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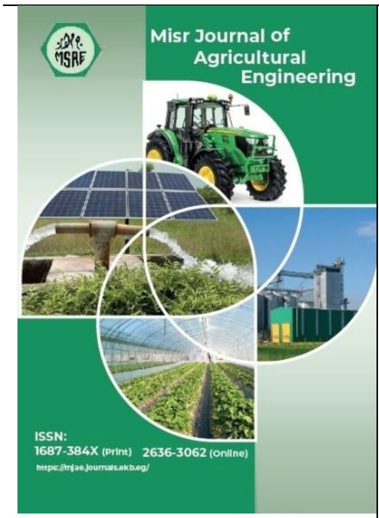
DEVELOPMENT AND PERFORMANCE EVALUATION OF LIVESTOCK FEED MIXER

Ebrahim Mohamed Gomaa[1&*]; Mohamed Nabih Omar[2]; Ayman Hafiz Amer Eissa[3]; Said Fathi Elsisi[4]

[1] Assist. Prof., Ag. and Biosystem Eng. Dept. Fac. of Ag., Menoufia U., Shebin EL-Kom, Egypt.
[2] Prof., Ag. and Biosystem Eng. Dept., Fac. of Ag., Menoufia U., Shebin EL-Kom, Egypt.
[3] Prof., Ag. and Biosystem Eng. Dept., Fac. of Ag., Menoufia U., Shebin EL-Kom, Egypt and Dean of the Faculty of Organic Agriculture, Heliopolis University, Egypt.
[4] Assoc. Prof., Ag. and Biosystem Eng. Dept., Fac. of Ag., Menoufia U., Shebin EL-Kom, Egypt.
* E-mail: ebrahim.mohamed32@agr.menofia.edu.eg



ABSTRACT

Small farms in Egypt often face challenges in meeting their daily feed requirements due to the continuous rise in feed prices and transportation costs. The main objective of this study was to fabricate, develop, and evaluate the performance of a prototype feed mixing machine tailored for small farms. The experimental studies focused on determining the effects of mixing duration, rotational speed, and rotation direction for mixing unit on mixing efficiency, machine productivity, power requirements, and specific energy consumption. The machine was tested and evaluated under four different mixing durations (5, 10, 15, and 20 minutes), four different rotational speeds (20, 25, 30, and 35 rpm), and two rotation directions for the mixing unit (clockwise and alternating between clockwise and anticlockwise). The 50 kg test mixture included crushed yellow corn (21 kg), cotton seed meal (11.5 kg), bran (11 kg), corn seeds (5 kg), limestone (0.7 kg), table salt (0.5 kg), sodium bicarbonate (0.15 kg), and vitamins and minerals (0.15 kg). The results show that the optimal efficiency (98.27% to 98.60%) was obtained at 30-35 rpm and 15–20-minute durations using both rotation directions. Power requirements increased with higher speeds. The maximum required power, 0.345 kW. Increasing the mixing duration increased specific energy, while rotation direction and speed had no significant effect. The maximum specific energy (2.37 Wh/kg) was observed at 35 rpm with a 20-minute, two-direction process. It is recommended to use a mixing duration of 15 minutes, with bi-directional rotation, and a rotation speed of 30 rpm.

Keywords:
Mixing machine;
Livestock feeds;
Mixing efficiency.

INTRODUCTION

Livestock is an integral part of agriculture, contributing to the agricultural economy through live animals and their products. In 2021, the cattle stock in Egypt amounted to approximately 2.82 million heads. Sheep stocks followed with around 2.24 million animals. Additionally, the number of rabbits and hares in the country reached 6.8 million. In contrast, pigs and mule stocks were the lowest, with 11,000 and 3,090 heads, respectively **(statista, 2023)**. Feeding is one of the most essential needs for animal survival. Therefore, food and machinery are closely related in terms of production, preparation, and other processes. Traditionally, small-scale cattle and poultry farmers manually mixed crushed feed. However, for medium-scale production, machinery is necessary to mix ingredients into animal feed. A machine is a well-known structure with a framework and various moving parts designed to make the job easier, faster, and of higher quality **(Cajindos, 2014)**. According to **Chikwado (2015) and New (2007)** the purpose of the mixing device is to create an even distribution of all components using flow generated by mechanical motion. After mixing, the feed is extruded and pelletized. The mixing operation is of great importance, as it is the process through which two or more ingredients are combined to form a feed. This process ensures that the ingredients are evenly distributed, resulting in a homogeneous mixture that meets the nutritional requirements of the target livestock, poultry, or aquatic life **(Balami, et al., 2013)**. The mixing experiment is tedious because it involves measuring the standard deviation of critical components. This requires taking multiple samples, at least ten, from various parts of the mixer at different times. Mixing times are often determined using an easy-to-analyze component, such as salt. However, it is important to ensure that the results are applicable to the material of interest, as it may have different particle sizes and densities than salt **(Clark, 2005)**. **Makange et al. (2016)** tested an animal feed mixing machine using a feed composition consisting of 3.5 kg of maize bran, 1.25 kg of cotton/sunflower cake, 0.15 kg of lime, 0.075 kg of bone meal, and 0.018 kg of salt, replicated three times at two mixing durations of 10 and 20 minutes. The average coefficient of variation (CV) was 5.93%, indicating a significant reduction in feed component variability for the tested samples. The degree of mixing achieved was 94.06%. **Abo-Habaga et al. (2017)** emphasized that mixing duration is a crucial variable influencing the performance of the manufactured horizontal animal feed mixer

With the expansion of animal production farms, there is a growing need to develop various types of equipment used in farm management. The goal of creating a feed mixing machine model suitable for the farm is to save time and effort, reduce costs for the farmer, and ensure the quality of the feed. This involves knowing the correct proportions of ingredients and ensuring the feed contains all the necessary nutritional elements for the animals. Ultimately, this leads to increased productive efficiency on the farm. This study aims to fabricate and evaluate the performance of a prototype machine capable of mixing feed components for small farms. The machine was designed to reduce manual exhaustion, and the time required for the mixing process while achieving high mixing efficiency.

