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Effect of Operational Parameter on Loss of Sheath and Power Consumption of Arecanut Sheath Shredder

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A B S T R A C T

Arecanut palm has some beneficial parts, except arecanut as a main produce such as husk, leaves and sheath which can be used for different purpose. Among those, arecanut sheath is one of the raw materials obtained from the arecanut palm. It is mainly used for commercial plate making. But recently the arecanut sheath was investigated to use as a dry fodder for cattle. Therefore, electric motor operated arecanut sheath shredder has been designed for chopping of arecanut sheath into small pieces suitable for animal fodder. The performance of arecanut sheath shredder was evaluated at three different cylindrical cutterhead speeds (13.1, 15.71 and 18.33 m s^{-1}), three feed roller speeds (0.28, 0.36 and 0.45 m s^{-1}) and numbers of knives (2, 3 and 4) was used, the effect of these operational parameters on percentage loss of sheath and power consumption was determined.

Introduction

Arecanut leaf sheath is obtained from the arecanut palm (*Areca catechu Linn*) is highly heterogeneous having variations in structure, shape and thickness. The rear end is thicker and the two edges are thinner. Sheath of arecanut tree is a hard material (good tensile strength), slow in bio-degradation and has low calorific value. Quality of areca leaf sheath varies with locations and seasons (Kalita *et al.*, 2008). Leaf sheath completely encircles the stem forming a protective covering for the developing inflorescence. Freshly fallen sheaths contain 55-60 per cent moisture. This reduces to 11-16 per cent after drying in open, under shade for 5-6 days. The sheath of an adult palm shows a concavity in the center.

The outer surface of the sheath is greenish or brown, waxy and tough, while the inner surface is creamy in color and has a natural glossy finish. The constituents of the leaf sheaths are cellulose - 43 per cent, crude fibre - 33 per cent and ash – 5 per cent (Biddappa, 1960). In certain regions of Kerala and Dakshina Kannada, leaf sheath is also used as cattle feed by cutting of sheath into small pieces using kathi (sharp edged straight blade hand tool) and machets (Bavappa, *et al.*, 1982).

In India, arecanut is considered as a commercial crop, because, of its higher economic profitability and relatively low investment many farmers have replaced paddy cultivation with arecanut, resulting in shortage of paddy straw for its use as animal fodder. Recently, some researcher has been found that the arecanut sheath can be used as a dry fodder for cattle, as an alternative to paddy straw. But, the available machinery for chop making have been tried to chop the arecanut sheath into suitable fodder size. However, due to its physical and biological characteristics of the arecanuts heath, none of them were found suitable to get desired size (Gaikwad and Bhargav, 2012). Hence, keeping the above factors in view, an attempt has been made to develop and evaluate an arecanut sheath shredding machine for making arecanut sheath into suitable fodder size for animals.

Materials and Methods

The experiments were conducted at different levels of independent parameters *viz.*, cylindrical cutterhead speed, feed rollerspeed and number of knives. In order to chopping of arecanut sheath, the required cylindrical cutter head speed of 13.1 to 18.33 ms^{-1} and feed roller speed of 0.28 to 0.45 ms^{-1} with 2 to 4knives was selected. The research was conducted in order to determine the percentage loss of sheath and power consumption of shredder after chopping of sheath by developed arecanut sheath shredder. The laboratory trials were carried out at College of Agricultural Engineering, University of Agricultural Sciences, Raichur during 2014-15. The samples of arecanut sheath can be brought from the Sirsitaluk, Dakshinakannada, Karnataka. The performance evaluation of arecanut sheath shredderwas carried out one hour duration at specified cylindrical cutter head speed, feed rollerspeed and varied number of knives. During the evaluation, a sample was collected from chop outlet for further analysis. The procedure used for evaluating arecanut sheath shredder is given below.

