A STUDY ON SOME ENGINEERING PARAMETERS OF CUTTING AND CHOPPING MACHINE FOR AGRICULTURAL WASTES

M. A. Mady[1], M. A. Abdel-Hadi[1], Y. E. Abd-Allah[2] and M. F. Ali[3].

ABSTRACT

This study aimed to evaluate the performance of chopping machine during cutting some farm residues (rice straw and faba bean stalks) to minimize their size and volume. The results indicated that the highest machine productivity for rice straw and faba bean stalks of 0.144 and 0.120 Mg/h and the highest machine efficiency of 99.5 and 98.0% and the lowest energy requirements of 12.50 and 15.0 kW.h/Mg and the lowest operating cost of 21.22 and 25.46 LE./Mg for rice straw and faba bean stalks respectively, were obtained at speed of knives 1800 rpm (37.68 m/s), number of knives 32, serrated knife edge and spacing between bars of concave 20 mm. On the other side, the highest percent of cutting length < 2 cm of 53.40 and 43.30% for rice straw and faba bean stalks respectively, were obtained at speed of knives 1800 rpm (37.68 m/s), number of knives 32, serrated knife edge and spacing between bars of concave 10 mm.

***Keywords**: chopping machines; cutting machines; threshing machines; recycling crop residues; agricultural wastes.*

INTRODUCTION

Field crop residues are considered to be one of the most critical problems facing the Egyptian farmers. The estimated amount of agricultural residues in Egypt ranges from 30 to 35 Mg/y where estimated the amount of rice straw generated annually 3.6 Mg/y **(AWRU, 2005)** and estimated the amount of beans residues generated annually 0.35 Mg/y **(Abou Hussien and Sawan, 2010). Abdel Hamid *et al*. (2004**) mentioned that, the portion of rice straw residue is disposed by burning or mulched in rice fields.

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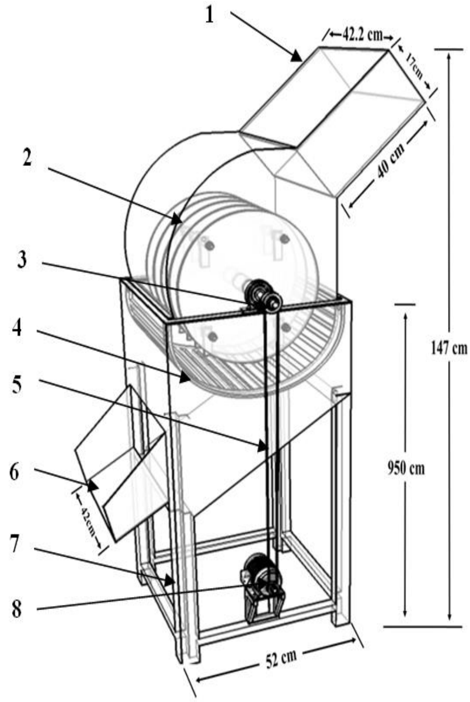
However, an attractive alternative usage of rice straw is composting. **Saxena *et al*. (2009)** stated that, to satisfy world's energy needs other sources must be developed. Renewable bioenergy sources such as agricultural plant residues (cereal straws, rice husks, corn stalks, sawdust and peat), animal wastes and forest residues can provide a continuous supply of liquid and gaseous biofuels. Before using agricultural wastes it should be chopped and cutting. Physical and mechanical properties of biomasses species and varieties are very important when considering the energy requirements for particle size reduction of agricultural residues. **Fellow (2003)** stated that, size of agricultural products may be reduced by several ways. The main methods used are crushing, impact, shearing and cutting. Size reducing devices include crushers, slicers, grinders, and hammer mills. **Moiceanu *et al.* (2012)** reported that, of the various types of grinding equipment available, hammer mills are the best known equipment used for the shredding/grinding, in which the material fragment are subjected to complex forces and then the resulted particles are used in the following operations from the pellet obtaining technology. **El-Khateeb *et al*. (2010)** evaluated rice straw chopper, they found that, the increase of cutter head knives speed from 23.0 to 33.0 m/s tends to decrease the chopping length from 14.0 to 10.5 mm and increase energy required from 2.593 to 3.198 kW.h/Mg, chopping efficiency from 79.0 to 88.0% and increase the degree of destruction from 52.0 to 62.0%, respectively. **Abdel Mottaleb and Obaia (2006)** investigated and evaluated a hammer mill machine for milling date palm leaves. The machine was used at different concave hole diameters to assess the machine productivity, efficiency, energy requirements and fineness degree. They showed that, the optimum machine performance was obtained at 22 mm concave hole diameter. **Ismail *et al.* (2009)** developed a chopping machine for agricultural residue. They used two different shapes of cutting knives (smooth edge and serrated edge). The maximum value of machine efficiency and capacity resulted with a serrated edge. The optimum performance of the developed chopper was obtained at feeding mechanism speed of 0.28 m/s and cutter head speed of 1.88 m/s by using serrated edge of cutting knives. **Marey *et al.* (2007)** developed and evaluated a chopper for chopping sugarcane bagasse. They found that, increasing number of knives tends to increase the percentage of short pieces (< 25 mm). **Metwally *et al*. (2006)** developed and evaluated technically and economically the feeding and cutting mechanisms of chopping machine to be used for cutting the different crop residuals and pruning the fruit tree branches. They reported that, the cutting length of ≤ 50 mm suitable to produce compost and animal organic. **Savani *et al.*** (**2004**) designed and developed agricultural wastes shredder. The results indicated that, the shredding capacity was 162, 156 and 179 kg/h for castor, cotton and pigeon pea stalks, respectively. **Arafa (2007)** modified the stationary machine to become suitable for chopping and cut farm crop residues. He found that, the energy requirement were found to be 29.9, 27.3 and 25.8 kW.h/Mg for rice straw, corn stalks and cotton stalks respectively. The objective of the present study some operating parameters affecting the performance of crop residues chopping machine.

MATERIALS AND METHODS

Cutting and chopping machine:

A cutting and chopping machine was designed and constructed in the work shop of the Department of Agricultural Engineering, Faculty of Agriculture, Suez Canal University as shown in Fig. (1). The frame was consisted from two parts: The first part was constructed from square iron base of 520 x 520 mm and a height of 950 cm. Motor stand (secondary part) was an extension of the primary part was made of horizontal rectangle 400 x 250 mm and 470 mm height from the surface of earth. The chopping unit consisted of five flanges 250 mm diameter and 12 mm thickness passes through these flanges four axes 10 mm diameter and 700 mm length and cutting knives were mounted on these axes Fig. (2). The knife was made from steal with dimension 95x30x7 mm with edge angle of 29.4^{o}. It had two shapes of edge the first was smooth and the second was serrated. The chopping unit was assembled on an axial shaft of 25 mm diameter rested on two bearings on the frame. A concave was made to semicylinder and constructed of a number of rectangular iron bars with dimensions of (500x10x2 mm). The bars are fitted to make whole grates have a shape of rectangular cross section with 50 cm of length and 1 or 2 cm of width. The concave was fixed under the drum at distance of 3 cm.

Two pulleys of 140 and 90 mm diameter were fitted on each of motor and drum shaft, respectively. The electric motor was connected by inverter device to provide or reduce the speed of knives. The power transmission unit comprised of an electric motor of 2 HP (1.47 kW) as a power source.

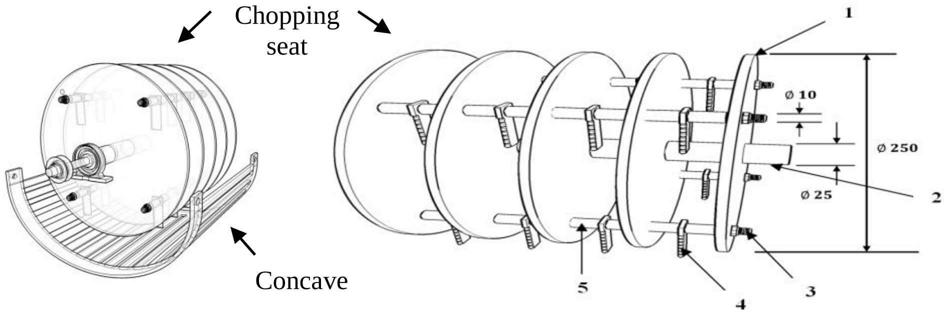


(1) Feeding opening (2) Chopping seat (3) Drum shaft
(4) Concave (5) Conveyor belt (6) Outlet of residues
(7) Frame of machine (8) Electrical motor

Fig. (1): Schematic diagram of cutting and chopping machine.

