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Development of a Mechanical System to Produce Animal Feed from Rice Straw

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ABSTRACT

Rice straw stands out as the primary agricultural residue posing significant challenges for both farmers and the Egyptian government. Its volume accounts for approximately 18% of the total annual waste generated. Livestock farmers typically harvest the straw and feed it to their animals. However, the process of manually mixing molasses, urea, and salts with the straw often leads to inconsistent blending and uneven distribution of the mixture. This inconsistency poses a considerable risk to the health of the animals, potentially resulting in fatalities. Thus, a mechanical system for producing animal feed (rice straw cutting mixed with additives of urea, minerals and molasses) was developed. This system consists of a chopping unit, mixing unit, and pumping & distribution unit. Measurements included the uniformity of the cut rice straw pieces within the preferred size, the uniformity of the dissolved additives mixture and the uniformity of the additives distribution on cut rice straw. Crude protein and urea percentages were measured in the final product. The results showed a maximum production rate of 0.6 ton h^{-1} the suitability of the developed system for mixing the additives with the cut rice straw. The suitability of the developed system was determined through the uniformity of the distribution of the additives on the cut rice straw. The results showed that the optimum content of crude protein of 6.2% was found at urea content of 5% and a mixing unit shaft speed of 300 rpm and 5 min mixing time. Also, the developed system achieved a rate of return of 19% and a payback period of about two years.

Keywords: *Additive, Animal feed, Rice straw, Mechanical system*

INTRODUCTION

Egypt cultivates about 400,000 ha of rice every year, which produce 3.39 million tons of rice straw. This quantity presents a sizable problem to the farmers, government and the environment (CMAE, 2020). In Egypt, animal feed resources are not sufficient to meet the nutritional requirements of the livestock. This shortage of feed and low genetic potential of the local animals is the major factors causing the low productivity of the indigenous breeds. Rice straw is a poor-quality fibrous material, which is not suitable for use as an animal feed without treatments to changes its physical structure. Cutting rice straw and adding supplements, such as non-protein nitrogen plus molasses and minerals, will encourage animals to consume it. These treatments will also increase the digestibility and nutritive value of this type of feeding. Nowadays, farmers cut rice straw by machines and manually add a mixture of molasses and urea. This primitive process is very harmful to the animals, since the product is not homogeneous and some parts will have high percentage of urea which is toxic when consumed by the animals. Wang *et al.* (2021) found that treating rice straw with 5% urea increased the crude protein *CP* content from 3.42% to 8.07%. Mu *et al.* (2022) observed that processing and neutralizing cut rice straw, whether chopped into lengths of 2-3 cm or 15-20 cm, significantly enhanced the digestibility of crude protein (*CP*) and dry matter (*DM*). Chopping the straw into 2-3 cm lengths prior to treatment yielded superior outcomes compared to longer-cut straw. Neutralization also affected the chemical composition of the straw and increased its Sulphur content. Mohammed Aliyi (2021) studied the effect of urea treatment of rice and wheat straw on feed intake and milk yield of buffaloes. Chemical treatment of straw increased dry mater intake (*DMI*) over untreated straw and improved milk yield. Availability of urea was the major limitation to the process. Radwan (2000) developed a feed preparation unit, which chops the crop residual, and mix the chopped material with the additives determined for the feed ration. He found that the output decreased from 1320, 760 and 508 kg h^{-1} to 1400, 800 and 600 kg h^{-1} for corn stalks, corn Stover and rice straw respectively. Adding molasses increased the mean weight length (MWL) by 31%. Radwan (2000) developed a feed preparation unit which chops the crop residual to the desired sizes and mixes the chopped materials with the additives determined for the feed ration. He found that the chopper speed should surpass 1400 rpm, while the mixing speed should range between 60 rpm and 100 rpm. Mohamed *et al.* (2001) developed a rice straw chopper and they found that the productivity of the developed machine was 0.95 ton h^{-1} at 2000 rpm rotor speed. Patel *et al.* (2023) evaluate and optimize the chopping unit of straw chopper cum mixture machine for paddy straw management. The effect of operational parameters i.e., blade type, rotational and forward speed of the machine, and crop parameters i.e. days after harvesting (DAH) on the power requirement was determined. They found that the cutting torque was significantly affected by the rotational speed, forward speed and DAH of the paddy straw. A straw management system (SMS) serrated blade operating at rotational and forward speed of 900 rpm and 1 km h^{-1} respectively with average cutting torque of 3.8 Nm was found to be optimal for cutting the paddy straw. The objective of this research is to develop a mechanical system for producing animal feed by cutting the rice straw then mixing it with additives, such as urea, molasses and minerals.