Percentage loss

The per cent of arecanut sheath was obtained in the powder form after chopping of arecanut sheath by arecanut sheath shredder was considered as a percentage of loss of arecanut sheath. Percentage loss of arecanut sheath incurred during chopping of sheath can be expressed by using formula (Fayose, 2007).

$$\text{Percentage loss (per cent)} = \frac{\text{Total mass of sample (kg) - Mass after cutting (kg)}}{\text{Total mass of sample (kg)}} \times 100$$

Power consumption (C_i)

The power consumption of arecanut sheath shredder can be expressed by using formula

$$\text{Ci} = \frac{\text{Amount of material fed, kg}}{\text{Time taken for feeding, h} \times \text{Average wattmeter reading, kW}}$$

Results and Discussion

The performance of arecanut sheath shredder was evaluated under lab conditions. The parameters such as power consumption and percentage loss were recorded during the lab test. Statistical analysis was carried out by using the Stat-Ease version 7 Design-Expert software to study the effect of operational parameters. This program helps to optimize the operational parameters and also this software provides highly efficient design of experiments for factorial designs. A three factor completely randomized block design and factorial variance analysis techniques were used to analyze the effect of feed roller speed, cylindrical cutterhead speed and number of knives on percentage loss of sheath and power consumption of arecanut shredder was determined and explained below.

Percentage of loss

The effect of cylindrical cutterhead speed, feed roller speed and numbers of knives on percentage of loss and analysis of variance for percentage of loss were presented in Tables 1 and 2, respectively. It was observed that the percentage of loss at feed roller speed of 0.28, 0.36 and 0.45 $ms^{-1}$for cylindrical cutterhead speed of 13.1 ms^{-1} was found to be 0.5, 0.37 and 0.2 per cent respectively for 2 numbers of knives whereas, for 3 numbers of knives these values were 0.8, 0.53 and 0.31 per cent and for 4 numbers of knives these values were 0.97, 0.81 and 0.62 per cent respectively.

The percentage of loss at feed roller speed of 0.28, 0.36 and 0.45 ms^{-1} for cylindrical cutterhead speed of 15.77 ms^{-1} was found to be 1.03, 0.97 and 0.83 per cent respectively for 2 numbers of knives whereas for 3 numbers of knives these values were 1.4, 1.23 and 1.13 per cent and for 4 numbers of knives these values were 1.63, 1.5 and 1.46 per cent respectively.

It was observed that the percentage of loss at feed roller speed of 0.28, 0.36 and 0.45 ms^{-1} for cylindrical cutterhead speed of 18.33 ms^{-1} was found to be 1.7, 1.68 and 1.55 per cent respectively for 2 numbers of knives whereas for 3 numbers of knives these values were 1.89, 1.84 and 1.75 per cent and for 4 numbers of knives these values were 2.13, 1.97 and 1.93 per cent respectively.

The mean values of percentage of loss for 2 numbers of knives was 1.07, 1 and 0.86 per cent at feed roller speed of 0.28 ms^{-1}, 0.36 ms^{-1}, and 0.45 ms^{-1} respectively at all levels of cylindrical cutterhead speeds (13.1, 15.67 and 18.33 ms^{-1}). The mean values of chopping length for 3 numbers of knives was 1.36, 1.2 and 1.06 per cent at feed roller speed of 0.28 ms^{-1}, 0.36 ms^{-1}, and 0.45 ms^{-1} respectively at all levels of cylindrical cutterhead speeds and for 4 numbers of knives 1.57, 1.42 and 1.33 per cent at a feed roller speed of 0.28 ms^{-1}, 0.36 ms^{-1}, and 0.45 ms^{-1} respectively at all levels of cylindrical cutterhead speeds. The effect of feed roller speeds and numbers of knives on percentage of loss at different cylindrical cutterhead has been presented in Figures 1, 2 and 3 respectively. Table 2 presents the effect of feed roller speed, cylindrical cutterhead speed and number of knives of arecanut sheath shredder on percentage of loss was significantly influenced at 1 per cent level of significance. There was an interaction effect (C x F, F x K, K x C and C x F x K) on percentage of loss of arecanut sheath shredder at 1 per cent level of significance.

The percentage of loss decreased as the feed roller speed increased because, the feed rate increases as the feed roller speed increases, thus the number of beating actions on the sheath may be less due to this increasing the chopping length, it means that less powder form of sheath was obtained as a chop and deposited in the bottom of cylindrical cutterhead unit, Hence the percentage of loss decreases at higher feed roller speeds.

The percentage of loss increased as the cylindrical cutterhead speed increased due to the feed rate decreases as the cylindrical cutterhead speed increases thus the number of beating actions on the sheath may be more due to this decreasing the chopping length it means that more powder form of sheath was obtained as a chopped material and some amount deposited in the bottom of cylindrical cutterhead unit, hence the percentage of loss is more towards increasing cylindrical cutterhead speed.