Crops residues:

Rice *(Oryza sativa)* straw and faba bean (*Vicia faba*) stalks were cutting and chopping to evaluate the performance of chopper. The experiments were carried at the experimental farm of Faculty of Agriculture, Suez Canal University, Ismailia - Egypt during the period of 2013-2014. Some physical properties of residues used in experiment are shown in Table (1).



(1) Flange (2) Cutting shaft (3) Knives axe
(4) Cutting knife (5) Iron bushing

Fig. (2): Chopping unit (all dimension in mm)

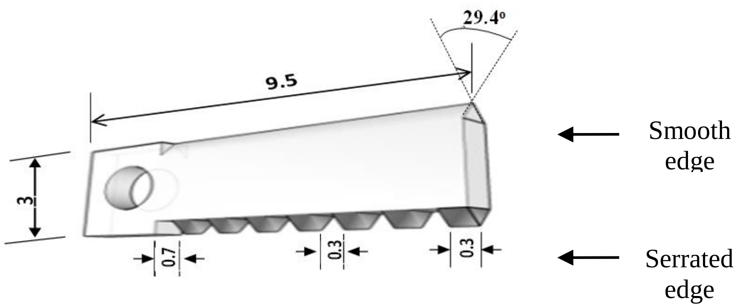


Fig. (3): Cutting knife (all dimension in cm)

Table (1): Some physical properties of rice straw and faba bean stalks.

Residue	Variety	Stem diameter, (mm)	Stem length, (mm)	Average length, (mm)	Moisture content, (%)
Rice straw	Sakha 101	3-4	900-1230	1065	5.5
Faba bean stalks	Giza 461	12-15	600- 1300	950	5

The following parameters were investigated:

1- Three number of knives 16, 24 and 32.

2- Four rotational speeds of cutting knives of 1200, 1400, 1600 and 1800 rpm (25.12, 29.31, 33.49 and 37.68 m/s, respectively).

3- Two shapes of cutting knives edge (serrated and smooth).

4- Two concaves, spacing between bars 10 and 20 mm.

The following points were taken into consideration to evaluate the performance of chopper:-

1- Cutting length percentage, cm. 2- Chopping efficiency, %.

3- Machine productivity, Mg/h. 4- Energy requirements, kW.h/Mg.
5- Operating cost, LE./Mg.

- Cutting length percentage.

The cutting length was assessed by taking a sample of 1 kg from product of cutting crop material into laboratory and separating into four categories (< 2, 2-5, 5-10 and > 10 cm). Each cutting length in the sample was weighed and calculated as a percentage of the total weight of the sample. The cutting length percentage was calculated by the following formula**:**

$$\textbf{Cutting length percentage} = \frac{\text{Weight of the category}}{\text{Weight of total output sample}} \times 100, \% \qquad (1)$$

- Chopping efficiency.

Three samples each of 1 kg of rice straw and faba bean stalks were fed into the chopper for each treatment after completed chopping operation the output materials weighted and the chopping efficiency was calculated as follows:

$$\textbf{Chopping Efficiency} = \frac{W_{out} - W_{uncut}}{W_{in}} \times 100 \qquad (2)$$

Where:

W_{out}: output mass, Mg; W_{in}: input mass, Mg and
W_{uncut}: uncut residues after chopping process, Mg.

- Machine productivity.

Three samples each of 1 kg of rice straw and faba bean stalks were fed into the chopper for each treatment and the chopping time in minutes were recorded the machine productivity was calculated as following:

$$P = \left(\frac{W}{T}\right) \times 60 \qquad (3)$$

Where:

P: productivity, Mg/h; W: mass of the sample, Mg
T: time, min.

- Energy requirements.

The power requirement (kW) was measured by using wattmeter and the energy requirements (kW.h/Mg) can be calculated by dividing the required power with the machine productivity as following:

$$\textbf{Energy Requirements} = \frac{\text{Useful power, kW}}{\text{machine productivity, Mg/h}}, \text{kW.h/Mg} \qquad (4)$$

- Operating cost.

The operating cost (LE./Mg) was calculated according to the price of materials in year 2013 by the following formula.

$$\textbf{Operating cost} = \frac{\textbf{Machine cost (LE./h)}}{\textbf{Machine productivity, Mg/h}}\ \textbf{, LE./Mg} \qquad \textbf{(5)}$$

The machine cost was determined by using the following formula according to (**Awady, 1978**).

$$\mathbf{C} = \frac{P}{h}\left(\frac{1}{a} + \frac{i}{2} + t + r\right) + (W\ x\ e) + \frac{m}{288} \qquad \textbf{(6)}$$

Where:

C: machine hourly cost, L.E/h;

P: price of machine, 4000 L.E;

h: yearly working hours, 3500 h;

a: life expectancy of the machine, 10 years;

i: interest rate / year, 10%;

t: taxes and over heads ratio, 10%;

r: repairs and maintenance ratio, 10%; W: required power, kW;

e: electricity cost, 0.15 LE. /kW.h;

m: the monthly average operators wage,700 L.E and

288: the monthly average operators working hours.

RESULTS AND DISCUSSION

Percentage of cutting length:

- Effect of knife speed.

To study the effect of speed of cutting knives on percentage of cutting length; spacing between bars and knife numbers are kept constant at 10 mm and 32 knives. Concerning rice straw, the results in Fig. (4) showed that, increasing speed of cutting knife from 25.12 to 37.68 m/s lead to increase the percentage of cutting length of category < 2 and category 2-5 cm from 44.92 to 53.40% and from 35.29 to 43.55%, respectively. On the other hand increasing speed knives from 25.12 to 37.68 m/s tends to decrease the percentage of cutting length of category 5-10 and category >10 cm from 9.63, to 1.52% and from 10.16 to 1.52%, respectively for rice straw. Relating to faba bean stalks the results revealed that, increasing speed of knives from 25.12 to 37.68 m/s lead to increase the percentage of cutting length of category < 2 and category 2-5 cm from 31.52 to 43.30% and from 31.52 to 39.18%, respectively. On the other hand increasing speed of knives from 25.12 to 37.68 m/s tends to decrease the percentage of cutting length of category 5-10 and category > 10 cm from 18.48 to 10.31% and from 18.48 to 7.22%, respectively. These results could be attributed to the increase of impacting force on the residues. The results of cutting length percentage of category < 2 cm and category 2-5 cm were agree with the use of composting and animal fodder suitable cut length in average of 5 cm according to **Metwally *et al.* (2006).**

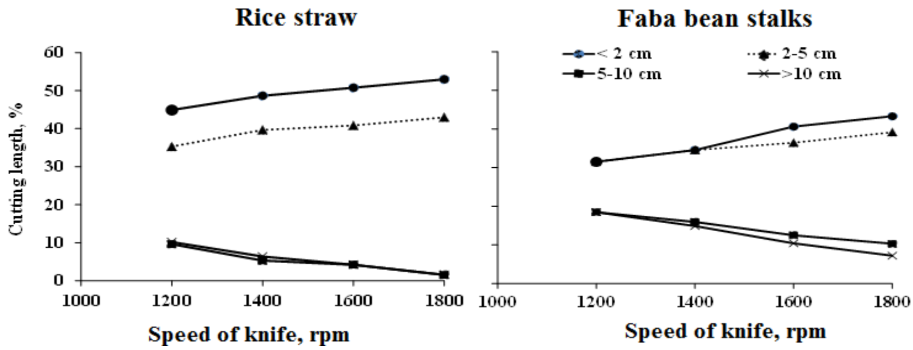


Fig. (4): Effect of speed of knives on cutting length percentages.