MATERIALS AND METHODS

Methodology

The design calculations utilized for the development and fabrication of the prototype livestock feed mixer are presented in this part.

Volume of mixing chamber

The mixing chamber is a cylinder. The volume v of the cylinder is given by:

$$v = \pi \frac{d^2}{4} L \qquad (1)$$

Where, d = the diameter of the circular base (0.55 m) and L = the length of the cylinder (0.88 m). From following equation, the volume is given as;

$$v = 3.14 \times \frac{0.55^2}{4} \times 0.88$$

$$v = 0.208 m^3$$

Volume of mixture

The density of each component of the mixture was determined. Subsequently, the total density of the mixture was calculated to be 500 kg/m³. The volume of the mixture was then determined, based on a total mass of 50 kg for the mixture, using the following equation:

$$\mathrm{v} = \frac{\text{mass}}{\text{density}} \quad (2)$$

$$v = \frac{50}{500} = 0.1\ m^3$$

The filling percentage was calculated using the following equation:

$$\text{Filling percentage} = \frac{\text{volume of mixture}}{\text{Volume of mixing chamber}} \times 100 \quad (3)$$

$$\text{Filling percentage} = \frac{0.1}{0.208} \times 100 = 48\%$$

A minimum fill level of over 60% is recommended for optimal performance in ribbon mixers, even though some manufacturers suggest these mixers can operate effectively at fill levels below 50%, according to **Detlef Bunzel, (2019)**.

Theoretical torque of drum shaft

According to **Khurmi and Gupta (2005)**, shafts can be designed based on both rigidity and strength. When subjected solely to a twisting moment, the torque in the shaft is given by the following equation.

$$T = \frac{\pi \tau d^3}{16} \quad (4)$$

Where, T is the torque, τ is the maximum shear stress (N/m^2) and d is the diameter of the agitator ribbon (mixing unit), m.

$$\tau = \frac{F}{A} \quad (5)$$

Where, F is the force acting on the body (N) and A is the cross-sectional area of the body (m^2)

$$A = \frac{\pi d^2}{4} \quad (6)$$

$$F = mg \quad (7)$$

Where, m is the mass of the body (kg) and g is the acceleration due to gravity (m/s^2)

$$F = 50 \times 9.81$$

$$F = 490.5\ N$$

$$\tau = \frac{490.5 \times 4}{\pi \times (0.55^2)}$$

$$\tau = 2065.59\ N/m^2$$

From Equation 4, the shaft torque is calculated, where d represents the diameter of the shaft. It is assumed that the diameter of the mixing shaft is approximately the chamber's diameter, as the shaft generally extends near, but not entirely to, the chamber's edge.

$$T = \frac{3.14 \times 2065.59 \times (0.55)^3}{16}$$

$$T = 67.44\ N.m$$

Power transmission

Power transmitted by the shaft is given by:

$$\mathrm{P} = \frac{(2\pi \mathrm{N})\mathrm{T}}{60} \qquad (8)$$

Where, P is the power rating of the electric motor (Watt), T is the torque transmitted in Nm and N is the number of revolutions per minute (Assume the number of revolutions per minute is 35) according to company **Ross company (2024).**

$$P = \frac{2 \times 3.14 \times 35 \times 67.44}{60}$$

$$P = 247.06W \quad \rightarrow \quad P = 0.247\ kW$$

Using a power factor of 1.2, the required power is calculated to be 0.3 kW. Therefore, an electric motor with a capacity of 0.75 kW will be adequate to provide sufficient power to drive the belts and shafts, as well as to ensure effective operation of the mixing chamber, regardless of the type or composition of the feed components being processed.

Experimental study

The experiments were carried out in the workshop of the Department of Agricultural and Biosystems Engineering, Faculty of Agriculture, Menoufia University. The following materials were used for formulating the livestock feed mixture and testing the machine: crushed yellow corn, cottonseed meal, bran, limestone, table salt, sodium bicarbonate, and a mixture of vitamins and minerals. The performance evaluation of the machine was conducted to determine the mixing efficiency, specific energy consumption, and required power by utilizing different time durations and two rotation directions for the ribbon agitator at four different rotational speeds. The weight and percentage materials in the mixture are shown in table 1.

Table 1: Mass, percentage, and bulk density of materials used in the production of 50 kg of livestock feed.

	Materials	Mass of materials (kg)	Percentage mass of mixture (%)	Bulk Density g/cm^3
1	Crushed yellow corn	21	42	0.54-0.58
2	Cotton seed meal	11.5	23	0.64
3	Bran	11	22	0.21
4	Corn seeds	5	10	0.3
5	Limestone	0.7	1.4	0.96
6	Table salt	0.5	1	1.38
7	Sodium bicarbonate	0.15	0.3	0.8
8	Mixture of vitamins and minerals	0.15	0.3	0.56
	Total	50	100	0.494

Prototype mixing machine

The properties of the materials used in fabricated machine are inexpensive, and readily available. The prototype machine consists of a main frame, mixing chamber (Figure 1), feeding gate, driving shaft, mixing ribbons and Control panel (Figure 2).

