

Development and evaluation of a multifunctional agricultural waste shredder-mixer machine

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Abstract:

Efficiently managing the significant amounts of agricultural waste generated by farming activities is essential to prevent environmental issues such as pollution and soil degradation, making developing a processing machine crucial for sustainable practices. There is a need to efficiently manage agricultural waste, enhance resource utilization, provide economic benefits, support sustainable agriculture, and innovate agricultural machinery. This study aims to develop and evaluate a multifunctional agricultural waste shredder-mixing machine made from locally available materials. A two-way factorial design was employed to test the throughput capacity of the shredder-mixer machine, focusing on operation speed (150 rpm, 300 rpm, 450 rpm, and 600 rpm) and time (15, 20, 25, and 30 minutes). Experiments were conducted on dry Guinea corn stalks and Napia Grass. The results showed that the machine's throughput capacity improved with longer operation times and higher speeds. Specifically, it reached a maximum throughput of 20.6 kg/h when operated for 30 minutes and 22.1 kg/h at 600 rpm. When the operation time and speed were adjusted to 30 minutes and 600 rpm, respectively, the throughput capacity peaked at 28.1 kg/h. An analysis of variance (ANOVA) confirmed that the operation time, speed, and their interaction significantly influenced the throughput capacity. Additionally, a thorough safety analysis confirmed the machine's structural integrity, with a safety factor greater than 1, and validated the shear stress on the frame. This study will help improve agricultural waste management, enhance soil fertility, provide economic benefits, support environmental sustainability, advance agricultural technology, and aid small farmers.

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1. Introduction

Agricultural waste management is a crucial problem that impacts environmental sustainability and agricultural productivity. Agricultural leftovers, which include crop stalks, leaves, and other organic matter, should be disposed of properly to prevent air pollution from burning, soil erosion, and an increase in pests and illnesses. On the other hand, these agricultural wastes have significant potential as resources for mulching, composting, and bioenergy generation. As a result, creating effective, multipurpose technology to handle agricultural trash can provide a sustainable solution that improves resource usage and lessens environmental impact. The agricultural sector is crucial for human and economic development, but it generates significant waste, posing health and environmental risks if not properly managed [1]

Agricultural waste, derived from the cultivation and processing of raw materials such as fruits, crops, meat, vegetables, poultry, and dairy products, represents a significant challenge and opportunity in agricultural industries. These by-products, which include manure,

animal carcasses, food processing waste, crop residues, and hazardous agricultural chemicals, vary widely in composition and form, encompassing liquids, slurries, and solids. Despite containing potentially valuable materials, the economic value of these wastes is often less than the cost of collecting, transporting, and processing them for beneficial use, leading to substantial amounts of waste being underutilized [2]. As noted by Obi, *et al.* [2], agricultural waste is assumed to account for a large fraction of total waste, yet precise estimates are rare.

Traditionally, feed mixers in mills have combined feed materials manually, a method that is cumbersome, inefficient, and potentially unsafe for animals. Mechanical mixers have since been developed to address these drawbacks, enhancing efficiency and safety [3]. The need for locally accessible, cost-effective machinery for shredding and mixing agricultural waste, transforming it into economically beneficial products. Previous studies, such as those Adil, *et al.* [4] highlight the design of machines to convert agricultural waste into compost and other useful products, emphasizing user safety and operational

efficiency. Abdulkadir, *et al.* [5] focused on creating a shredder from locally available materials, optimizing its performance using response surface methodology (RSM) to achieve high shredding efficiency and throughput. Kumar and Kumar [6] demonstrated the advantages of using shredding machines to reduce agricultural waste for composting, showing that these machines are cost-effective, user-friendly, and capable of high output.

Further, Lawal [3] and Adusei-Bonsu, *et al.* [7] have discussed the critical role of feed mixers in producing animal feeds, noting that mechanical mixing significantly improves efficiency and safety compared to manual methods. Lindley [8] underscored the importance of pre-treating food waste to enhance processing efficiency, with the homogenization process being vital for achieving a uniform mixture.