- Effect of shape of knife edge on cutting length.

To investigate the effect of shape of knife edge on the percentage of cutting length, spacing between bars, knife numbers and speed of knives are kept constant at 10 mm, 32 knives and 1800 rpm (37.68 m/s), respectively. For both rice straw and faba bean stalks the results in Fig. (5) showed that, using serrated knife edge led to increase the cutting length of < 2 and category 2-5 cm while decreased the cutting length of category 5-10 and category > 10 cm. Concerning of rice straw the cutting length of category < 2 and category 2-5 cm were increased from 51.55 to 53.40% and from 42.27 to 43.55% with smooth and serrated knife edges respectively. On the other hand the cutting length of category 5-10 and category >10 cm were decreased from 3.09 to 1.52% and from 3.09 to 1.52% with smooth and serrated knife edges respectively. Relating to faba bean stalks, the cutting length of category < 2 and category 2-5 cm were increased from 40.63 to 43.30% and from 38.54 to 39.18% with smooth and serrated knife edges, respectively. On the other side the cutting length of category 5-10 and category >10 cm were decreased from 12.50 to 10.31% and from 8.33 to 7.22%, respectively.

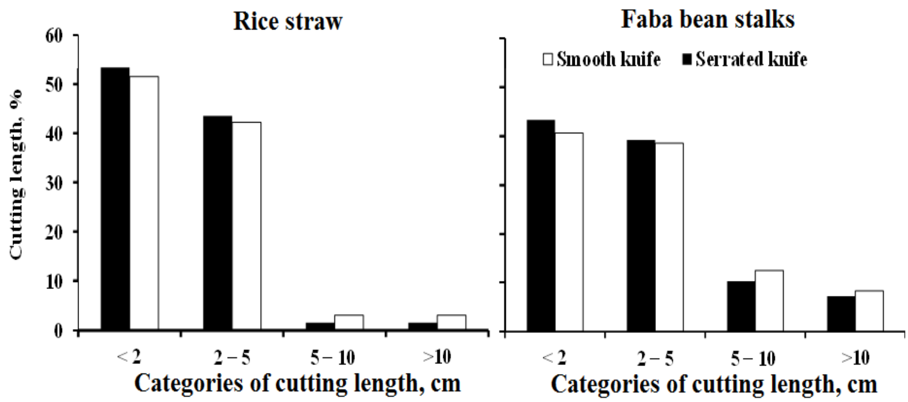


Fig. (5): Effect of shape of knife edge on cutting length percentage.

- Effect of knife numbers on cutting length.

To investigate the effect of knife numbers on percentages of cutting length, speed of knives, spacing between bars and shape of knife edge are kept constant at 1800 rpm, 10 mm and serrated, respectively. Concerning rice straw, results in Fig. (6) indicated that, increasing number of knives from 16 to 32 leads to increase the percentages of cutting length of category < 2 cm from 49.19 to 53.40%, respectively. Also the cutting length percentage of category 2-5 cm increased from 32.43 to 43.55%, respectively. On the other hand the percentages of cutting length of category 5-10 decreased from 9.19 to 1.52% and from 9.19 to 1.52% for cutting length of category > 10 cm. As to faba bean stalks, the results showed that, increasing number of knives from 16 to 32, leads to increase the percentages of cutting length from 32.26 to 43.30%, respectively for cutting length of category < 2 cm and from 33.33 to 39.18%, respectively for cutting length of category 2-5 cm. On the other hand the cutting length percentage were decreased from 17.74 to 10.31%, respectively for cutting length of category 5-10 cm and from 16.67 to 7.22% for cutting length of category > 10 cm. This is may be due to increase the number of knives led to decrease the space between knives and increase of knives knocking number in time unit on the residues.

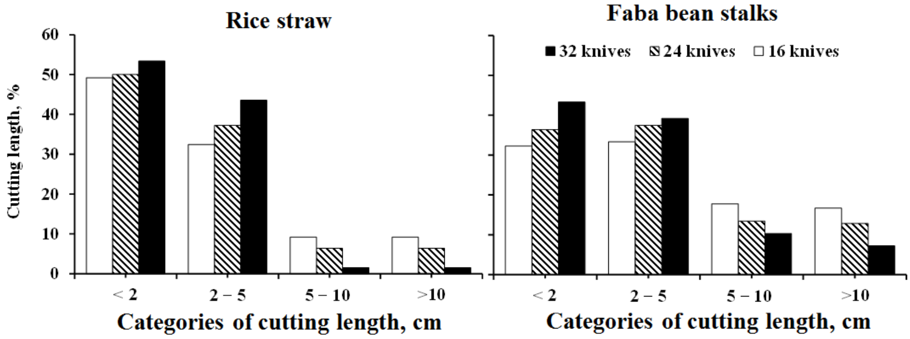


Fig. (6): Effect of knife numbers on cutting length percentages.

- Effect of spacing between bars on cutting length.

To study the effect of spacing between bars on cutting length percentage, speed of knives, number of knives and shape of knife edge are kept constant at 1800 rpm (37.68 m/s), 32 knives and serrated knife edge, respectively. With regard rice straw, results in Fig. (7) show that, increasing spacing between bars from 10 to 20 mm led to decrease the percentage of cutting length of category < 2 and category 2-5 cm from 53.40 to 48.74% and from 43.55 to 40.20%, respectively. On the other hand the cutting length of category 5-10 cm and category > 10 cm were increased from 1.52 to 5.03% and from 1.52 to 6.03%, respectively. Relating to faba bean stalks. Also results showed that, increasing spacing between bars from 10 to 20 mm decrease the percentage of cutting length of category < 2 and category 2-5 cm from 43.30 to 34.69% and from 39.18 to 31.63%, respectively. Meanwhile, the cutting length of category 5-10 and category > 10 cm were increased from 10.31 to 13.27% and from 7.22 to 20.41%, respectively.

Machine efficiency.

The general trend of the effect of knife numbers on machine efficiency was increasing number of knives tends to increase the machine efficiency. Concerning rice straw, the results in Fig. (8) showed that increasing number of knives from 16 to 32 led to increase the machine efficiency from 91.5 to 97.0% and from 92.5 to 98.5% for smooth and serrated edges of knife, respectively using spacing between bars of concave 10 mm and speed of knives 1800 rpm (37.68 m/s).

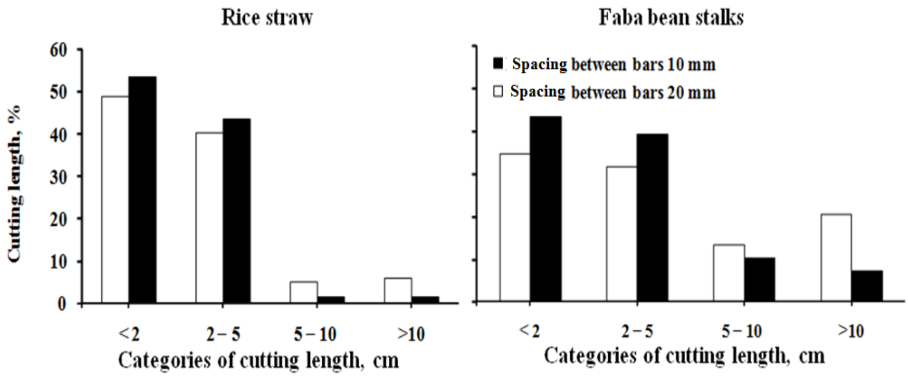


Fig. (7): Effect of spacing between bars on cutting length percentages.

At the same time, the machine efficiency increased from 92.5 to 99.0% and from 93.5 to 99.5% for smooth and serrated edges of knife, respectively, using spacing between bars of concave 20 mm and speed of knives 1800 rpm (37.68 m/s). Relating to faba bean stalks, the results showed that increasing number of knives from 16 to 32 led to increase the machine efficiency from 92.0 to 96.0% and from 93.0 to 97.0% for smooth and serrated edges of knife, respectively using spacing between bars 10 mm and speed of knives 1800 rpm (37.68 m/s). Also, the machine efficiency increased from 93.0 to 96.5% and from 94.0 to 98.0% for smooth and serrated edges of knife, respectively using spacing between bars of concave 20 mm and speed of knives 1800 rpm (37.68 m/s).