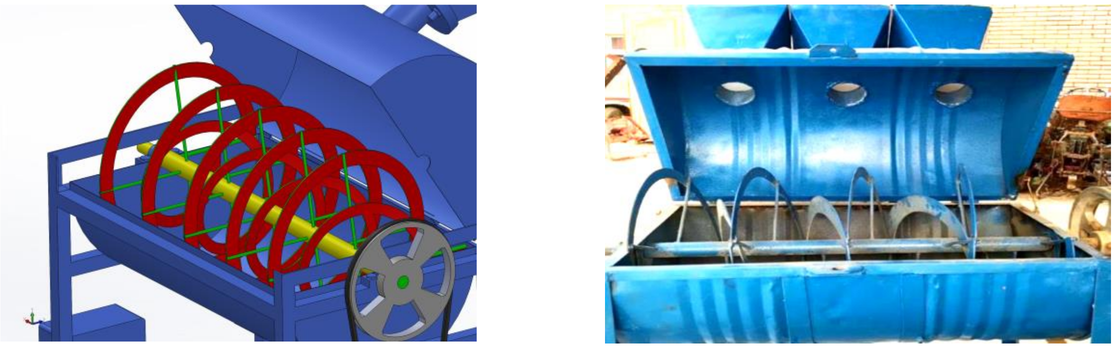


Fig. (1): Mixing chamber

1. Main switch: used to disconnect electricity from the entire machine.
2. Sub-switch: used to connect electricity to the Timer device.
3. Digital display: Through it, the time required to operate the machine in both directions can be controlled.

1. Machine operating key.
2. Direction key.
3. A key to close the control panel door.

A **b**

Fig. (2): Control panel

Description of the developed feed mixer

Machine views and sketches shown in figs. (1-3). Components of the mixing machine: mixing chamber, double ribbon agitator, feeding gate, motor, Control board. Machine overall dimensions length, width, and height were 120, 58, 170 cm, respectively.

1. Machine frame

The frame is made of iron L section 3.8, 3.8 cm, with dimensions 58 cm wide, 100 cm length, and 57 cm high. The frame was carried on 4 wheels to make it easy to move. The electric motor had been installed on the frame.

2. Mixing chamber

The mixing chamber is barrel with 88 and 55 cm inside dimensions length and diameter, respectively. And the driving shaft has two spirals were installed to move the materials in two directions. The barrel has two gates in the middle,30cm length and 30cm width inlet gate in the top and 13 cm length and 10cm width outlet in the bottom.

3. Mixer unit

The double agitator ribbon (Figure 3) is mounted on the driven shaft, rotate in two opposite directions. The diameter of the largest ribbon is 50 cm, and the diameter of the smaller ribbon is 32 cm. The function of the ribbon agitator is to mix the feed ingredients to obtain the best homogeneity ratio.

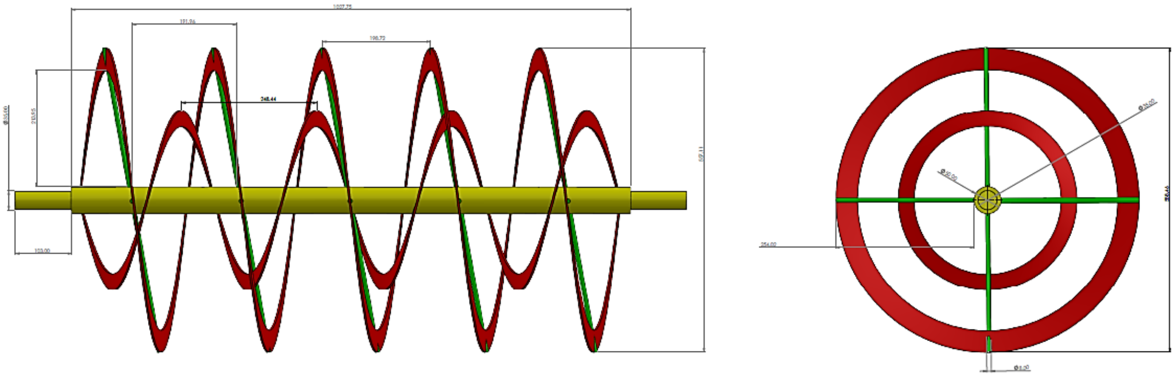
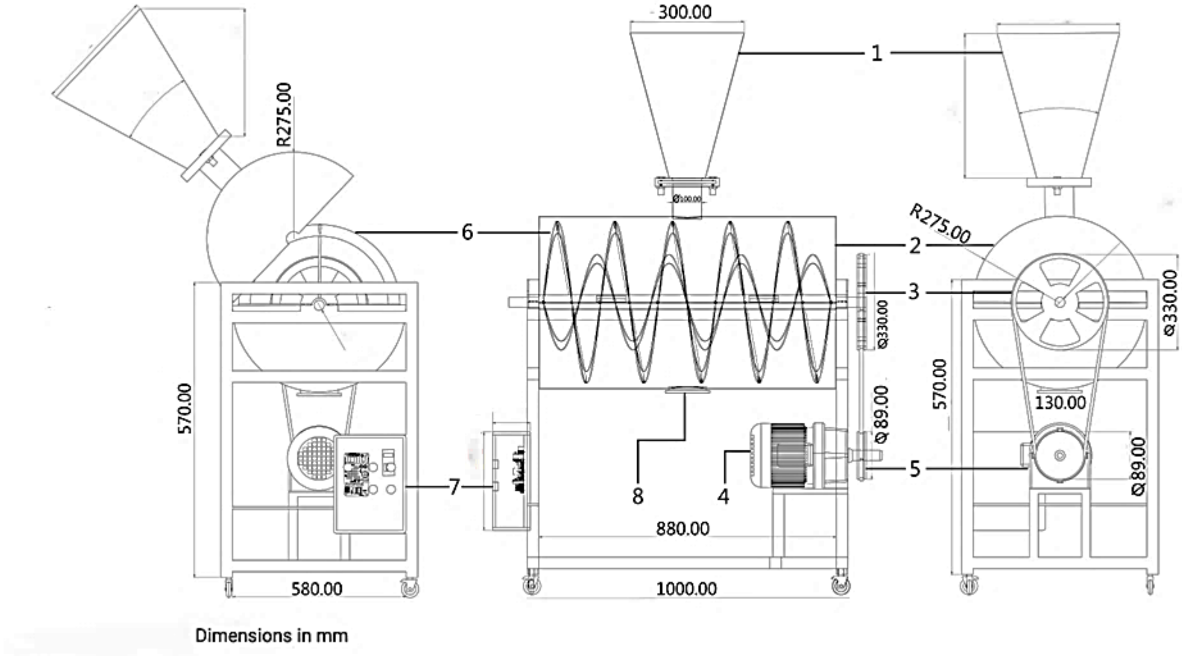