The 4 numbers of knives shows that, the more percentage of loss as compared to 2 and 3 numbers of knives may be due to the beating actions of 4 numbers of knives is more than the 2 and 3 numbers of knives due to this decreasing the chopping length in powder form and deposited in the bottom of cylindrical cutterhead unit, hence the percentage of loss is more for 4 numbers of knives.

Fig.1 Effect of feed roller speed (F) and number of knives (K) on percentage of loss at 13.1 m s^{-1} cylindrical cutterhead speed (C)

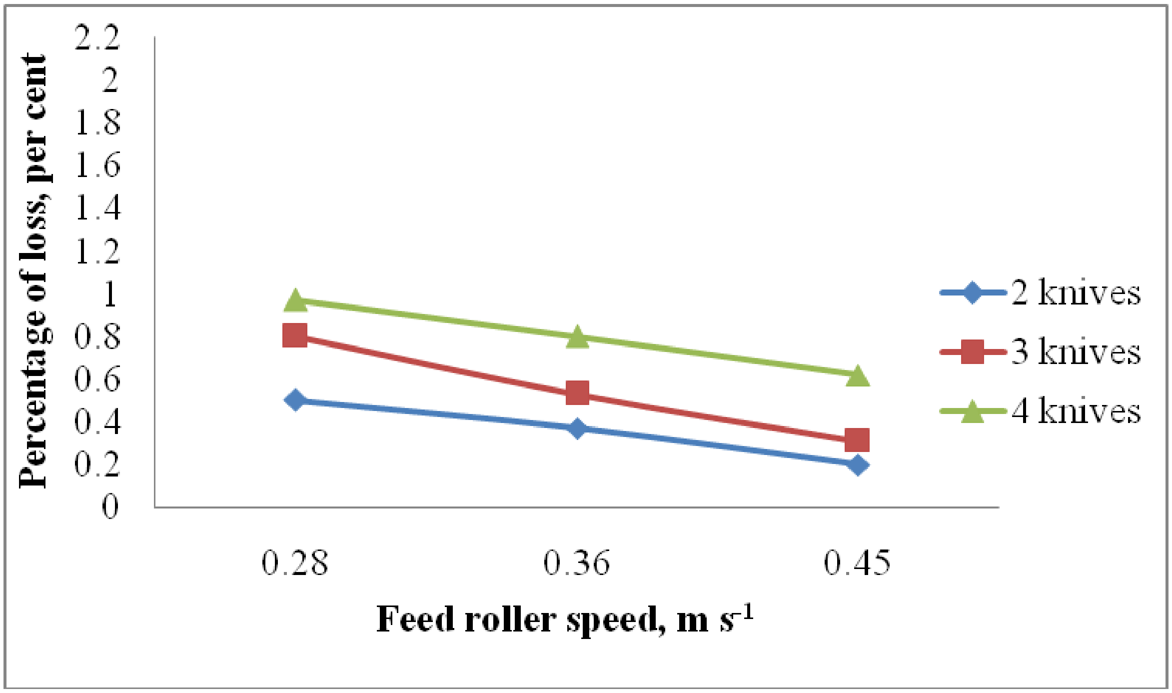

Fig.2 Effect of feed roller speed (C) and number of knives (K) on percentage of loss at 15.71 m s^{-1} cylindrical cutterhead speed (C)