MATERIALS and METHODS

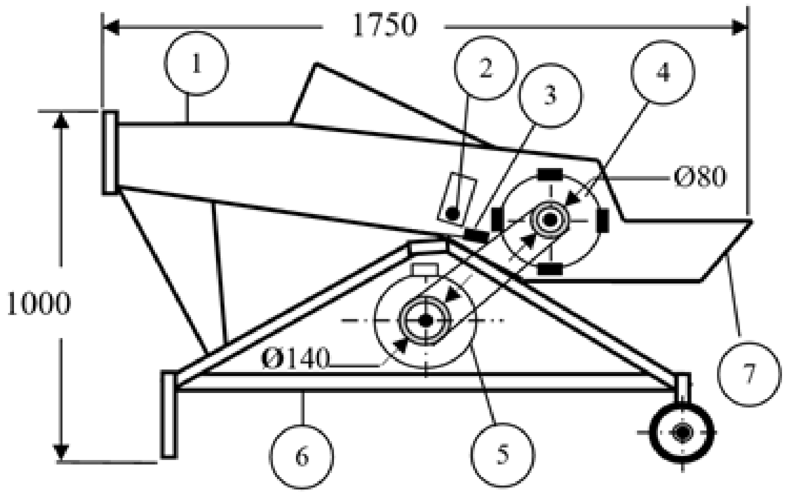
The developed system consists of chopping unit, mixing unit, and pumping & distribution unit.

The chopping unit

A diagram showing the components of the chopping unit is shown in Figure (1). The cutting-head is a cylinder drum type. The chopping mechanism consists of fixed knife and a cutting head equipped with four movable knives, the angle between each two knives is 90 degrees. This unit is used for chopping crop residues such as maize stalks and rice straw. The overall dimensions of chopping unit are 1750 mm long, 400 mm wide and 1000 mm high. The chopping unit consists of:

1. *Cutting-head*

The cutting head, Figure (2), has four parallel knives which are mounted on a cylinder. The cutting head consists of four cutting knives which are fixed to the rotating axis. Each knife is fastened by five bolts and rotates with high speed corresponding to a lower speed of feeding drums. The fixed knife length, width and thickness are 300, 60 and 5 mm, respectively. The chopping cylinder has a diameter of 300 mm and is 300 mm long.



1. Feeding hopper, 2. Feeding drum, 3. Fixed knife, 4. Cutting drum, 5. Electric motor, 6. Frame, 7. Outlet dimensions in mm

Figure 1. *The chopping unit.*

2. *Feeding drum*

The feeding drum, Figure (2), pushes the rice straw to the cutting-head. The feeding drum length, outside diameter, and thickness were 300, 40, and 5 mm respectively. The cutting head and feeding drum are operated by an electric motor fixed on the machine frame.

3. *Source of power*

The chopping unit is powered by an electric motor, 7.35 kW (10 HP), 3 phase and with a rotating speed 1400 rpm.

4. *Transmission system*

The transmission system of the chopping unit consists of two units. The first unit transmits the motion from the electric motor to the cutting drum. The second unit transmits the motion from the cutting drum to the feeding drum. V-belts are used to transmit the motion between driving and driven pulleys.