The results in Fig. (9) indicated that, increasing speed of knives using serrated knife edges and spacing between bars of concave 20 mm led to increase machine efficiency as compared with using smooth knife edge and spacing between bars of concave 10 mm with rice straw and faba bean stalks. For rice straw, increasing speed of knives from 25.12 to 37.68 m/s led to increase the machine efficiency from 92.0 to 97.0% and from 93.5 to 98.5%, respectively for smooth and serrated knife edges using spacing between bars of concave 10 mm and from 93.0 to 99.0% and from 94.0 to 99.5% with using smooth and serrated knife edges, respectively at spacing between bars of concave 20 mm and 32 knife numbers.

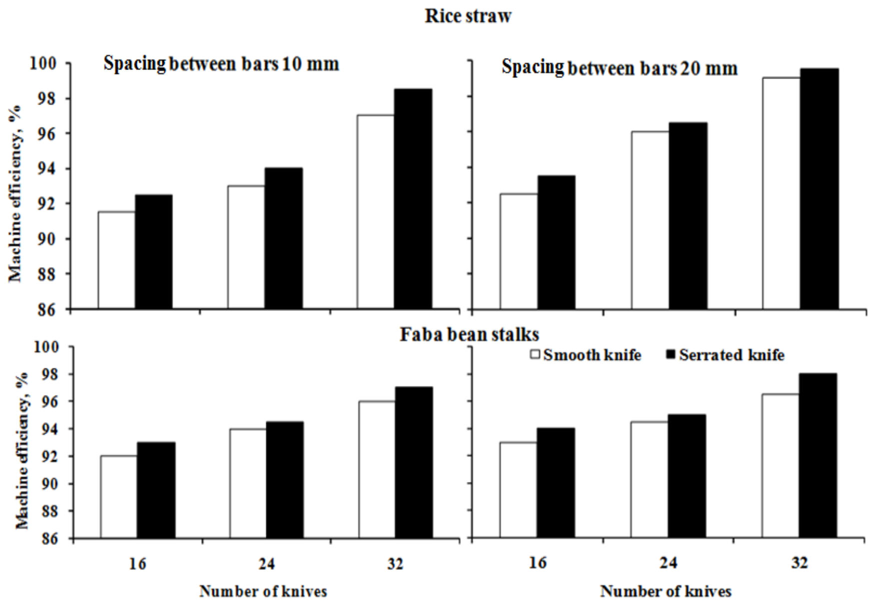


Fig. (8): Effect of knife numbers, shape of knife edge and spacing between bars of concave on machine efficiency.

At the same time, for faba bean stalks increasing speed of knives from 25.12 to 37.68 m/s rpm led to increase the machine efficiency from 91.5 to 96.0% and from 92.0 to 97.0%, respectively for smooth and serrated knife edges with using spacing between bars of concave 10 mm and from 93.5 to 96.5% and from 94.0 to 98.0% with using smooth and serrated knife edges respectively at spacing between bars of concave 20 mm and 32 knives.

The results in Fig. (10) revealed that increasing machine effeciency using serrated knife edge as compared with smooth knife edge for rice straw and faba bean stalks. Concerning rice straw, the results indicated that changing the knife edge from smooth to serrated led to increase the machine efficiency from 92.0 to 93.5, from 93.0 to 94.5, from 94.0 to 95.5 and from 97.0 to 98.5% at speed of knives 25.12, 29.31, 33.49 and 37.68 m/s, respectively using spacing between bars 10 mm.

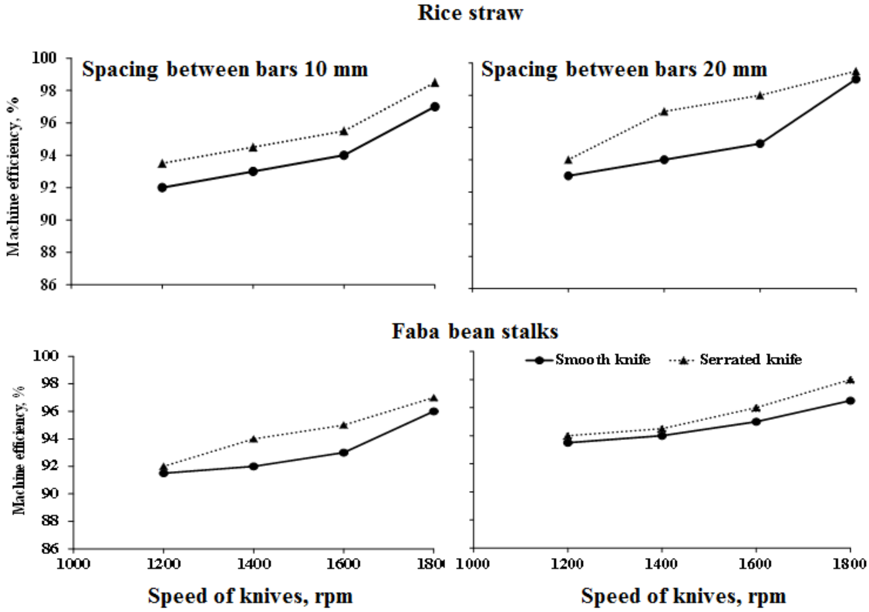


Fig. (9): Effect of speed of knives on machine efficiency.

Meanwhile, the machine efficiency increased from 93.0 to 94.0, from 94.0 to 97.0, from 95.0 to 98.0, from 99.0 to 99.5% at speed of knives 25.12, 29.31, 33.49 and 37.68 m/s, respectively with using spacing between bars 20 mm. Concerning faba bean stalks, the obtained results indicated that changing the knife edge from smooth to serrated led to increase the machine efficiency from 91.5 to 92.0, from 92.0 to 94.0, from 93.0 to 95.0 and from 96.0 to 97.0% at speed of knives 25.12, 29.31, 33.49 and 37.68 m/s, respectively using spacing between bars 10 mm. Meanwhile, the machine efficiency increased from 93.5 to 94.0, from 94.0 to 94.5, from 95.0 to 96.0 and from 96.5 to 98.0% at speed of knives 25.12, 29.31, 33.49 and 37.68 m/s, respectively with using spacing between bars 20 mm.

Machine productivity:

Concerning rice straw, the results in Fig. (11) show that increasing number of knives from 16 to 32, the machine productivity increased from

0.082 to 0.103 and from 0.090 to 0.129 Mg/h for smooth and serrated knife edges respectively with using spacing between bars of concave 10 mm and speed of knives 1800 rpm (37.68 m/s).

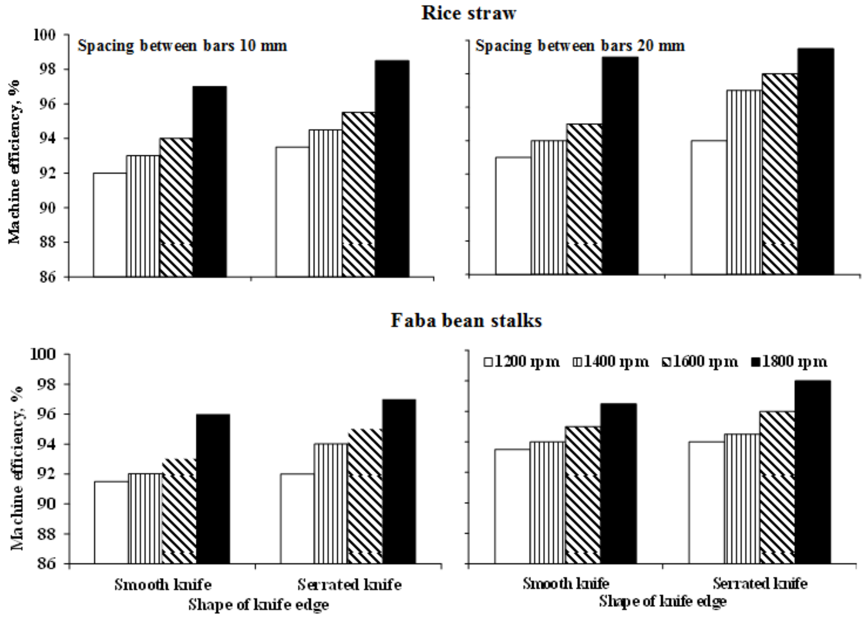


Fig. (10): Effect of shape of knife edge on machine efficiency.

