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Research Article

Evaluation of Soya Bean Grinding Machine for Pulse Splitting

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Abstract

Pulses are defined as dried edible seeds of cultivated legumes. Pulses occupy an important place in the human diet. The demand for pulses is fast increasing; both in developed and developing countries, where they meet the minimum protein requirements of an increasing population turning to a vegetarian diet. The potential and prospect as a source of income and its capacity to generate household income were low due to the lack of appropriate splitting machines and the farmer's offer for the market simply without splitting. To solve the above problem evaluating a JAERC-developed soya bean grinding machine for pulses splitting is needed. The machine is comprised of three main units- a power transmission unit, a grinding unit, and a delivery unit beside the frame. The maximum splitting capacity (414.40 kg/hr and 418.41 kg/hr) was obtained at the operation speed of 500 rpm and 7 kg/min feeding rate for beans and peas respectively. The maximum splitting efficiency of the machine (93.15% and 97.26%) was recorded at a feeding rate of 6 kg/min and 500 rpm of the operated speed for the beans and peas respectively. The performance of the machine was significantly affected by the feeding rate and speed of the operation. Splitting efficiency, in general, increased when increasing the speed of the operation and decreased when increasing the feeding rate. The broken percentage of the pulse increases, when the speed of the disc increases and decreases as the feeding rate increases for each pulse. The splitting capacity of the machine increases as both the feeding rate and operating speed increase for each crop. The evaluated machine was good for peas and beans at 500 disc speed and a feeding rate of 7 kg/min. The machine needs further modification for better splitting purposes.

Keywords

Efficiency, Pulses, Splitting

1. Introduction

Soybean is considered to be an important oilseed crop because of contains highly nutritious oil in large quantities [3]. Soybean contains about 40% protein and 20% oil. This staple crop contributes significantly to global food security and the economy of agriculture [5]. Soy protein is the most economical protein produced in the world. The high quality of soy

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protein is illustrated by its content of all the essential amino acids except Sulphur which contains amino acids. Supplementation of the cereal-based diet with soy-protein gives an amino-acid complementation which results in increased protein quality and quantity approaching that of animal protein [2].

Nowadays, soybean can be mentioned as an important plant for agriculture, because it is one of the main food sources for human and animal nutrition. It is a food source that contains high-quality protein and does not contain cholesterol and saturated fatty acids. The best-known and most widely used products from soybeans are soybean oil and soybean meal. Soybean oil is the most widely used edible oil in the world and soybean meal is the leading protein and energy source for animal feeds. Soybean oil is used as cooking oil and as the base for shortening, margarine, salad dressings, and mayonnaise. The soymilk has rich vegetable protein to greatly meet the demand for the people of protein, in addition to containing vitamins B_1, B_2, and iron, calcium, especially water-soluble calcium, which could suit calcium deficiency in elderly people and growing [6]. Japanese soymilk is processed in four phases soaking soybeans, grinding, boiling soymilk, and each stage has been mechanized and works closely together in all phases of production, so the soymilk efficiency and quality are very high.

In China, soymilk preparation has a relatively long history and has been processed by handmade stone for a long time [1]. The soymilk ground by the stone mill originated in China and has been used nowadays, in more than 2,000 years of history. The soybean hull is loosely attached to the cotyledons. A simple mechanism of rubbing the soybean seed/grain between two surfaces can detach the hull. Five types of dehullers have been developed for soybeans in Iran. These are rotor concave type, hand grinder, manually operated, power operated, and cylinder-concave.

The increasing rate of soybean usage, high food value, and production-exportation growth, necessitated more investigation and attention toward this product. The mechanized process of soybean production before and after harvesting has great impacts on quality, food value, competitive market, and the world production of this strategic product. On the other hand, any analytical and applicable investigation for a better production process, directly or indirectly, has pronounced effects on farmer's income [3].

Pulse crop splitting in Ethiopia at present predominantly by traditional and manual methods which is accomplished by women's use of two stones. The traditional practice of pulse grinding is time-consuming, more labor requirements, high energy consumption, and loss of material. This work is needed to have a multi-purpose machine for a different operation with the objective of evaluating JAERC-model soya bean grinding machine for pulse splitting.

2. Materials and Method

2.1. Experimental Site

The experiment was conducted at Limmu and Shabe woreda of Jimma zone and Chewaka of Buno Bedele zone.

2.2. Materials

JAERC-model soya bean grinding machine, and samples (bean and pea).

2.3. Lab and Field Equipment

Digital weight balance, oven-dry, tachometer, stopwatch, etc.

2.4. Description of the Machine

The machine is comprised of three main units- a power transmission unit, a grinding unit, and a delivery unit beside the frame. The power transmission unit includes a v-belt, v-pulley with power shaft, and machine shaft. The grinding unit is the rotating stone and the cylindrical grinding chamber. The delivering unit is the hopper and chute. The frame is to give rigidity and support to all other components and parts of the machine. The splitting operation is by continuous impact of the solid particle of materials to be split between the two walls of the stones.

Figure 1. *Soybean grinder for pulse splitting.*

2.5. Data Collected

The mass of grain introduced to the machine, mass of splited grain, mass of unsplited grain, mass of broken grain, moisture content, and time of splitting.

2.6. Performance Evaluation

The equations used in determining the parameters are described as follows:

2.6.1 Splitting Efficiency

Splitting efficiency: - is the ability of a machine to split the grain and calculated by the equation below [7].

$$\eta_m = \frac{w_s}{wg} * 100$$

Where, W_s-total weight of grains splitted; W_g-total weight of grains.