Shredded agricultural waste can be repurposed into industrial products like hardboards, particle boards, corrugated boards, boxes, and paper pulp, or used as a lignin source in animal feed. This study aims to develop a shredder and mixing machine tailored for small and medium-sized agricultural enterprises, using low-cost locally sourced materials to ensure affordability and ease of maintenance. By addressing the inefficiencies of traditional waste processing methods and enhancing the economic value of agricultural by-products, this research seeks to contribute to sustainable agricultural practices and improved financial outcomes for local farmers and processors.

2. Materials and Method

2.1 Materials

All the materials for the fabrication of the Shredder and Mixing machine were sourced locally. Materials used in the construction of the Machine include metal, Angle Iron, Prime mover Shaft, Transmission Belt, Pullies, bearings, Hitches, Bolts, and nuts. The instrumentations used were a stopwatch, a digital weighing balance, and a Contact speed digital tachometer model (DT-2235B).

2.2 Methods

The agricultural waste shredder and mixer machine is made up of several essential parts. While the shredder chamber contains the blades that break down garbage, the frame offers structural stability. Then, employing mixing blades, the mixer chamber blends these ingredients. To ensure the right speed and torque, shafts and belts transfer mechanical power from the engine to the pulleys and blades. Machine assembly is held together securely by bolts and nuts, and bearings support the shafts for smooth rotation. A key component of the machine's efficient operation is the power transmission that pulleys provide from the motor to other sections. Every part is necessary for the overall performance and efficiency of the machine.

2.3 Design Considerations

In the successful design and production of the machine, a comprehensive approach was taken, encompassing mechanical, manufacturing, operational, and economic aspects. Machine design involves applying engineering principles and rules to create machine parts. Key mechanical factors considered included stresses,

rigidity, strength, and ductility. Operational considerations focused on achieving homogeneity in the shreds and the quality of mixing produced. Economic factors pivotal to the development of the multipurpose agricultural waste shredder and mixer included the availability and cost-effectiveness of local raw materials, low manufacturing costs, and minimal maintenance expenses [11].

The operational factors considered included the uniformity of shreds and the quality of mixing produced, high operational speed to ensure fast processing of the materials to be shredded, ease of operation and maintenance, and a high level of operational safety. Economic factors taken into account during the development of the agricultural shredding and mixing machine included the availability of local raw materials for fabrication, low fabrication costs, and low maintenance costs [11].

2.4 Design Analysis

The design procedure, processes, and calculations used to determine the machine's operating parameters for its parts are as follows.

2.4.1 Cutter Blade Angle

The angle formed by the cutting teeth of one blade with the cutting teeth of the neighboring blade in an assembled blade pair [9].

2.4.2 Teeth Angle:

The angle formed by a tooth on a blade with subsequent teeth on the same blade [9].

2.4.3 Rate of Shredding:

The number of shredded particles produced per unit of time, usually measured in mass or volume [9].

2.4.4 Particle Size

The size of the resulting particles or chips after the shredding operation, involving length and width measurements [9].

2.4.5 Cutter-to-Cutter Clearance

The distance between overlapping cutters in the cutting chamber, is adjusted to provide the most effective shearing [9].

2.4.6 Reference Angle:

The angle formed by the first tooth of the cutter blade with the horizontal, or X-axis [9]

2.4.7 Design of Hopper

The volume of the hopper can be calculated using equation 1.

$$V_H = V_1 + V_2 + V_3 \quad (1)$$

Where:

V_1 = Volume of trapezoid calculated using equation 2

$$V_1 = \frac{1}{2} (a + b) * h * L \quad (2)$$

V_2 = Volume cylinder calculated using equation 3.

$$V_2 = \pi R^2 h \quad (3)$$

V_3 = The volume of a rectangular cube calculated using equation 4.

$$V_3 = L * B * h \quad (4)$$

2.4.8 Design of shaft

Shaft design primarily involves determining the correct shaft diameter to ensure adequate strength and rigidity when transmitting power under various operating and loading conditions. For this design, the countershaft, which links the prime mover to other machine elements, is used. The shaft is made of carbon steel with a carbon content ranging from 0.1% to 35%. The process includes the determination of the appropriate shaft diameter to meet these requirements. The diameter of the shaft was determined using the maximum stress theory. The diameter is determined using equation 5.