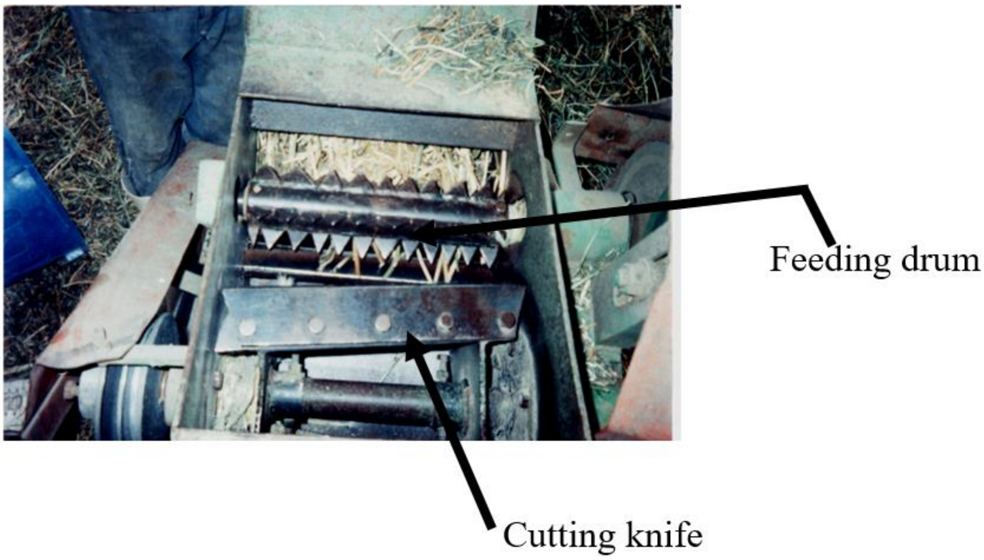


Figure 2. *The chopping machine.*

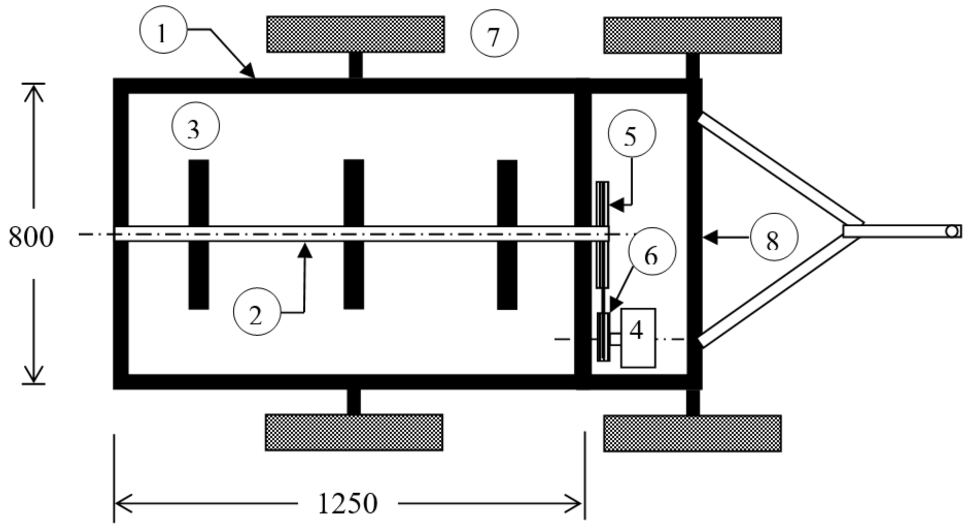
The chopping unit was tested to chop rice straw at three rotating speeds of 1450, 1550 and 1650 rpm equivalent to liner speed (22.8, 24.3 and 25.9 m s^{-1}) (Younis *et al.*, 2002) and three levels of clearances between the fixed knife and cutter head drum of 1, 2 and 3 mm.

The mixing unit

The mixing unit, Figure 3, consisted of:

1. *Frame and hitching*

The frame of mixing unit was manufactured from steel 50, U section 100 mm and 6 mm thickness. The mixing unit is attached to the tractor by draw bar pull. The frame length, width and height are 1850, 1000 and 1000 mm respectively. Four tires 15×15 ×85 cm were used to trail this frame.



1. Tank, 2. Mixing shaft, 3. Blade vane, 4. Motor, 5. Driven pulley, 6. Driving pulley, 7. Tire, 8. Frame dimensions in mm

Figure 3. *The mixing unit.*

2. Tank

The tank, Figure (4), consists of steel hollow cylinder, diameter 800 mm, 1250 mm long and with 4.3 mm thickness. The tank has a 400 mm diameter orifice for the introduction of the additives. The tank capacity is 600 liters.

3. Mixing shaft

The mixing shaft, Figure (5), is a 40 mm diameter steel 50 rod. Three blade vanes were welded on the shaft for mixing the additives. The blade dimensions are 50 mm wide, 400 mm long and 2 mm thickness. The mixing shaft rotates on two ball bearings size 6206.