2.6.2. Machine Efficiency

Machine efficiency: - is the total running efficiency of the machine

$$\eta_e = \frac{w_i - w_r}{w_i} * 100$$

Where; w_i-total weight of grain introduced into the machine; w_r-total weight of grains retained by the machine.

2.6.3. Machine Capacity

Machine capacity: the rate of grains introduced into the machine over time.

$$M_r = \frac{w_g}{t} * 100, kg / h$$

Where; t= time (s); W_g =total weight of grain.

2.7. Experimental Design

The experimental design is a split plot design with three replications. Treatment consisted of factorial combinations of three levels of engine speed, two types of pulses, and two levels of feeding rate. Data were subjected to analysis of variance following a procedure appropriate to the design of the experiment. The treatment means that are different at a 5% level of significance were separated using LSD. The experimental design was laid as 3*2*2*3 with three replications and has a total of 36.

2.8. Data Analyzing

The data were analyzed using R-statistical software.

3. Results and Discussion

3.1. Splitting Capacity

The maximum splitting capacity (414.40 kg/hr) was obtained at the operated speed of 500 rpm and 7 kg/min feeding rate for beans. Where the minimum splitting capacity (349.68 kg/hr) was obtained at 300 rpm of engine speed and 6 kg/min of feeding rate for beans. The maximum splitting capacity (418.41 kg/hr) was obtained at the operated speed of 500 rpm and 7 kg/min feeding rate for peas. The minimum splitting capacity (352.16 kg/hr) was obtained at an engine speed of 300 rpm and a 6 kg/min feeding rate for peas. ANOVA showed that feeding rate and engine speed had a significant effect ($p<0.05$) on splitting capacity. Tables 1 and 2 show that splitting capacity increased as the feeding rate and engine speed increased. As the feeding rate and disc speed increase the splitting capacity increases. The result is similar to the result reported by [4].

3.2. Splitting Efficiency

The maximum splitting efficiency of the machine (93.15%) was recorded at 6 kg/min feeding rate and 500 rpm of the operated speed for the bean. The maximum splitting efficiency of the machine (97.26%) was recorded at 6 kg/min feeding rate and 500 rpm of the operated speed for peas. ANOVA showed that feeding rate and engine speed had a significant effect ($p<0.05$) on splitting efficiency. Generally, as the feeding and speed of the operation increase, the splitting efficiency increases. The trend agrees with the result reported by [4].

3.3. Breakage Percentage

The maximum percentage of breakage of the machine (4.20%) was recorded at 6 kg/min feeding rate and 500 rpm of the operation speed for fava bean. The minimum percentage of breakage of the machine (1.52%) was recorded at 7 kg/min of feeding rate and 300 rpm of operated speed. The maximum percentage of breakage of the machine (2.61%) was recorded at 6 kg/min feeding rate and 500 rpm of the operation speed for peas. The minimum percentage of breakage of the machine (1.01%) was recorded at a 7 kg/min feeding rate and 300 rpm of operating speed. This means the higher operating speed causes a high broken percentage and a high feeding rate would be subjected to a low broken percentage.

Table 1. *Effect of the operating speed and feeding rate on performance evaluation of the machine for fava bean.*

Feeding rate (kg/min)	Speed (rpm)	Capacity (kg/hr)	Efficiency (%)	Breakage (%)
6	300	349.68^{f}	84.23^{e}	2.24^{e}
	400	351.00^{e}	87.05^{c}	3.51^{c}
	500	355.14^{c}	93.15^{a}	4.20^{a}

Feeding rate (kg/min)	Speed (rpm)	Capacity (kg/hr)	Efficiency (%)	Breakage (%)
	300	407.36^{d}	82.33^{f}	1.52^{f}
7	400	411.42^{b}	85.04^{d}	3.08^{d}
	500	414.40^{a}	92.54^{b}	4.14^{b}
CV		0.55	0.77	6.29
LSD$_{(0.05)}$		2.07	1.11	0.37

Table 2. *Effect of the operating speed and feeding rate on performance evaluation of the machine for peas.*

Feeding rate (kg/min)	Speed (rpm)	Capacity (kg/hr)	Efficiency (%)	Breakage (%)
	300	352.16^{f}	91.26^{e}	1.53^{e}
6	400	355.77^{d}	94.14^{c}	2.13^{c}
	500	357.93^{c}	97.26^{a}	2.61^{a}
	300	411.30^{e}	89.96^{f}	1.01^{f}
7	400	415.69^{b}	93.20^{d}	1.82^{d}
	500	418.41^{a}	96.72^{b}	2.51^{b}
CV		0.28	0.73	0.75
LSD$_{(0.05)}$		1.68	1.14	0.03

4. Conclusion and Recommendation

4.1. Conclusion

Based on the performance evaluation made and results obtained, the following conclusions can be drawn:

The maximum splitting capacity (414.40 kg/hr and 418.41 kg/min) was obtained at the operating speed of 500 rpm and 7 kg/min feeding rate for beans and peas respectively. The maximum splitting efficiency of the machine (93.15% and 97.26%) was recorded at a feeding rate of 6 kg/min and 500 rpm of the operating speed for the bean and peas respectively.

The performance of the machine was significantly affected by the feeding rate and speed of the operation. Splitting efficiency, in general, increased when increasing the speed of the operation and decreased when increasing the feeding rate. The broken percentage of the pulse increases, when the speed of the disc increases and decreases as the feeding rate increases for each pulse. The splitting capacity of the machine increases as both the feeding rate and operating speed increase for each crop.

4.2. Recommendation

The evaluated machine was good for peas and beans at 500 operation speed and 7 kg/min of feeding rate.

Abbreviations

CV	Coefficient of Variation
LSD	Least Significant Difference

Conflicts of Interest

The authors declare no conflicts of interest.

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