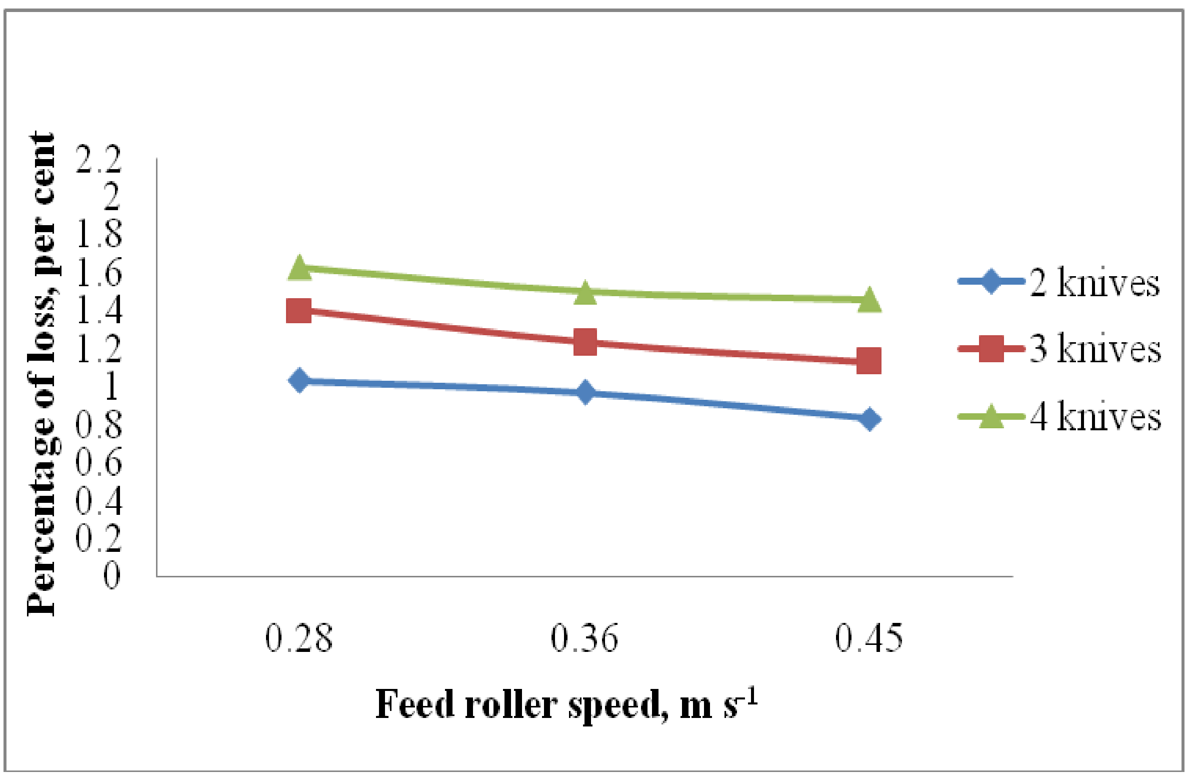

Fig.3 Effect of feed roller speed (F) and number of knives (K) on percentage of loss at 18.33 m s^{-1} cylindrical cutterhead speed (C)