Fig. (3): The double agitator ribbon



1. Feeding gate
2. Mixing chamber
3. Large pulley
4. Electric motor
5. Small pulley
6. Agitator ribbon
7. Control Board
8. Exit gate

Fig. (4): Schematic diagram of the fabricated mixing machine

4. Feeding gate

The machine has a gate for feeding materials into the mixing chamber. This gate is located on the lid of the mixing barrel and has dimensions of 30 x 30 cm.

5. The motor

The system was powered by an electric motor (Motor No: M4480079) with 0.75 kW power and a speed of 1420 rpm were reduced to 130 rpm using gearbox.

6. Control panel

This control panel is used to manage the mixing time and the driving shaft directions.

7. Transmission

V-belt and pulley arrangements were chosen to transmit power from gearbox to the driven shaft due to their flexibility, simplicity, and low maintenance costs. Additionally, can absorb shocks and reduce the impact of vibratory forces (**Cary HB, Helzer SC, 2005**). A pulley transmission system was used, consisting of a large pulley with a diameter of 33 cm and four smaller pulleys with diameters of 51, 64, 77, and 89 mm. The large pulley is connected to the driven shaft and receives movement from the smaller pulleys via belts to operate the ribbon agitator, which mixes the feed ingredients. The small pulleys are connected to the gearbox shaft (drive shaft), which is attached to the electric motor.

Studied factors

The study focused on the effects of changing three main factors: mixing duration time (5, 10, 15, and 20 min.), rotational speed of the mixing unit (20, 25, 30, and 35 rpm), and the direction of rotation of the mixing unit (one direction: clockwise, or two directions: clockwise and anticlockwise).

Measurements

The mixing machine was evaluated according to the following indicators:

1. Productivity (kg/h)

The machine productivity is determined according to the following formula**:**

$$\text{Machine productivity} = \frac{\text{Mass of mixed materials (kg)}}{\text{Time (h)}} \qquad (9)$$

2. Required power (kW)

The required power was measured using a clamp meter to gauge changes in electrical current during the mixing process. The required power was determined using the following formula. The clamp meter used had the following specifications: AC Voltage: 450V (Accuracy: ±1.2%), AC Current: 20 - 400A (Accuracy: ±2.0%), and Resistance: 200KΩ (Accuracy: ±1.0%).

$$P = \sqrt{3}\cos\varphi \times I \times V \times \frac{1}{1000} \qquad (10)$$

Where, P = Required power (kW), I = Electrical current (A), V = Voltage (volt), cosϕ= Power factor (0.74) and $\sqrt{3}$ = In the case of 3 phases.

3. Specific energy consumption:

Specific energy was determined according to the following formula:

$$Es = \frac{P}{SR} \qquad (11)$$

Where, Es = Specific energy (kJ/kg), P = Required power (kW) and SR = Machine productivity (kg/sec)

4. Mixing efficiency (%)

To assess the efficiency of the mixing process, 5 kg of unground corn were introduced into the mixture as tracers. The mixing efficiency was evaluated by monitoring the distribution of corn within the sample (150 g). Three samples were randomly collected from each treatment, with each sample collection being replicated three times. The mass of corn seeds in each sample was measured, and these measurements were subsequently used to calculate the overall mixing efficiency.

Mixing efficiency was determined mathematically according to the following formula:

$$Me = 100 - \left(\frac{|x-15|}{15}\right) \times 100 \qquad (12)$$

Where, Me = Mixing efficiency (%), x =Mass of corn seeds in the sample (gram) and 15 = Standard mass of the tracer (corn seeds) in the sample.

The steps for calculating the mixing efficiency are illustrated in Figure 5.