Also, using spacing between bars of concave 20 mm and speed of knives 1800 rpm (37.68 m/s), the machine productivity increased from 0.095 to 0.133 and from 0.100 to 0.144 Mg/h for smooth and serrated edges of knife, respectively. Regarding faba bean stalks, the results showed that, increasing number of knives from 16 to 32, the machine productivity increased from 0.071 to 0.084 and from 0.075 to 0.090 Mg/h for smooth and serrated edges of knife, respectively with using spacing between bars of concave 10 mm and speed of knives 1800 rpm (37.68 m/s). At the same time using spacing between bars 20 mm, machine productivity increased from 0.090 to 0.106 and from 0.095 to 0.120 Mg/h for smooth and serrated edges of knife, respectively.

The results in Fig. (12) revealed that increasing speed of knives using serrated knife edge and spacing between bars of concave 20 mm led to increase the machine productivity as compared with using smooth knife edge and spacing between bars of concave 10 mm for rice straw and faba bean stalks. For rice straw, increasing speed of knives from 25.12 to 37.68 m/s tends to increase the machine productivity from 0.100 to 0.133 and from 0.109 to 0.144 Mg/h with using smooth and serrated knife edges respectively at spacing between bars of concave 20 mm and 32 knife numbers. Relating to faba bean stalks, increasing speed of knives from 25.12 to 37.68 m/s led to increase the machine productivity from 0.086 to 0.106 and from 0.090 to 0.120 Mg/h with using smooth and serrated knife edges respectively at spacing between bars of concave 20 mm. These results mean that the parameters of speed of knives of 1800 rpm (37.68 m/s), serrated edge of knife and spacing between bars of concave 20 mm at 32 knives were the suitable for chopping each of rice straw and faba bean stalks.

The results in Fig. (13) revealed that increasing machine productivity using serrated knife edge as compared with smooth knife edge for rice straw and faba bean stalks. Concerning rice straw, changing the knife edge from smooth to serrated led to increase the machine productivity from 0.084 to 0.095, from 0.090 to 0.103, from 0.097 to 0.116 and from 0.103 to 0.129 Mg/h at speed of knives 25.12, 29.31, 33.49 and 37.68 m/s, respectively with using spacing between bars 10 mm. Meanwhile, the machine productivity increased from 0.100 to 0.109, from 0.113 to 0.120, from 0.120 to 0.133 and from 0.133 to 0.144 Mg/h at speed of knives 25.12, 29.31, 33.49 and 37.68 m/s, respectively with using spacing between bars 20 mm. Relating to faba bean stalks, changing the knife edge from smooth to serrated led to increase the machine productivity from 0.069 to 0.075, from 0.072 to 0.080, from 0.080 to 0.086 and from 0.084 to 0.090 Mg/h at 25.12, 29.31, 33.49 and 37.68 m/s, respectively with using spacing between bars 10 mm. Meanwhile the machine productivity increased from 0.086 to 0.090, from 0.090 to 0.095, from 0.097 to 0.106 and from 0.106 to 0.120 Mg/h at 25.12, 29.31, 33.49 and 37.68 m/s, respectively with using spacing between bars 20 mm.

Energy requirements:

Considering rice straw, the results in Fig. (14) showed that, increasing number of knives from 16 to 32, the energy requirements decreased from

21.90 to 17.40 and from 20.00 to 14.00 kW.h/Mg for smooth and serrated knife edges respectively with using spacing between bars of concave 10 mm and speed of knives 1800 rpm (37.68 m/s).

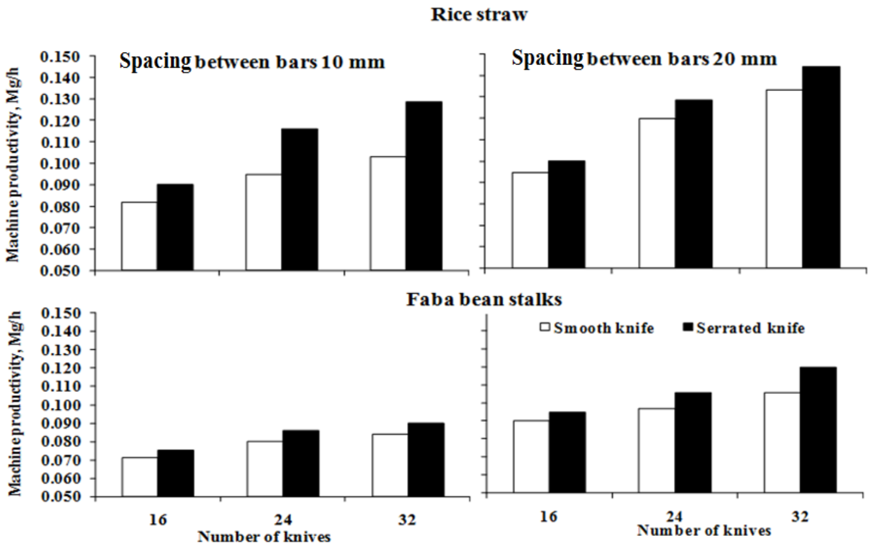


Fig. (11): Effect of knife numbers on machine productivity.

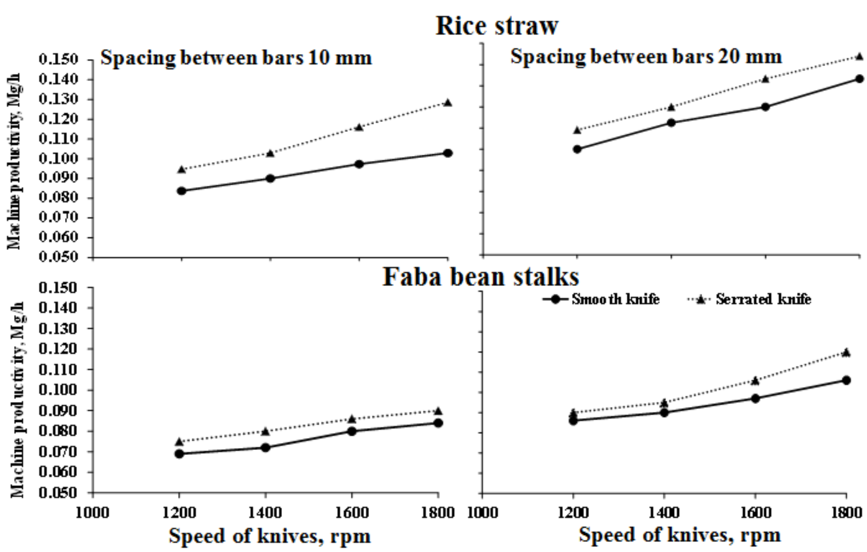


Fig. (12): Effect of speed of knives on machine productivity.

Also at spacing between bars 20 mm and speed of knives 1800 rpm (37.68 m/s) the energy requirements decreased from 19.0 to 13.05 and from 18.00 to 12.50 kW.h/Mg for smooth and serrated edges of knife, respectively.