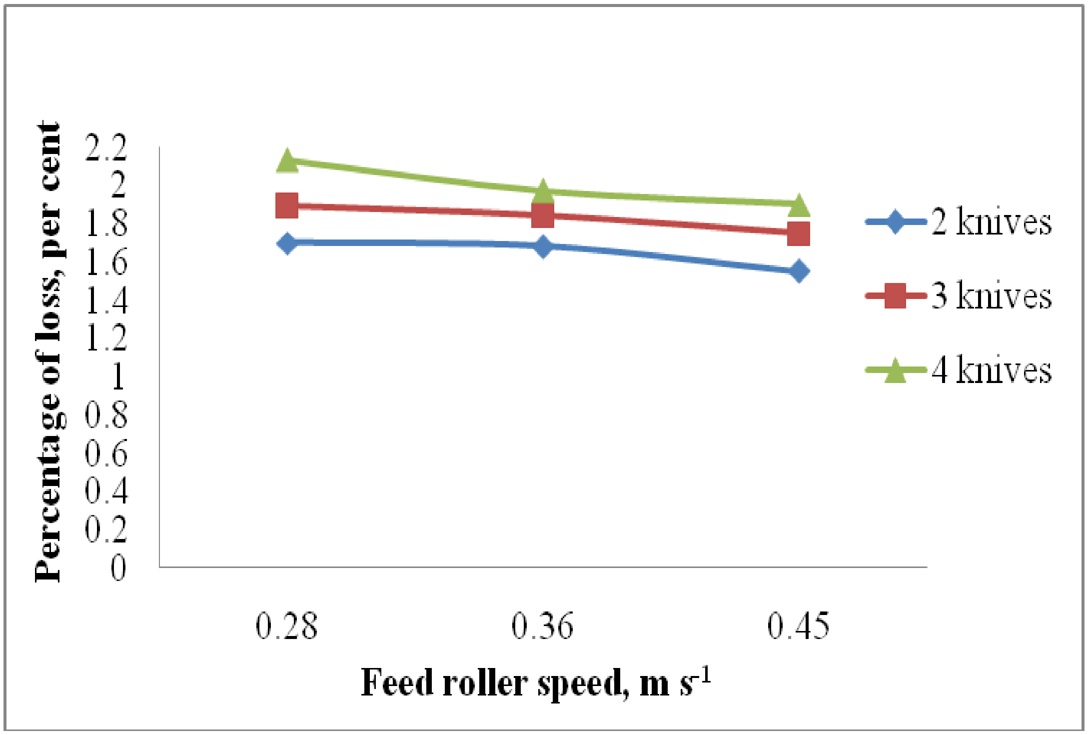

Fig.4 Effect of feed roller speed (F) and numbers of knives (K) on power consumption at 13.1 m s^{-1} cylindrical cutterhead speed (C)

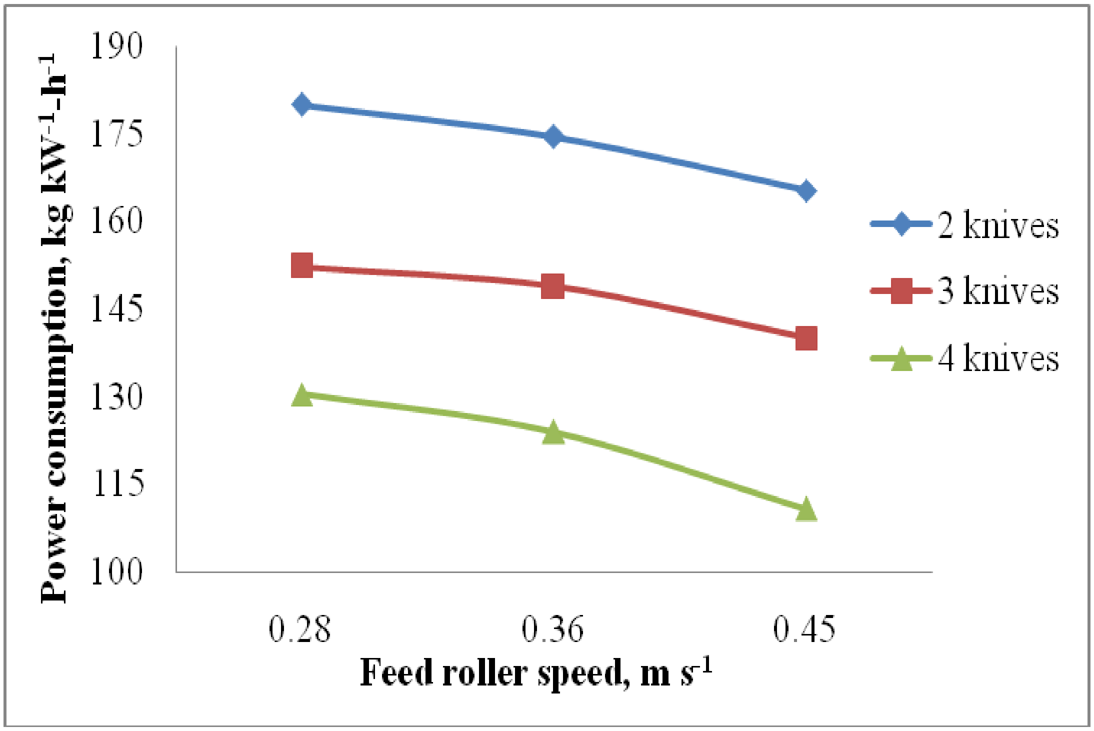

Fig.5 Effect of feed roller speed (F) and numbers of knives (K) on power consumption at 15.71 m s^{-1} cylindrical cutterhead speed (C)