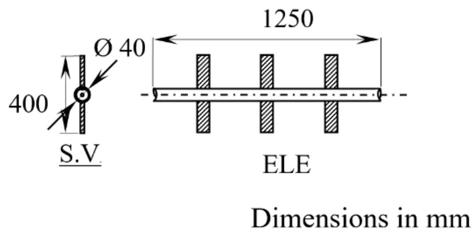


Figure 4. *The mixing tank*

Figure 5. *The mixing shaft*

4. Power

Diesel engine, 2.94 kW (4 HP) at 1000 rpm, was used to transmit the power to the mixing shaft. Belt drive and pulley was used to reduce the speed transmitted from the engine to the mixing shaft.

5. Power transmission system

V-belts are used to transmit the motion between driving and driven pulleys. The length of the V-belts was calculated according to Tinder (2022) and meets the ANSI

American standards. The mixing unit was evaluated at three levels of rotating speeds 100, 200 and 300 rpm and at three mixing time intervals of 5, 10 and 15 minutes.

Pumping and distribution unit

The components of pumping and distribution unit are pump, pipes, sprinklers and limit electric switch.

1. Pump

Gear pump was used to move the dissolved additives mixture through pipes to sprinklers. This pump was adjusted to discharge 85 Lh^{-1} equivalent to 118.5 kg mixture per hour at a head of 20 m. This pump is operated by a motor 0.37 kW (0.5 HP) at 2860 rpm rotating speed. A speed reducer was used to control the discharge of the pump by controlling the rotating speed of the motor.

2.Pipes

The pipes in the distribution unit were one-inch diameter rubber tubes. There are two parts, one connected between the dissolving unit and the pump to take in the dissolved additives mixture from the dissolving unit, (150 mm length). The other part is connected between the pump and cutting machine for delivering the mixture to sprinklers, (100 mm length).

3. Sprinklers

Three sprinklers, 3 mm in diameter, were used to distribute the dissolved additives mixture on the rice straw. These sprinklers were fixed in a pipe 200 mm length at the outlet of the chopping unit. The end of the pipe is connected with a tube to return the excess additives to the tank.

4.Limit electric switch

A limit electric switch (model XCK-P 106, 220V and 3A), is used to transmit the electric current to the pump motor during operation when the rice straw touches the switch. The switch is mounted at the entrance of cutting unit Figure (6). The chopping unit, the mixing unit and the pumping and distribution unit are assembled in compacted system as shown in Figure (7).

Figure 6. *The limit electric switch*

Figure 7. *The developed mechanical system*

Measurements and calculations:

1. Mass of residues

The weight of the machine output was determined using a spring balance, 500 N capacity, with 5 N accuracy.

2. Cutting length and diameter of residues

The cutting length and diameter of the residue were measured using vernier caliper, accuracy ± 0.1 mm.

3. Cutting head rotating speed

The rotating speed of the cutting head was determined using hand-held mechanical tachometer, accuracy 1-6 rpm.

4. Chopping unit productivity (Pc)

The chopping unit productivity (Pc) was calculated from the Equation 1.

$$Pc = \frac{M}{T} \qquad (1)$$

Where: *Pc* is chopping unit productivity, kg h^{-1}; *M* is mass of chopped material, kg; *T* is operating time, h.

5. The uniformity of the dissolved additives mixture

Chemical analyses were performed at the Animal Production Research Institute, Agric. Research Center, Ministry of Agriculture, Giza, Egypt. This analysis was done to determine the uniformity of the dissolved additives mixture by determination of the ratio of urea in the dissolved additives mixture. The samples of the dissolved additives mixture were taken from inside the tank at three levels (bottom from 0 to 250 mm, middle from 250 to 500 mm and top from 500 to 800 mm). Twenty-five samples were taken from each level.

6. The uniformity of the additives distribution on cut rice straw

The uniformity of the additives distribution on cut rice straw was determined by the calculation of the percentage of crude protein *(CP)* in the samples. Three percentages of urea 1, 3 and 5% were distributed on the chopped rice straw (according to Abreu *et al.,* 2022*)*. Five samples (S_1, S_2, S_3, S_4 and S_5) were taken from the final product for each urea percentage. Chemical analyses were performed to compute the crude protein.