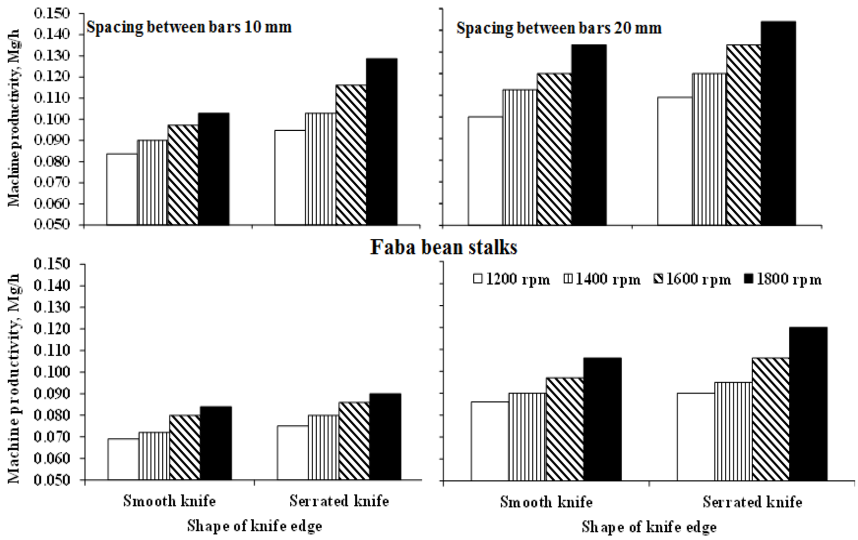


Fig. (13): Effect of shape of knife edge on machine productivity.

Concerning faba bean stalks, the results showed that increasing number of knives from 16 to 32, the energy requirements decreased from 26.0 to 22.0 and from 25.0 to 20.0 kW.h/Mg, respectively for smooth and serrated edges of knife with using spacing between bars of concave 10 mm and speed of knives 1800 rpm (37.68 m/s). At the same time using spacing between bars 20 mm and speed of knives 1800 rpm (37.68 m/s) the energy requirements decreased from 20.0 to 17.0 and from 19.0 to 15.0 kW.h/Mg for smooth and serrated edges of knife, respectively.

The results in Fig. (15) show the Effect of speed of knives, shape of knife edge and spacing between bars on energy requirements. The results indicated that, increasing speed of knives with serrated edge of knife and spacing between bars 20 mm reduced the energy requirements with rice straw and faba bean stalks as comparing with spacing between bars 10 mm and smooth knife edge. For rice straw increasing speed of knives from 25.12 to 37.68 m/s tends to decrease the energy requirements from 21.50 to 17.40 and from 19.20 to 14.00 kW.h/Mg, respectively with using smooth and serrated shape of knife edges and spacing between bars 10 mm. Also, using spacing between bars 20 mm the energy requirements was decreased from 18.30 to 13.05 and from 16.46 to 12.50 kW.h/Mg using smooth and serrated knife edges. Concerning faba bean stalks. It's noticed that, increasing speed of knives from 25.12 to 37.68 m/s caused a decrease of energy requirements from 26.0 to 21.50 and from 24.0 to 20.0 kW.h/Mg, respectively for smooth and serrated knife edges respectively with using 32 knives and spacing between bars 10 mm. At the same time, the energy requirements was decreased from 21.0 to 17.0 and from 20.0 to 15.0 kW.h/Mg, respectively for smooth and serrated shape of knife edges respectively with using spacing between bars 20 mm.

Relating to rice straw, the obtained results in Fig. (16) indicated that, changing the knife edge from smooth to serrated tends to decrease the energy requirements from 21.50 to 19.20, from 20.02 to 17.49, from 18.50 to 15.50 and from 17.40 to 14.00 kW.h/Mg at speed of knives 25.12, 29.31, 33.49 and 37.68 m/s respectively with using spacing between bars 10 mm. Meanwhile, using spacing between bars 20 mm the energy requirements were decreased from 18.30 to 16.46, from 16.02 to 15.00, from 15.00 to 13.50 and from 13.05 to 12.50 kW.h/Mg at speed of knives 25.12, 29.31, 33.49 and 37.68 m/s, respectively. With regard faba bean stalks, the obtained results show that, changing the knife edge from smooth to serrated tends to decrease the energy requirements from 26.0 to 24.0, from 25.0 to 23.0, from 22.5 to 21.0 and from 21.5 to 20.0 kW.h/Mg at speed of knives 25.12, 29.31, 33.49 and 37.68 m/s, respectively with using spacing between bars 10 mm. Meanwhile, using spacing between bars 20 mm the energy requirements were decreased from 21.0 to 20.0, from 20.0 to 19.0, from 18.5 to 17.0 and from 17.0 to 15.0 kW.h/Mg at speed of knives 25.12, 29.31, 33.49 and 37.68 m/s, respectively.

Operating cost:

With regard rice straw, the results in Fig. (17) show the relationship between knife numbers and operating cost. It's noticed that, increasing number of knives from 16 to 32, the operating cost decreased from 37.34 to 29.70 and from 33.94 to 23.76 LE./Mg for smooth and serrated knife edges, respectively with using spacing between bars of concave 10 mm. At the same time using spacing between bars of concave 20 mm the operating cost decreased from 32.25 to 22.91 and from 30.55 to 21.22 LE./Mg for smooth and serrated edges of knife, respectively.

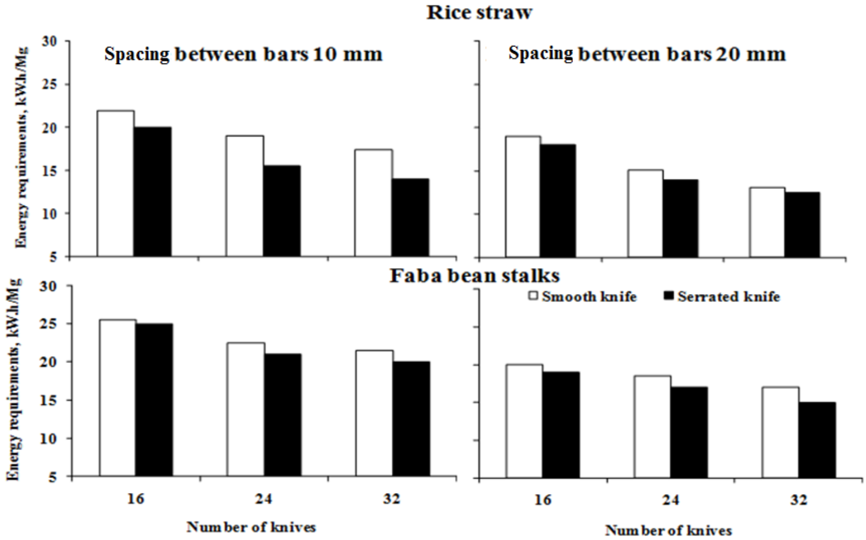


Fig. (14): Effect of knife numbers on energy requirements.

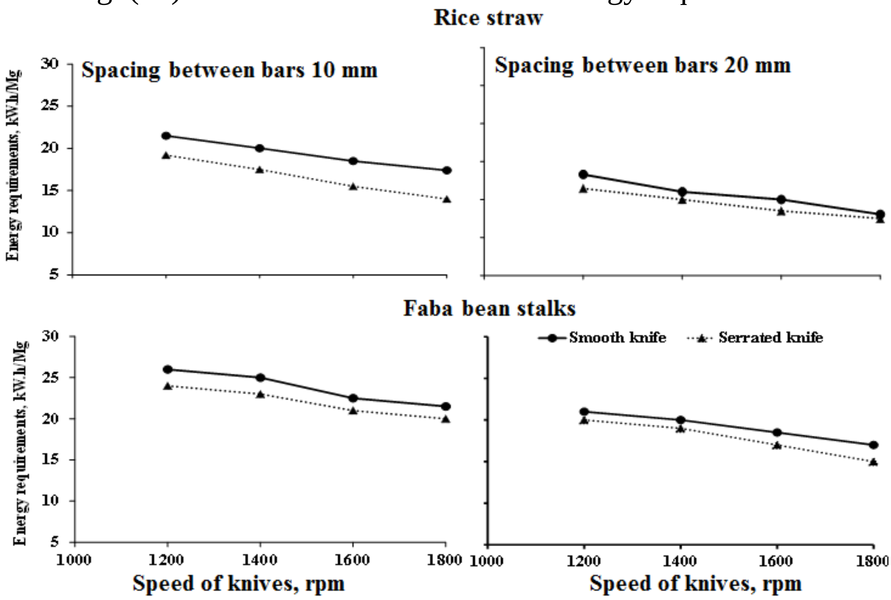


Fig. (15): Effect of speed of knives on energy requirements.