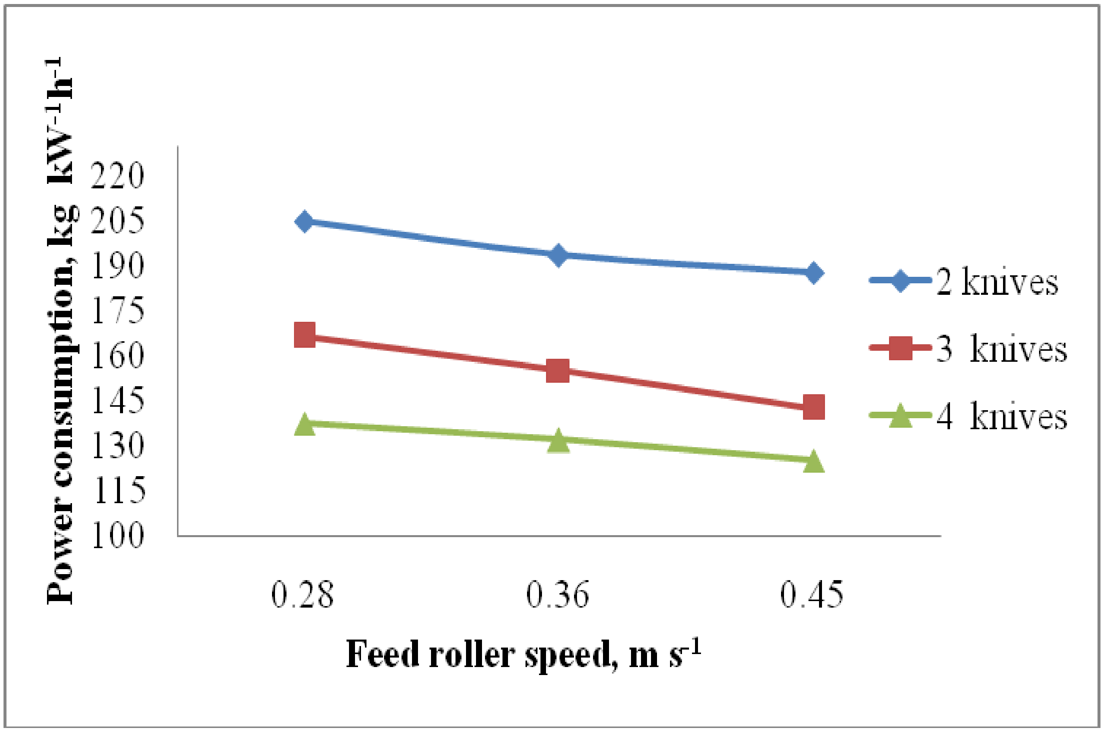

Fig.6 Effect of feed roller speed (F) and numbers of knives (K) on power consumption at 18.33 m s^{-1} cylindrical cutterhead speed (C)