7. Cost analysis and economic evaluation

The cost analysis (Oida, 1997) was performed in two steps. The first step was to calculate the cost of the materials and the fabrication. The second step was to calculate the mechanical system operating cost. In order to evaluate the financial viability of the developed system, three parameters were computed and were analyzed. These parameters include developed system operating cost, the internal rate of return *(IRR)* and the pay back period *(PBP).*

RESULTS AND DISCUSSION

Physical and chemical properties of rice straw

The ranges of the stem diameter and length of the rice straw were 2-4 mm, and 50-110 cm respectively. Chemical analysis of the rice straw and molasses are shown in Table (1). Table (1) shows the average values of the percentage of crude fiber *(CF),* ether extract *(EE),* crude protein *(CP),* nitrogen free extract *(NFE)*, ash *(Ash)* and the moisture content *(MC).*

Table 1. *Chemical analysis of rice straw and molasses*

Components, %	*CF*	*EE*	*CP*	*NFE*	*Ash*	*MC*
Rice straw	33.40	1.90	3.35	36.36	17.99	7.00
Molasses	0.00	0.00	4.90	60.10	12.00	23.00

The performance of the chopping unit

Effect of cutting head speed on chopping unit productivity

The average values of the chopping unit productivity (*Pc*) are shown in Figure (8). It is clear that the *Pc* was increased by increasing the cutting head speed from 1450 rpm (22.8 m s^{-1}) to 1650 rpm (25.9 m s^{-1}) at the same clearance. Meanwhile, the *Pc* was decreased by increasing of clearance at the same speed. The maximum value of *Pc* of 600 kg h^{-1} was found at speed 1650 rpm (25.9 m s^{-1}) and clearance 1 mm. Meanwhile, the minimum value of *Pc* of 400 kg h^{-1} was found at speed 1450 rpm (22.8 m s^{-1}) and clearance 3 mm. This agree with what Hashem *et al.* (2022) reported they found that the productivity of the chopping unit decreased with reducing the clearance and increased with the increase of the chopping drum rotational speed. They achieved a maximum capacity of 350 kg h^{-1} at a chopping drum rotational speed of 1200 rpm. These results are also similar to those found by (Arif and Elaiwa, 2009; Abo-Habaga *et al.*, 2019; Jiang *et al.*, 2021). Abo-Habaga *et al.* (2019) reported that the maximum chopper productivity of 1.2 Mg h^{-1} was achieved using a chopping-drum speed of 2350 rpm and a feeding-mechanism speed of 0.42 m s^{-1}. Conversely, the minimum chopper productivity of 0.92 Mg h^{-1} was observed with a chopping-drum speed of 1450 rpm and a feeding-mechanism speed of 0.26 m s^{-1}, regardless of the type of cutting knives used. Also, Arif and Elaiwa (2009) indicated that the maximum productivity of 171 kg h^{-1} was achieved by employing two knives with a clearance of 4 mm, a cutting drum speed of 18.7 m s^{-1}. Employing two knives on the cutting drum resulted in higher machine productivity compared to using three or four knives. Hashish *et al.* (1994) conducted a study investigating various factors influencing the performance of chopping, crushing, and grinding equipment for field raw material. Their findings indicated several key conclusions: Firstly, they identified an optimum PTO speed of 700 rpm across the three different raw materials examined. Secondly, they observed that the highest production rates and efficiency were achieved at low moisture content levels, specifically 2.5% for rice straw, 5.3% for cotton stalks, and 6.26% for maize stalks. Lastly, they noted that equipment modifications led to improvements in both fineness degree and productivity, increasing from 37% to 48%.

At a cutting head speed 1450 rpm (22.8 m s^{-1}), the *Pc* increased by 15% by decreasing the clearance from 3 to 2 mm, and increased by 8.69% by decreasing the clearance from 2 mm to 1 mm. The same trend was also observed at cutting head speed 1550 rpm (24.3 m s^{-1}) and 1650 rpm (25.9 m s^{-1}).

The maximum chopping unit productivity was achieved when the cutting head speed was 1650 rpm (22.8 m s^{-1}) and 1 mm clearance. For these conditions the chopper productivity was 600 kg h^{-1}.