1 2 3

Fig. (5): Steps to calculate mixing efficiency

RESULTS AND DISCUSSION

1. Mixing efficiency (%)

The effects of the agitator ribbon's rotational speed, mixing duration, and rotation direction on mixing efficiency are shown in Figure 6. Increasing the rotational speed of the agitator ribbon led to an increase in mixing efficiency for all durations and at both levels of rotation direction. Increasing the mixing duration led to an increase in mixing efficiency for all rotational speeds and both rotation directions. As the mixing duration increases, the materials have more time to interact and distribute evenly throughout the mixing chamber. The longer mixing time improves particle dispersion, reduces clumps, and minimizes unmixed areas, which enhances overall mixing efficiency. Furthermore, using both directions (clockwise and anticlockwise) for the agitator ribbon produces higher mixing efficiency than using only one direction (clockwise) for all mixing times and rotational speeds. Using both clockwise and anticlockwise directions for the agitator ribbon enhances mixing efficiency by introducing more dynamic and comprehensive mixing conditions. Bidirectional motion disrupts existing flow patterns, promotes greater particle interactions, and facilitates a more uniform distribution of materials throughout the mixture. The lowest mixing efficiency (50.63%) was recorded at an agitator ribbon rotational speed of 20 rpm, with a 5 min. mixing duration and a single direction (clockwise). The maximum mixing efficiencies, recorded as 98.43%, 98.27%, 98.60%, and 98.53%, were observed at mixing durations of 15 and 20 min., with rotational speeds of 30 and 35 rpm, respectively, under both clockwise and anticlockwise rotation directions.

2. Productivity (kg/h)

The effect of mixing duration on mixer productivity is shown in Figure 7. The results indicate that as the mixing duration increased from 5 to 20 min., the machine productivity decreased from 600 to 150 kg/h.

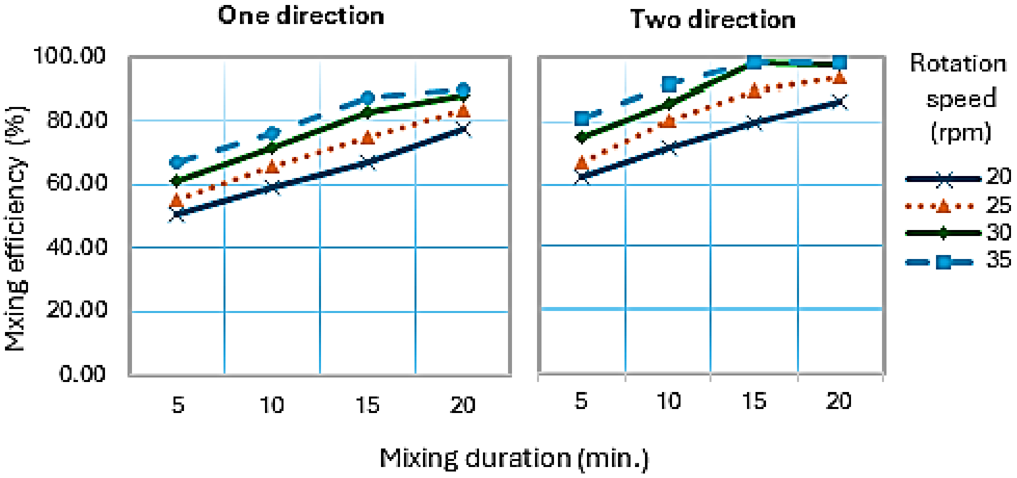


Fig. (6): Effect of mixing duration (min), and rotation direction on mixing efficiency (%) at rotation speeds (rpm)

This decrease in productivity with longer mixing durations is attributed to the additional time required to mix the same feed formula. While the rotational speed and direction of the mixing unit do not affect productivity, it caused significant impact on the efficiency of the mixing process. Machine productivity, defined as the amount of material processed per unit of time, remains constant regardless of changes in rotational speed or direction. It may be due to productivity done by the overall mixing duration rather than the mechanical settings of the mixer. The lowest productivity (150 kg/h) was observed at a 20 min. mixing duration, while the highest productivity (600 kg/h) occurred at a 5 min. mixing duration.

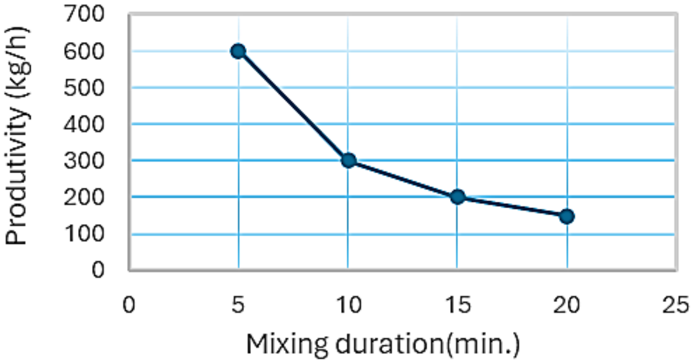


Fig. (7): Effect of mixing duration on mixer productivity.

3. Required power (kW)

The power requirements are shown in Figure 8 as affected by rotation speed and mixing direction. Increasing the rotation speed led to an increase in required power for two levels of mixing direction. The power requirements, as influenced by rotation speed and mixing direction, are presented in Figure 8. An increase in rotation speed resulted in higher power requirements for both levels of mixing direction. This may be due to the increased resistance encountered by the machine. As the ribbon rotates faster, it creates greater friction between the material and the mixer walls, as well as within the fodder itself. This added resistance requires more energy from the motor. The use of both mixing directions (clockwise and counterclockwise) led to an increase in power requirements at all levels of rotation speed. The alternating movement creates additional friction between the mixer components and the materials, leading to greater power requirements.