Relating to faba bean stalks, the results showed that, increasing number of knives from 16 to 32, the operating cost decreased from 43.28 to 36.49 and from 42.43 to 33.94 LE./Mg for smooth and serrated knife edges, respectively with using spacing between bars of concave 10 mm.

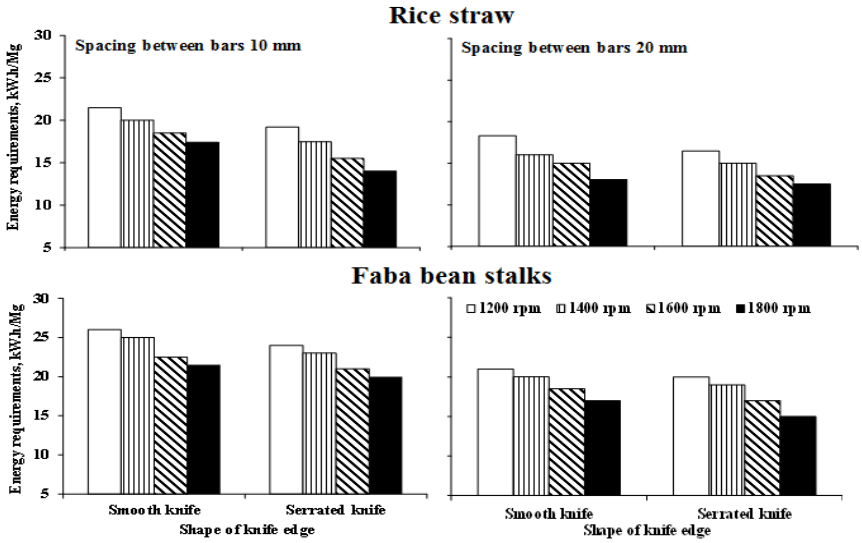


Fig. (16): Effect of shape of knife edge on energy requirements.

Also using spacing between bars of concave 20 mm the operating cost decreased from 33.94 to 28.85 and from 32.25 to 25.46 LE./Mg for smooth and serrated knife edges, respectively. The results in Fig. (18) indicated that**,** increasing speed of knives using serrated edge of knife and spacing between bars of concave 20 mm reduced the operating cost as compared with using smooth edge of knife and spacing between bars of concave 10 mm with rice straw and faba bean stalks**.** As to rice straw, the results showed that increasing speed of knives from 25.12 to 37.68 m/s the operating cost decreased from 36.49 to 29.70 and from 32.25 to 23.76 LE./Mg, respectively for smooth and serrated knife edges with using spacing between bars 10 mm. Also, the operating cost was decreased from 30.55 to 22.91 and from 28.00 to 21.22 LE./Mg, respectively for smooth and serrated knife edges with using spacing between bars 20 mm. Relating faba bean stalks, the results showed that, increasing speed of knives from 25.12 to 37.68 m/s the operating cost decreased from 44.13 to 36.49 and from 40.73 to 33.94 LE./Mg, respectively for smooth and serrated knife edges with using spacing between bars 10 mm. Meanwhile the operating cost was decreased from 35.64 to 28.85 and from 33.94 to 25.46 LE./Mg, respectively for smooth and serrated knife edges and spacing between bars 20 mm. Concerning rice straw, the obtained results in Fig. (19) indicated that changing knife edge from smooth to serrated tends to decrease the operating cost from 36.49 to 32.25, from 33.94 to 29.70, from 31.40 to 26.31 and from 29.70 to 23.76 LE./Mg at speed of knives 25.12, 29.31, 33.49 and 37.68 m/s, respectively using spacing between bars 10 mm. At the same time the operating cost was decreased from 30.55 to 28.00, from 27.16 to 25.46, from 25.46 to 22.91 and from 22.91 to 21.22 LE./Mg at speed of knives 25.12, 29.31, 33.49 and 37.68 m/s, respectively with using spacing between bars 20 mm for smooth and serrated edges of knife, respectively.

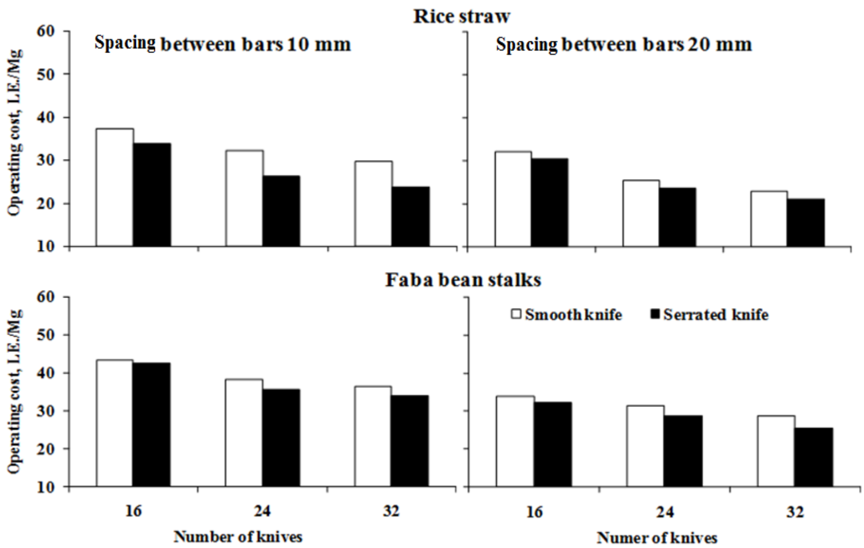


Fig. (17): Effect of knife numbers on operating cost.

Considering faba bean stalks, the obtained results indicated that changing of the knife edge from smooth to serrated tends to decrease the operating cost from 44.13 to 40.73, from 42.43 to 37.73, from 38.19 to 35.64 and from 36.49 to 33.94 LE./Mg at speed of knives 25.12, 29.31, 33.49 and 37.68 m/s, respectively with using spacing between bars 10 mm. Also the operating cost decreased from 35.64 to 33.94, from 33.94 to 32.25, from 31.40 to 28.85 and from 28.85 to 25.46 LE./Mg at speed of knives 25.12, 29.31, 33.49 and 37.68 m/s with using spacing between bars 20 mm for smooth and serrated edges, respectively.

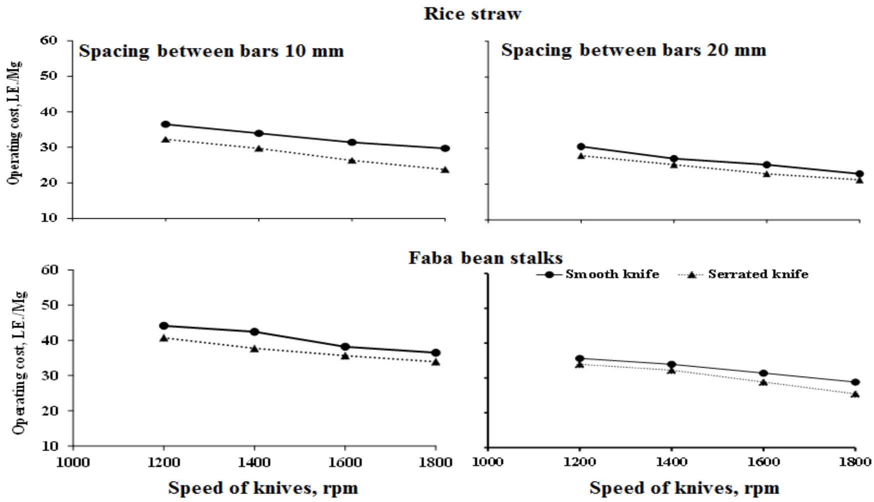


Fig. (18): Effect of speed of knives on operating cost.