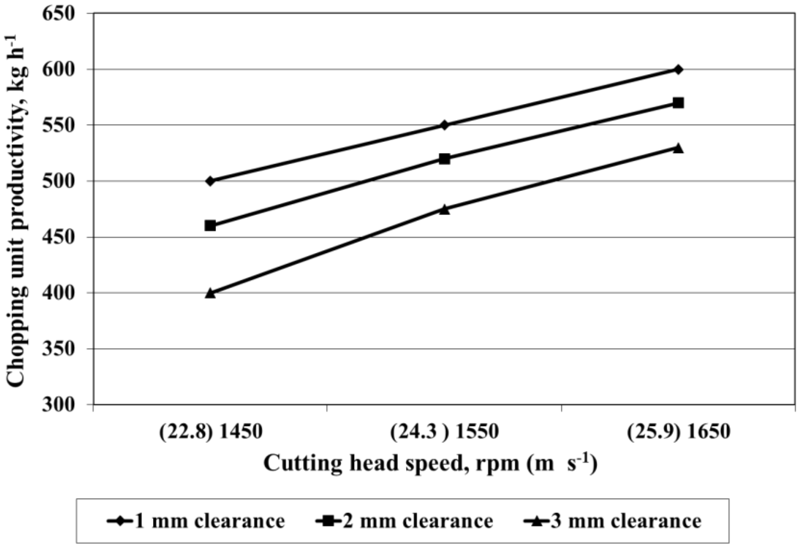


Figure 8. *Effect of cutting head speed and clearance on the chopping unit productivity.*

Effect of cutting head speed on the rice straw cutting length

The length of the cut rice straw was classified into three groups, the first was less than 20 mm, the second (favorite length) was from 20 to 80 mm, and the third was greater than 80 mm. The results of cutting length distribution at different speeds and clearances are shown in Table (2).

Table 2. *Effect of cutting head speed and clearance on the percentage of rice straw cutting lengths.*

Speed, rpm (m s^{-1})	Clearance, mm	Cutting length, %		
		<20 mm	20 to 80 mm	> 80 mm
1450 (22.8)	1	0	50	50
1550 (24.3)	1	2	63	35
1650 (25.9)	1	4	81	15
1450 (22.8)	2	0	40	60
1550 (24.3)	2	1	54	45
1650 (25.9)	2	2	73	25
1450 (22.8)	3	0	25	75
1550 (24.3)	3	0	35	65
1650 (25.9)	3	0	50	50

At clearance 1 mm, the percentage of rice straw cutting length <20 mm was zero % at cutting head speed 1450 rpm (22.8 m s^{-1}) but it was increased to 2% and 4% when the cutting head speed increased to 1550 rpm (24.3 m s^{-1}) and 1650 rpm (25.9 m s^{-1}). The percentage of favorite cutting length (20 to 80 mm) increased from 50% to 63 and 81% when the cutting head speed increased from 1450 rpm (22.8 m s^{-1}) to 1550 (24.3 m s^{-1}) and 1650 rpm (25.9 m s^{-1}) respectively. Also, the percentage of cutting length of > 80 mm was decreased from 50% to 35 and 15% when the speed increased from 1450 rpm (22.8 m s^{-1}) to 1550 rpm (24.3 m s^{-1}) and 1650 rpm (25.9 m s^{-1}) respectively. The same trend was found at clearances 2 and 3 mm.

The highest percentage of favorite length of the cut rice straw from 20 to 80 mm was achieved with cutting head speed of 1650 rpm (25.9 m s^{-1}) and 1 mm clearance. For these conditions, favorite length of the cut rice straw percentage was 81%. Abo-Habaga *et al.* (2019) reported an average cutting length of 91.2 mm at a cutting speed of 1450 rpm and they said that the average decreased to 33.1 mm when the rotational speed was increased to 2350 rpm. They reported that although the increase in the speed of the chopping drum reduced the average cutting length and increased the productivity it also raised the power requirement from 3.51 kW at 1450 rpm to 8.24 kW at 2350 rpm.

Evaluation of the mixing unit

The mixing unit was evaluated by determining the urea percentage in the dissolved additives mixture. Any increase in this ratio may be harmful to the health of the animals.

The average values of urea percentage at mixing shaft rotating speeds (100, 200 and 300 rpm) and dissolve time (5, 10 & 15 min) are shown in Figure (9). It is clear that the urea percentage has increased at the bottom of tank more than the top and middle. Also, the urea percentage was increased by increasing both of the dissolving time and mixing shaft rotating speed. At 5 min dissolve time, the urea percentage increased by increasing of mixing shaft rotating speed.

At the bottom of tank, the urea percentage increased by 0.9 and 1.4% by increasing the mixing shaft rotating speed from 100 to 200 and 300 rpm respectively. At the middle of tank, the percentage of urea increased by 1.0% and 1.5% while the mixing shaft rotating speed increased from 100 rpm to 200 and 300 rpm respectively. At the top of tank, the urea percentage increased by 0.9 and 1.6% by increasing the mixing shaft rotating speed from 100 rpm to 200 and 300 rpm respectively. The same trend was found at dissolve times 10 and 15 min.

