, as it recorded a production capacity of 62.96 kg / h, while it ranged from 55.31 - 56.77 for the treatments with blades 2 and 3 at the rate of feeding 180 kg / h respectively, and the treatment was recorded with blades 2 and 3 when feeding 90 kg / h is the lowest value of production capacity. From Table 5, we notice that the four blades at a feeding rate of 180 kg / h recorded the lowest specific energy consumption compared with the rest of the treatments**.**

Table 4 The effect of combinations between the number of blades and the feed rate on capacity

Feed rate kg\h (c) / Blade number (A)	90	180
2	33.07 ef	56.77 b
3	34.37 de	55.31 bc
4	36.78 d	62.96 a

LSD $_{AC}$ 2.99 The difference indicate a significant differences between the averages of the treatments

Table 5 The effect of combinations between the number of blades and the feed rate on capacity

Feed rate kg\h (c) / Blade number (A)	90	180
2	0.045 a	0.029 cd
3	0.044 ab	0.030 c
4	0.044 ab	0.023 e

LSD $_{AC}$ 0.04 The difference indicate a significant differences between the averages of the treatments on

Conclusions and recommendations

- Significant increase in the production capacity of the mill by using the number of four blades compared to two blades, and a decrease in the specific energy consumption by increasing the number of blades

- A direct relationship indicating an increase in production capacity with an increase in blade thickness

- A inverse relationship indicating a decrease in the specific energy consumed by an increase in the thickness of the blades

- Increase production capacity and decrease the specific energy consumed by increasing the feeding rate

-Hammer mills can be designed with the lowest blade thickness, especially when using a large number of blades, in order to reduce the cost of materials used in manufacturing, as well as reduce the cost of return operation due to the lower energy requirements of the production unit.

-Conduct a study on the effect of thickness, weight, and number of blades with different sieve openings on capacity, power requirements and degree of smoothing.

References

Oluwole, F. A., A. Guja and A. K. Abubakar (2019). Effect of number of beaters on the performance of household hammer mill. AZOJETE, 15(3):619-627.

Nwadinobi C. P (2017). Development and Performance Evaluation of Improved Hammer Mill. Journal of Scientific and Engineering Research,4(8):159-164.

Vigneault. C.; T.M. Rothwell and G. Bourgeois(1992). Hammer mill grinding rate and energy requirements for thin and conventional hammers. Canadian agricultural engineering Vol. 34, No. 2,PP. 203-207.

Ibrahim, M. M. ; M. S. Omran and E. N. Abd elrhman(2019). Design and evaluation of crushing hammer mill. Misr J. Ag. Eng., 36 (1): 1 – 24.

El Shal ,M.S. ; M.A. Tawfik ; A.M. El Shal and K. A. Metwally (2010). Study the effect of some operational factors on hammer mill. Misr J. Ag. Eng., 27(1): 54 - 74 .

Richard Jakes Baker (1960). Factors that affect the granulation and capacity in grinding of corn, oats, and sorghum grain with a hammer mill. A Thesis, requirements for the degree master of science. Kansas state university of agriculture and applied science

Basim.A.AL-Shemari (2013). the effect of sieve holes and type of grains (barely, sorghum and maize) on the production hammer mill and some physical and. chemical properties of the grinding. JJAS, 9(3).PP 404-412.