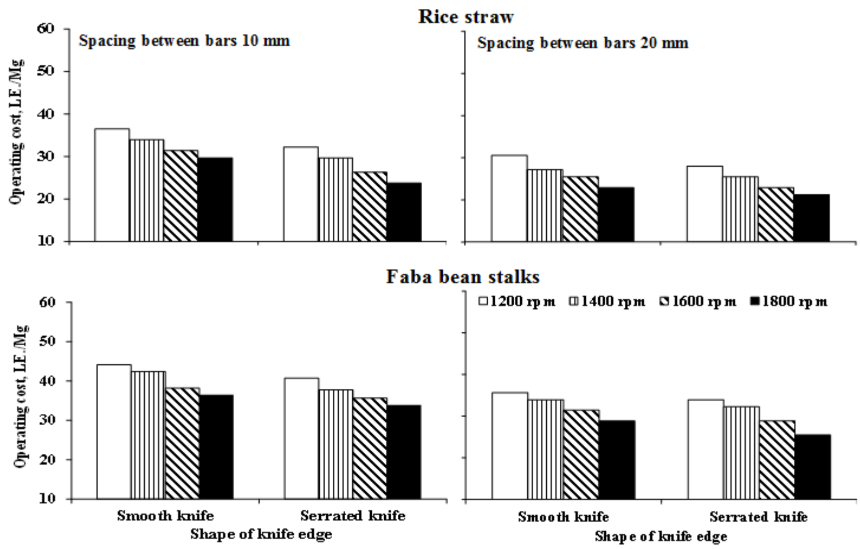


Fig. (19): Effect of shape of knife edge on operating cost.

CONCLUSION

The conclusion of present study can be summarized as follows:-

1. The highest values of machine productivity for rice straw and faba bean stalks were 0.144 and 0.120 Mg/h, respectively. The highest values of machine efficiency were 99.5 and 98.0% obtained at speed of knives 1800 rpm (37.68 m/s), serrated knife edge, 32 knife numbers and spacing between bars of concave 20 mm.

2. The highest values of cutting length percentages of category < 2 and category 2-5 cm were 53.40 and 43.55% for rice straw and 43.30 and 39.18% for faba bean stalks obtained at speed of knives 1800 rpm (37.68 m/s), spacing between bars of concave 10 mm, number of knives 32 and serrated edge of knife. On the other hand the highest values of cutting length percentages of category 5-10 and category >10 cm were 35.71 and 35.71% for rice straw and 32.04 and 44.20% for faba bean stalks obtained at speed of knives 1200 rpm (25.12 m/s), spacing between bars of concave 20 mm, 16 knife numbers and smooth edge of knife.

3. The least values of energy requirements for chopping rice straw and faba bean stalks were 12.50 and 15.0 kW.h/Mg obtained at speed of knives 1800 rpm (37.68 m/s), serrated edge of knife, 32 knife numbers and spacing between bars of concave 20 mm.

4. The least values of operating cost for chopping rice straw and faba bean stalks were 21.22 and 25.46 L.E/Mg obtained at speed of knives 1800 rpm (37.68 m/s), serrated edge of knife, 32 knife numbers and spacing between bars of concave 20 mm.

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الملخص العربي

دراسة بعض العوامل الهندسية لآلة تقطيع وفرم المخلفات الزراعية

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يعتبرالتخلص من المخلفات الحقلية من أهم المشاكل التي تواجه المزارع المصري وخاصة بعد حصاد المحاصيل, حيث تقدر مخلفات المحاصيل الحقلية بحوالي من ٣٠-٣٥ مليون طن سنويا ما بين اتبان واحطاب وقوالح وقش وعروش ومخلفات اخرى, حيث تقدر كمية قش الارز فقط المتولدة بمقدار ٣,٦ مليون طن سنويا بينما تقدر كمية مخلفات الفول بمقدار٠,٣٥ مليون طن سنويا. ونظرا لعدم توفر الوسائل المناسبة للإستفادة من هذه المخلفات في مصر فيقوم المزارعون بحرق كميات كبيرة من هذه المخلفات مما يؤدي إلى زيادة نسبة التلوث البيئي. وفي ظل التطور الذي نعيشه اليوم فإنه طرأت بعض الاستخدامات لهذه المخلفات مثل استخدام المخلفات كسماد عضوي وكعلف للحيوانات وأيضا في توليد الغاز الحيوي وصناعة الخشب الحبيبي وإستخدامات اخرى. ولتعظيم الفائدة من هذه المخلفات فإنه لابد من إجراء بعض المعاملات الميكانيكية والفيزيائية عليها قبل عمليات التصنيع المختلفة مثل التقطيع والفرم. ويهدف هذا البحث الى دراسة بعض العوامل الهندسية لآلة تقطيع وفرم المخلفات الزراعية (قش الارز وسيقان الفول البلدي). حيث تم تصميم وتصنيع الالة في ورشة قسم الهندسة الزراعية – كلية الزراعة – جامعة قناة السويس بالأسماعيلية.

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وتم تقييم آداء الالة تحت تأثير العوامل التالية حيث كانت السرعة الدورانية لسكاكين التقطيع ١٢٠٠, ١٤٠٠, ١٦٠٠ و ١٨٠٠ لفة/دقيقة (٢٥,١٢, ٢٩,٣١, ٣٣,٤٩ و ٣٧,٦٨ م/ث) وعدد سكاكين القطع ١٦, ٢٤ و٣٢ سكينة وشكلان لحافة السلاح ملساء ومسننة وصدران للالة المسافة بين القضبان في كل منهما ١٠ و ٢٠ مم. حيث أجريت التجارب الحقلية للالة في المزرعة التجريبية لكلية الزراعة بجامعة قناة السويس بالاسماعيلية.

وكانت أهم النتائج المتحصل عليها:

١- كانت أعلى إنتاجية للآلة ٠,١٤٤ و ٠,١٢٠ ميجاجرام/ساعة وكانت أعلى كفاءة للآلة ٩٩,٥ و ٩٨% عند فرم قش الارز و فرم سيقان الفول البلدي على التوالي وهذه النتائج تحققت عند سرعة دورانية لسكاكين التقطيع ١٨٠٠ لفة/دقيقة (٣٧,٦٨ م/ث) و حافة السلاح مسننة وعدد الاسلحة ٣٢ سلاح والمسافة بين قضبان الصدر ٢٠مم.

٢- كانت اعلى نسبة مئوية لاطوال التقطيع لقش الارز للفئة الاولى < ٢ سم ٥٣,٤٠% ولفئة التقطيع الثانية ٢-٥ سم كانت ٤٣,٥٥%. بينما كانت أعلى نسبة مئوية لأطوال التقطيع لسيقان الفول البلدي بالنسبة للفئة الاولى < ٢ سم ٤٣,٣٠% وللفئة الثانية ٢-٥ سم كانت ٣٩,١٨% عند سرعة دورانية لسكاكين التقطيع١٨٠٠ لفة/دقيقة (٣٧,٦٨ م/ث) و حافة السلاح مسننة وعدد الاسلحة ٣٢ سلاح والمسافة بين قضبان الصدر ١٠مم.

٣- - كانت أقل قيمة للطاقة المستهلكة عند فرم قش الارز ١٢,٥ كيلووات ساعة/ميجاجرام بينما كانت لسيقان الفول البلدي ١٥ كيلووات ساعة/ميجاجرام عند سرعة دورانية لسكاكين التقطيع١٨٠٠ لفة/دقيقة (٣٧,٦٨ م/ث) وحافة السلاح مسننة وعدد الاسلحة ٣٢ سلاح والمسافة بين قضبان الصدر ٢٠مم.

٤- كانت أقل قيمة لتكلفة التشغيل عند فرم قش الارز ٢١,٢٢ جنيه/ميجاجرام بينما كانت عند فرم سيقان الفول البلدي ٢٥,٤٦جنيه/ميجاجرام عند سرعة دورانية لسكاكين التقطيع١٨٠٠ لفة/دقيقة (٣٧,٦٨ م/ث) وحافة السلاح مسننة وعدد الاسلحة ٣٢ سلاح والمسافة بين قضبان الصدر ٢٠مم.