At mixing shaft speed 100 rpm, the urea percentage at the bottom of tank was increased from 2.9% to 3.4 and 4.0% by increasing the dissolving time from 5 min.to 10 and 15 min. respectively. The urea at the middle of tank was increased from 2.5% to 3.2 and 3.8% by increasing the dissolving time from 5 min. to 10 and 15 min respectively. In addition, the ratio of urea at the top of tank was increased from 2.2% to 2.6 and 3.5% by increasing the dissolving time from 5 min. to 10 and 15 min. respectively. The highest value of urea percentage, 4.8%, was found at mixing shaft rotating speed 300 rpm and 15min. dissolving time at the bottom of tank.

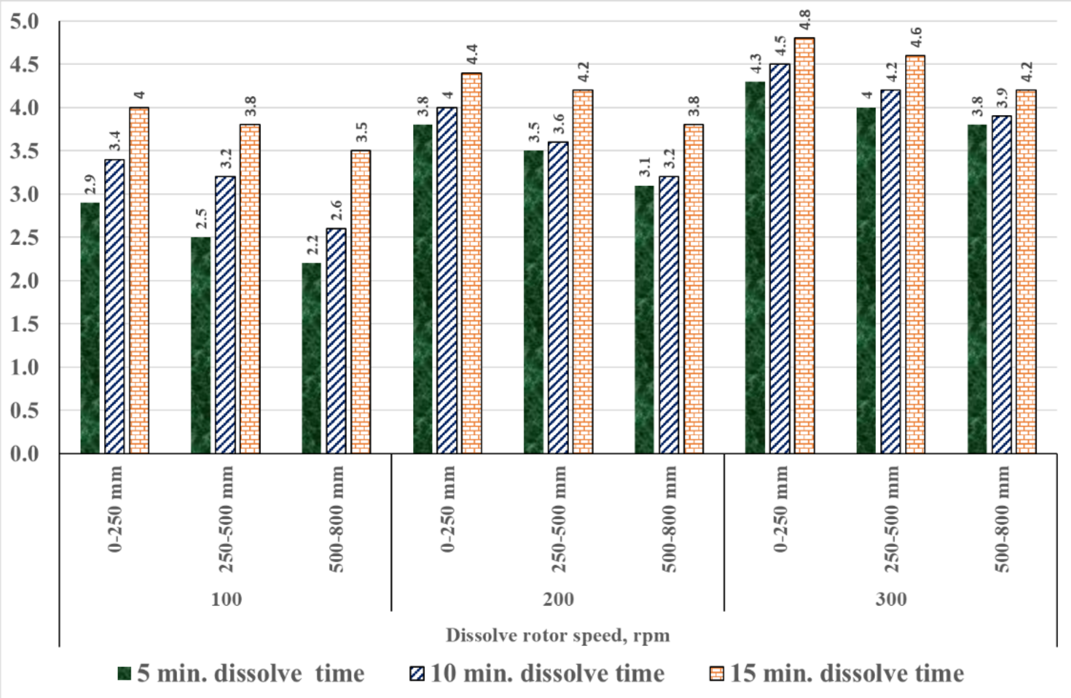


Figure 9. *Effect of mixing shaft rotating speed on urea percentage at different dissolved times*

The uniformity of the additives distribution on cut rice straw

The mechanical system included chopping unit, mixing unit and pumping and distribution unit was operated at the cutting head rotating speed of 1650 rpm, one mm clearance, 300 rpm mixing shaft rotating speed and 15 min. dissolving time. The uniformity of the additives distribution on cut rice straw was measured by the determination of the crude protein percentage *(CP)* in the final product. Five samples S_1, S_2, S_3, S_4 and S_5 were taken from the final product to determine the crude protein percentage. The results of crude protein percentage at three levels of urea percentage 1, 3 and 5% are shown in Table (3). The average values of crude protein were 3.6, 4.9 and 6.2% at urea percentage 1, 3 and 5 respectively. The coefficient of variations *(CV)* of urea percentage for samples at 1, 3 and 5 were 4.22, 4.99 and 5.46% respectively for S_1, S_2, S_3, S_4 and S_5. These values indicate that there are no differences in the uniformity of the additives distribution on cut rice straw at different levels of urea percentage. The maximum value of crude protein of 6.2% was found at 5% urea.