The lowest required power, 0.319 kW, was observed at a rotation speed of 20 rpm and one direction for mixing unit. The highest required power, 0.345 kW, was recorded at a rotation speed of 35 rpm and two rotation directions for mixing unit.

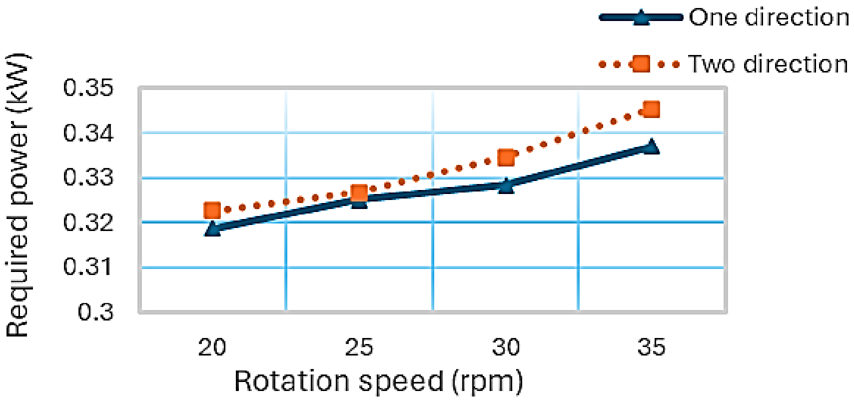


Fig. (8): Effect of rotation speed and mixing direction on required power.

4. Specific Energy (Wh/kg)

Figure 9 presents the influence of mixing duration and the direction of the mixing unit on specific energy. The results demonstrate that increasing the mixing duration led to an increase in specific energy for all rotation speeds and both rotation directions. Specifically, when the mixing duration was increased from 5 to 20 min., the specific energy increased from 0.53 to 2.12 Wh/kg for one rotation direction at a rotation speed of 20 rpm. Similarly, for two rotation directions at the same rotation speed, the specific energy increased from 0.54 to 2.16 Wh/kg as the mixing duration increased from 5 to 20 minutes. This increase in specific energy with longer mixing durations is attributed to the higher power required to complete the mixing process.

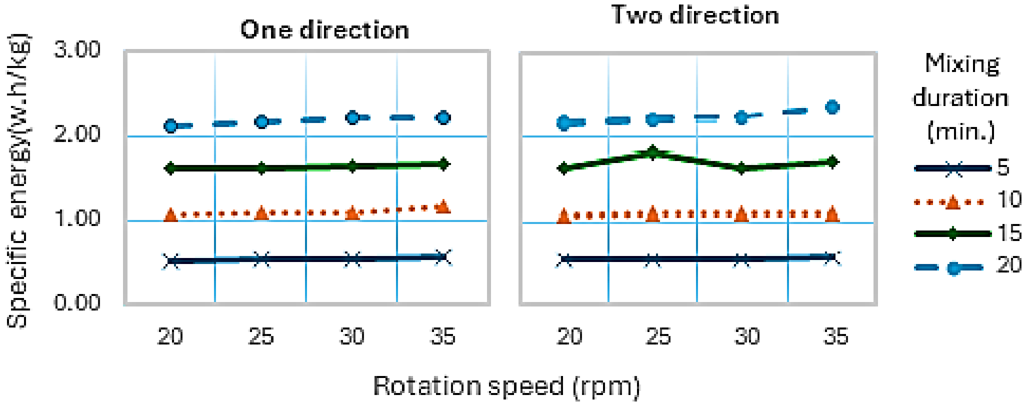


Fig. (9): Effect of rotation speed (rpm) on specific energy (Wh/kg) at mixing duration (min) and mixing direction.

The rotation direction and rotation speed of the mixing unit have no significant impact on specific energy consumption. This may be due to the mixing chamber being only half full during the experiments, allowing the material more space to move freely. As a result, the energy required for mixing becomes less sensitive to changes in rotational speed or direction, as the system is not contending with a fully loaded chamber. In the one-directional mixing process, the lowest specific energy of 0.53 Wh/kg was observed at an agitator ribbon rotational speed of 20 rpm with a 5-minute mixing duration, while the highest specific energy, 2.22 Wh/kg, occurred at 35 rpm with a 20-minute mixing duration. Similarly, in the two-directional mixing process, the lowest specific energy was 0.54 Wh/kg at 20 rpm with a 5-minute mixing duration, and the highest specific energy reached 2.37 Wh/kg at 35 rpm with a 20-minute mixing duration.

Table 2: Analysis of Variance for the effects of mixing duration, rotational speed, mixing unit direction, and their interactions on power requirements, specific energy consumption, and mixing efficiency.