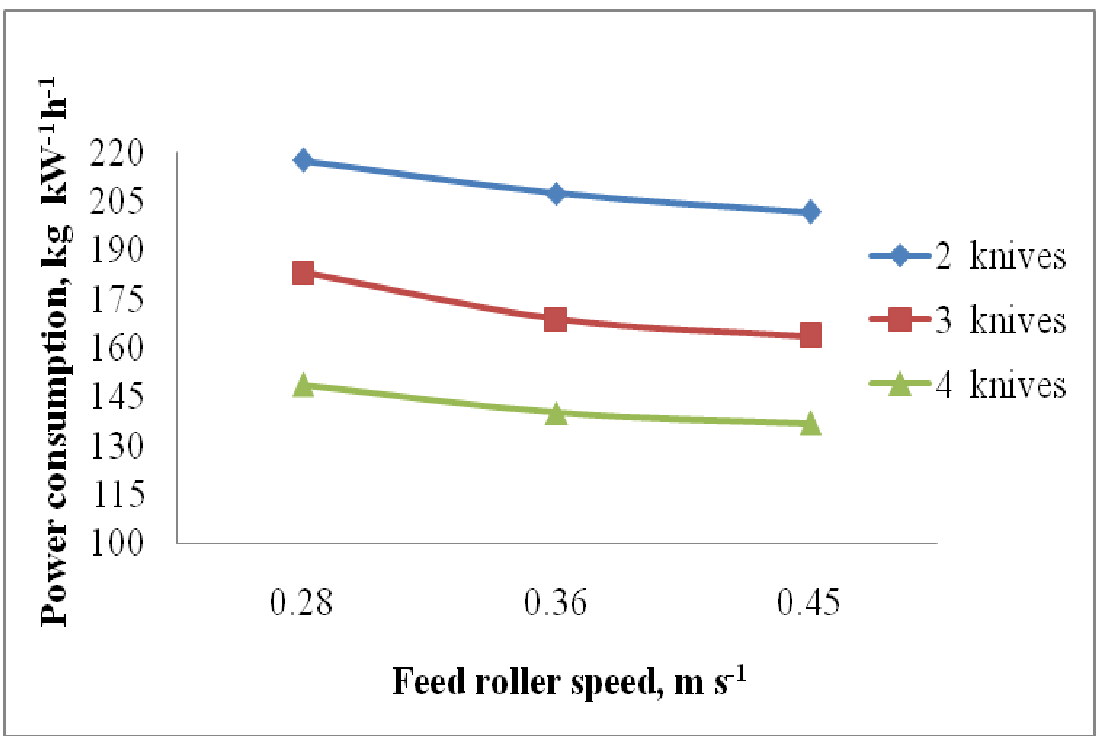

Table.1 Effect of cylindrical cutterhead speed (C), feed roller speed (F) and numbers of knives (K) on percentage of loss

Sl. No	Cylindrical cutterhead speed (C), m s^{-1}	Feed roller speed (F), m s^{-1}	Percentage of loss, per cent		
			Numbers of knives (K)		
			2	3	4
1	13.1	0.28	0.50	0.80	0.97
		0.36	0.37	0.53	0.8
		0.45	0.2	0.31	0.62
2	15.71	0.28	1.03	1.40	1.63
		0.36	0.97	1.23	1.50
		0.45	0.83	1.13	1.46
3	18.33	0.28	1.7	1.89	2.13
		0.36	1.68	1.84	1.97
		0.45	1.55	1.75	1.93

Table.2 Analysis of variance for percentage of loss

SV	DF	SS	MSS	F
Treatment	26	169.68	6.52	50.24 *
Cylindrical cutterhead speed (C)	2	55.30	27.65	212.90 *
Feed roller speed (F)	2	3.89	1.94	14.97 *
Numbers of knives (K)	2	98.80	49.40	380.36 *
C × F	4	1.73	0.43	3.34 *
C × K	4	5.72	1.43	11.02 *
F × C	4	1.47	0.36	2.83 *
C × F × K	8	2.74	0.34	2.64 *
Error	54	7.01	0.12	
Total	80	176.69		

CV = 5.66
SD = 0.36
* = Significant at 1 per cent level

Table.3 Effect of cylindrical cutterhead speed (C), feed roller speed (F) and numbers of knives (K) on power consumption

Sl. No	Cylindrical cutterhead speed (C), m s^{-1}	Feed roller speed (F), ms^{-1}	Power consumption, kg kW^{-1}-h^{-1}		
			Numbers of knives (K)		
			2	3	4
1	13.1	0.28	179.97	152.26	130.40
		0.36	174.46	148.77	124.00
		0.45	165.30	140.09	110.82
2	15.71	0.28	205.02	166.64	137.60
		0.36	193.67	155.13	132.04
		0.45	187.90	142.61	125.20
3	18.33	0.28	217.39	183.12	148.84
		0.36	207.43	168.69	140.00
		0.45	201.59	163.61	136.91

Table.4 Analysis of variance for power consumption

SV	DF	SS	MSS	F
Treatment	26	98964.08	3806.31	11.08 *
Cylindrical cutterhead speed (C)	2	8256.01	4128.00	12.01 *
Feed roller speed (F)	2	8544.15	4272.07	12.43 *
Numbers of knives (K)	2	45075.45	22537.73	65.61 *
C × F	4	9943.99	2485.99	7.23 *
C × K	4	3722.21	930.55	2.70 *
F × C	4	9844.49	2461.12	7.16 *
C × F × K	8	13577.76	1697.22	4.94 *
Error	54	18547.15	343.46	
Total	80	117511.2		

CV = 11.78; SD = 18.53; * = Significant at 1 per cent level

Power consumption

The effect of cylindrical cutterhead speed, feed roller speed and numbers of knives on power consumption and analysis of variance for power consumption were presented in Tables 3 and 4, respectively and discussed below.

It was observed that the power consumption at feed roller speed of 0.28, 0.36 and 0.45 ms^{-1} for cylindrical cutterhead speed of 13.1 ms^{-1} was found to be 179.97, 174.46 and 165.3 $kgkW^{-1}$-h^{-1}respectively for 2 numbers of knives whereas for 3 numbers of knives these values were 152.26, 148.77 and 140.09 $kgkW^{-1}$-$h^{-1}$and for 4 numbers of knives these values were 130.4, 124 and 110.82 $kgkW^{-1}$-h^{-1} respectively.