Table 3. *The effect of urea percentage on the crude protein percentage.*

Sample	Urea concentration, %		
	1	3	5
S_1	3.55	4.60	5.80
S_2	3.58	5.10	6.40
S_3	3.70	4.80	6.60
S_4	3.40	5.20	5.90
S_5	3.80	4.80	6.30
Ave.	3.60	4.90	6.20
STDEV	0.15	0.24	0.33
CV	4.2	5.0	5.5

Economic viability

The total fabrication cost of the developed system including workshop cost was 83,478 LE at 2020 prices. The developed system achieved an internal rate of return *(IRR)* of 19%. The developed system *IRR* shows that the investment is worthy. The developed mechanical system indicated the pay back period *(PBP)* was about two years.

One way to benefit from the rice straw is to use it in manufacturing unconventional animal feed after cutting it and treating it with urea, molasses, and mineral salts to try to bridge the gap in animal feed. This treatment leads to an increase in the percentage of protein and a decrease in the percentage of fiber, transforming the straw from just a filling feed into a fodder with a higher nutritional value, in addition to protecting the environment from serious damage (Abreu *et al.,* 2022). In this research, an automated system was developed for cutting rice straw, mixing nutritional additives (urea, molasses, mineral salts), and distributing the mixture to the straw during the cutting process. The mechanical system included three units; cutting unit, mixing unit, and the unit for distributing the mixture to the straw during the cutting process. The results indicated that the favorite cutting length of 20 to 80 mm was 81% at a cutting head speed 1650 rpm (25.9 m s^{-1}) and one mm knife clearance. These results are similar to those found by (Younis *et al.,* 2002; El Shal and El Didamony, 2018; Singh *et al.,* 2020; Jiang *et al.,* 2021). El Shal and El Didamony (2018) reported that the optimum knife speed of 2150 rpm (61.92 m s^{-1}), the chopping length of 15 mm, and chopping efficiency was 79.37%. The results also showed that the CP in rice straw after mixing the additive increased from 3.3 to 6.2%. Increasing the percentage of crude protein in the supplemented diet which may leads to improving the animal's rumination, and feed efficiency of dry matter (Mendes *et al.,* 2015). Abreu *et al.* (2022) mentioned that the feed supplementation is a powerful tool to adjust nitrogen (N) levels in the diet of ruminants during critical periods. Urea is commonly used as a source of non-protein nitrogen in molasses supplements. This dietary protein provides amino acids as well as nitrogen for microbial protein synthesis. Moreover, molasses has organoleptic characteristics, such as palatability, increasing dry matter intake, through microbial growth, especially for fiber-digesting bacteria.

CONCLUSION

A mechanical system for producing animal feed (cutting rice straw mixed with the additives of urea, minerals and molasses) was developed. This system consists of a chopping unit, mixing unit, and pumping & distribution unit. Cutting head speed of 1650 rpm and 1 mm clearance between fixed and the movable knives gave the highest chopping unit productivity of 600 kg h^{-1}, 81% favorite cutting length of 2 to 8 cm. The optimum content of crude protein of 6.2% was found at urea content of 5% and was obtained at mixing shaft rotating speed 300 rpm and 15 min dissolving time at the bottom of tank. The developed system achieved a rate of return of 19% and a pay back period of about two years.

DECLARATION OF COMPETING INTEREST

The author(s) must declare that they have no conflict of interest

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

This research work was carried out in collaboration with the authors (Ghonimy, Suliman, Morsy, Abdeel-Atty and Alzoheıry).
Mohamed Ghonimy contributed equally in various roles including setting research goals, development of methodology, performing the experiments, analyzing data, and writing the artical and also coordinated the activities with the co-author.
Ahmed Suliman contributed equally in various roles including setting research goals, development of methodology, performing the experiments, analyzing data, and writing the artical.
Mohamed Morsy contributed equally in various roles including setting research goals, development of methodology, performing the experiments, analyzing data, and writing the article.
Ahmed AbdeEl-Atty contributed equally in various roles including setting research goals, development of methodology, performing the experiments, analyzing data, and writing the article.
Ahmed Alzoheiry contributed equally in various roles including setting research goals, development of methodology, performing the experiments, analyzing data, and writing the article.

ETHICS COMMITTEE DECISION

This article does not require any ethical committee decision.

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