		Required power (kW)	**Mixing efficiency (%)**	**Specific energy (Wh/kg)**
Direction (D)	Mean Square	0.000585094	3813.012504	0.02085651
	F	1.388	28.171	0.051
	Sig.	0.242	0.000	0.821
		N.S.	**	N.S.
Speed (S)	Mean Square	0.000407649	1326.745596	0.005260649
	F	0.962	9.721	0.013
	Sig.	0.414	0.000	0.998
		N.S.	**	N.S.
Time (T)	Mean Square	0.000180816	2802.376779	12.4212007
	F	0.419	31.716	1112.272
	Sig.	0.739	0.000	0.000
		N.S.	**	**
Interaction D*S*T	Mean Square	0.000298793	531.4045902	1.209624766
	F	0.618	543.912	97.669
	Sig.	0.928	0.000	0.000
		N.S.	**	**

Source: Own calculation based on program of SPSS Ver.22
**: Highly significant at 1% level of significance
N.S.: Non-Significant

The Variance analysis table presents the effects of mixing duration, rotational speed, and mixing direction on required power, specific energy, mixing efficiency, and the significance of these factors and their interactions in the mixing process. Mixing direction does not have a statistically significant effect on required power or specific energy. However, it significantly impacts mixing efficiency. Rotational speed does not significantly affect required power or specific energy, but it significantly affects mixing efficiency. Mixing duration does not significantly affect required power, but it has a highly significant impact on both specific energy and mixing efficiency.

Table 3 indicates that alternating between clockwise and anticlockwise rotation significantly improves mixing efficiency, although there are no significant differences between them in specific energy consumption. The highest mixing efficiency occurred at rotation speeds of 30 and 35 rpm with mixing durations of 15 and 20 min., although there are no significant differences between them in mixing efficiency.

CONCLUSION

The experiments were conducted in the workshop of the Department of Agricultural and Biosystems Engineering, Faculty of Agriculture, Menoufia University. The mixing machine used in this study was locally fabricated in a workshop in Shebin El-Koum city, Menoufia Governorate, Egypt. The main objective of this research was to evaluate the performance of a developed mixing prototype, which was fabricated locally. The mixing machine comprises a mixing cylinder and a central longitudinal shaft, onto which a double ribbon agitator is fastened. The machine is equipped with a feeding hopper and an outlet for the mixed materials. Power is supplied by an electric motor, which is connected to the mixing unit via a belt and pulleys of varying sizes, allowing for the adjustment of rotational speeds. This study investigated the effects of various operational parameters, including rotational speed, mixing duration, and rotation direction of the agitator ribbon, on the mixing efficiency, productivity, and specific energy consumption of a mixing unit. The results demonstrated that both rotational speed and bidirectional rotation significantly enhance mixing efficiency, with higher speeds and the combination of clockwise and anticlockwise directions achieving the highest efficiency levels.

Table 3: Mean ± SE. of the interaction effects between mixing duration, rotational speed, and mixing unit direction on power requirements, specific energy consumption, and mixing efficiency

Direction	Rotation speed (rpm)	Mixing duration (min.)	Required Power (kW)	Mixing Efficiency (%)	Specific Energy ((Wh/kg))
1	20	5	0.327±0.006	50.633±0.285^{r}	0.545±0.010^{e}
		10	0.330±0.007	59.367±0.410^{p}	1.098±0.024^{d}
		15	0.323±0.010	67.267±0.536^{m}	1.617±0.051^{c}
		20	0.334±0.327	77.167±0.601^{j}	2.225±0.025^{ab}
	25	5	0.316±0.330	55.433±0.384^{q}	0.526±0.019^{e}
		10	0.326±0.323	65.507±0.248^{n}	1.084±0.031^{d}
		15	0.327±0.009	74.680±0.588^{k}	1.633±0.047^{c}
		20	0.326±0.010	83.233±0.504^{g}	2.175±0.065^{ab}
	30	5	0.325±0.006	61.400±0.666^{o}	0.542±0.011^{e}
		10	0.322±0.009	71.707±0.148l	1.072±0.040^{d}
		15	0.321±0.010	82.833±1.093^{g}	1.603±0.058^{c}
		20	0.317±0.006	87.967±0.484^{e}	2.116±0.074^{b}
	35	5	0.335±0.012	67.067±0.698^{mn}	0.558±0.019e
		10	0.347±0.008	76.067±0.581^{jk}	1.156±0.026^{d}
		15	0.333±0.009	87.167±0.441e^{f}	1.664±0.043^{c}
		20	0.331±0.013	89.900±0.208^{d}	2.206±0.087^{ab}
2	20	5	0.332±0.016	62.683±0.434^{o}	0.554±0.027^{e}
		10	0.329±0.005	71.500±0.289l	1.098±0.017^{d}
		15	0.327±0.002	79.833±0.441^{h}	1.634±0.008^{c}
		20	0.331±0.005	86.667±0.835^{ef}	2.203±0.035^{ab}
	25	5	0.323±0.006	67.167±1.093^{mn}	0.539±0.010^{e}
		10	0.325±0.010	80.450±0.732^{h}	1.083±0.032^{d}
		15	0.361±0.037	89.600±0.346^{d}	1.805±0.186^{c}
		20	0.324±0.012	93.667±0.882^{b}	2.163±0.076^{b}
	30	5	0.325±0.007	75.000±0.577^{k}	0.542±0.012^{e}
		10	0.320±0.013	86.000±0.577^{f}	1.065±0.043^{d}
		15	0.324±0.014	98.433±0.120^{a}	1.619±0.068^{c}
		20	0.356±0.031	98.267±0.384^{a}	2.372±0.210^{a}
	35	5	0.329±0.009	81.000±0.577^{h}	0.549±0.016^{e}
		10	0.332±0.011	91.667±0.882^{c}	1.108±0.035^{d}
		15	0.342±0.011	98.600±0.058^{a}	1.711±0.056^{c}
		20	0.337±0.003	98.533±0.145^{a}	2.247±0.019^{ab}

a, b, c, and ... exe means within the same row with each different superscript are significantly different ($P \leq 0.05$)

However, these efficiency gains do not come at the cost of increased specific energy consumption, as neither mixing direction nor rotational speed had a statistically significant effect on required power or specific energy. The results indicate that both higher rotational speeds and bidirectional rotation significantly enhance mixing efficiency, with the combination of clockwise and anticlockwise directions resulting in the highest efficiency levels. Importantly, these efficiency results did not increase specific energy consumption, as neither mixing direction nor speed had a significant effect on required power or specific energy. However, increasing the mixing duration from 5 to 20 min. consistently improved efficiency but also substantially reduced productivity and increased specific energy consumption.