The power consumption at feed roller speed of 0.28, 0.36 and 0.45 ms^{-1} for cylindrical cutterhead speed of 15.77 ms^{-1} was found to be 205.02, 193.37 and 187.9 $kgkW^{-1}$-h^{-1} respectively for 2 numbers of knives whereas for 3 numbers of knives these values were 166.64, 155.13 and 142.61 $kgkW^{-1}$-$h^{-1}$and for 4 numbers of knives these values were 137.60, 132.04 and 125.2$kgkW^{-1}$-h^{-1} respectively. It was observed that the power consumption at feed roller speed of 0.28, 0.36 and 0.45 ms^{-1} for cylindrical cutterhead speed of 18.33 ms^{-1} was found to be 217.39, 204.43 and 201.59$kgkW^{-1}$-h^{-1} respectively for 2 numbers of knives whereas for 3 numbers of knives these values were 183.12, 168.69 and 163.61 $kgkW^{-1}$-h^{-1} and for 4 numbers of knives these values were 148.84, 140 and 136.91 $kgkW^{-1}$-h^{-1} respectively.

The mean values of power consumption for 2 numbers of knives was 200.79, 191.85 and 184.93 $kgkW^{-1}$-h^{-1}at feed roller speed of 0.28 ms^{-1}, 0.36 ms^{-1}, and 0.45 ms^{-1} respectively at all levels of cylindrical cutterhead speeds (13.1, 15.67 and 18.33 ms^{-1}). The mean values of power consumption for 3 numbers of knives was 167.34, 157.53 and 148.77 $kgkW^{-1}$-h^{-1}at feed roller speed of 0.28 ms^{-1}, 0.36 ms^{-1}, and 0.45 ms^{-1} respectively at all levels of cylindrical cutterhead speeds and for 4 numbers of knives 138.94, 132 and 90.97 $kgkW^{-1}$-h^{-1}at a feed roller speed of 0.28 ms^{-1}, 0.36 ms^{-1}, and 0.45 ms^{-1} respectively at all levels of cylindrical cutterhead speeds. The effect of feed roller speeds and numbers of knives on power consumption at different cylindrical cutterhead have been presented in Figures 4, 5 and 6, respectively. Table 4 presents the individual effect of feed roller speed, cylindrical cutterhead speed and number of knives of arecanut sheath shredder on power consumption was significant at 1 per cent level of significance. There was an interaction effect (C x F, F x K, K x C and C x F x K) on power consumption of arecanut sheath shredder at 1 per cent level of significance.

The power consumption in terms of $kgkW^{-1}$-h^{-1}decreased as the feed roller speed increased because, as the feed roller speed increased the time taken for feeding decreases, hence the power consumption decreases at higher feed roller speeds at constant feed rate. Similar findings were reported by Ismail *et al.*, (2009). The power consumption increased as the cylindrical cutterhead speed increased due to the time taken for cutting decreases as the cylindrical cutterhead speed increase sat constant feed rate; hence the power consumption is more towards increasing cylindrical cutterhead speed.

Similar findings were reported by Ismail *et al.*, (2009) and El-hanfy and Shalby (2009). The 4 numbers of knives shows that, the less power consumption as compared to 2 and 3 numbers of knives may be due to the time taken for cutting of arecanut sheath decreases for 4 numbers of knives than the 2 and 3 numbers of knives. Similar findings were reported by El-hanfy and Shalby (2009).

The percentage of loss of arecanut sheath shredder was increased as the cylindrical cutterhead speeds and number of knives increased but it is decreased with increase a feed roller speeds. The minimum percentage of loss was observed at 0.45 ms^{-1} feed roller speed and 13.1 ms^{-1} cylindrical cutterhead speed with 2 numbers of knives. Power consumption of the arecanut sheath shredder decreased as the feed roller speed and number of knives increased and it has increased when cylindrical cutterhead speed increased. It was observed that, the minimum power consumption was observed at 0.45 ms^{-1} feed roller speed and 13.1 ms^{-1} cylindrical cutterhead speed with 4 numbers of knives.

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