The results recommended that, the optimization of mixing operations by balancing efficiency, productivity, and specific energy. The optimal conditions were using rotation speed of 30 rpm, bidirectional mixing unit and mixing duration of 15 min. is highly optimal, to give balance with a high mixing efficiency of 98.433% and a relatively lower specific energy consumption of 1.619 Wh/kg compared to other conditions.

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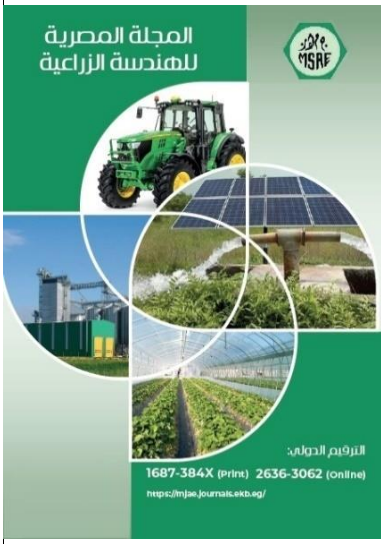
تطوير وتقييم أداء خلاط أعلاف الماشية

ابراهيم محمد جمعة[1]، محمد نبيه عمر[2] ، أيمن حافظ عامر عيسى[3] و سعيد فتحي السيسي[4]

[1] مدرس - قسم الهندسة الزراعية والنظم الحيوية - كلية الزراعة - جامعة المنوفية - شبين الكوم - مصر
[2] أستاذ - قسم الهندسة الزراعية والنظم الحيوية - كلية الزراعة - جامعة المنوفية - شبين الكوم - مصر
[3] أستاذ - قسم الهندسة الزراعية والنظم الحيوية - كلية الزراعة - جامعة المنوفية - شبين الكوم – مصر - عميد - كلية الزراعة الحيوية - جامعة هليوبوليس - مصر
[4] أستاذ مساعد - قسم الهندسة الزراعية والنظم الحيوية - كلية الزراعة - جامعة المنوفية - شبين الكوم – مصر



الكلمات المفتاحية:
آلة الخلط؛
الاعلاف الحيوانية؛
كفاءة الخلط.

الملخص العربي

المزارع الصغيرة في مصر غالبا ما تواجه تحديات في تلبية احتياجاتها اليومية من الأعلاف بسبب الارتفاع المستمر في أسعار الأعلاف وتكاليف النقل. كان الهدف الرئيسي من هذه الدراسة هو تصنيع وتطوير وتقييم أداء نموذج أولي لآلة خلط الأعلاف المصممة خصيصًا للمزارع الصغيرة. ركزت الدراسات التجريبية على تحديد تأثير مدة الخلط، وسرعة الدوران، واتجاه الدوران لوحدة الخلط على كفاءة عملية الخلط، وإنتاجية الآلة ، ومتطلبات القدرة، والاستهلاك النوعي للطاقة. تم اختبار الآلة وتقييمها تحت أربع فترات خلط مختلفة (٥، ١٠، ١٥، و٢٠ دقيقة)، وأربع سرعات دوران مختلفة (٢٠، ٢٥، ٣٠، و٣٥ دورة في الدقيقة)، واتجاهي دوران لوحدة الخلط (باتجاه عقارب الساعة والتناوب بين عقارب الساعة وعكس عقارب الساعة). تضمنت العينة الاختبارية التي تزن ٥٠ كجم مزيجًا من الذرة الصفراء المطحونة (٢١ كجم)، وكسب بذرة القطن (١١,٥ كجم)، النخالة (١١ كجم)، بذور الذرة (٥ كجم)، الحجر الجيري (٠,٧ كجم)، ملح الطعام (٠,٥ كجم)، بيكربونات الصوديوم (٠,١٥ كجم)، والفيتامينات والمعادن (٠,١٥ كجم). أظهرت النتائج أن الكفاءة المثلى (٩٨,٢٧٪ إلى ٩٨,٦٠٪) تحققت عند سرعة دوران ٣٠-٣٥ دورة في الدقيقة ولمدة خلط بين ١٥ و٢٠ دقيقة باستخدام كلا الاتجاهين لوحدة الخلط . زادت القدرة المطلوبة مع زيادة السرعة، وتم تسجيل أعلى متطلبات قدرة، ٠,٣٤٥ كيلوواط. أدت زيادة فترة الخلط إلى زيادة الاستهلاك النوعي للطاقة، بينما لم يكن لاتجاه الدوران السرعة تأثير كبير. تم تسجيل أعلى استهلاك نوعي للطاقة (٢,٣٧ واط.س/كجم) عند سرعة ٣٥ دورة في الدقيقة مع فترة خلط ٢٠ دقيقة واتجاهين لوحدة الخلط. يوصى باستخدام مدة خلط ١٥ دقيقة مع دوران في اتجاهين وسرعة دوران ٣٠ دورة في الدقيقة.