$$d^3 = \frac{16}{\pi \tau} \sqrt{(K_b m_b)^2 + (K_t m_t)^2} \quad [10] \quad (5)$$

According to maximum shear stress theory, Shear stress is given as:

$$\tau = \frac{\text{Yield stress}}{2} = \frac{380}{2} = 190 \text{ N/mm}^2$$

Where d = diameter of the shaft (mm), S_s = Allowable shear stress of metal with key way = $190 \times 10^6 \text{ N/mm}^2$, m_b = maximum bending moment (2000Nm), m_t = torsion moment (1500 Nm), K_b = combined shock and fatigue factor applied to bending moment = 2.0 (sudden loading) recommended values of K_b for shock load, K_t = combined shock and fatigue factor applied to torsional moment = 1.5 (sudden loading) recommended values of K_t for shock load.

2.4.9 Shaft Diameter

The diameter of the shaft was determined using equation 6:

$$d_s = \frac{16}{\pi S_s} \sqrt{((k_b M)^2 + (k_t T)^2)} \quad [6] \quad (6)$$

Where d_s = the diameter of the shaft (mm), S_s = the allowable shear stress of the shaft material = $40 \times 10^6 \text{ N/m}^2$, k_b = the combined shock and fatigue factor applied to bending moment = 2.0 (sudden loading), k_t = the combined shock and fatigue factor applied to torsional moment = 2.0 (sudden loading), M = the bending moment (Nmm), T = the torsional moment (Nmm)

2.4.10 Shredder chamber

The volume of the shredder chamber V_{SC} is calculated using equation 7.

$$V_{SC} = V_1 + V_2 + V_3 \quad (7)$$

Where, V_1 = Volume of input chamber mm^3 (trapezium)

$$V_1 = \left(\frac{1}{2}(a + b)h\right) \times d \quad (8)$$

Where a and b = the two parallel sides of the chamber (feeding chamber) and h = height of input chamber. d = depth of chamber

And V_2 = Volume of top cutting chamber (semi-circle) is given by equation 9.

$$V_2 = \frac{\pi r^2}{2} \times l \quad (9)$$

Where l = length of cutting chamber (semi-circle), the radius of the semi-circle of the inlet chamber, $r = \frac{l}{2}$

Also V_3 = Area of bottom chamber ($\frac{1}{4}$ of a full circle) is given by equation 10

$$V_3 = l \times b + \frac{\pi \times b^2}{4} \quad (10)$$

Where l = length of bottom chamber, b = breadth of bottom chamber and in this equation, $b = r$

2.4.11 Design of Mixer Chamber

The volume of mixer chamber V_{MC} is calculated using equation 11.

$$V_{MC} = \pi r^2 \times l \quad (11)$$

Where $r = \frac{D}{2}$, l = length of the mixer chamber, D = diameter of mixer chamber

2.4.12 Design of Cutter Blade

The cutter is made up of mild steel plate of length l , width w , and thickness t , all in mm. Therefore, area of blade A_{CB} is shown in equation 12:

$$A_{CB} = l \times w \quad (12)$$

Where length of blade = l and width of blade = w

2.4.13 Design of Mixer Blade

The mixer blade is made up of a mild steel plate of length l , width w , and thickness t , all in mm. The volume of the blade is obtained by multiplying the area of the blade by the thickness of the blade. Volume of blade is calculated using equation 13.

$$V_{MB} = A_B \times t \quad (13)$$

Where area of blade = A_B , thickness of blade = t ,

2.4.14 Determination of Power Required

The power required for the prime mover is given in equation 14

$$P = \frac{2\pi NT}{60} [10] \quad (14)$$

Where P - power required by machine (W) T = the torque (Nm), N = number of revolutions per minute (rpm)

2.4.15 Factors of Safety

The overall integrity of the machine design can be established by ensuring that the factor of safety, which can be obtained using equation 15, is greater than 1. This will guarantee that the machine will not collapse structurally

under the action of loads. The factor of safety FoS can be calculated using equation 15.

$$FoS = \frac{Y_s}{w_s} \quad (15)$$

Where FoS is the factor of safety, Y_s is the yield strength of the machine Frame and W_s is the working stress or maximum stress.

2.14 Shear Stress on Frame

The shear stress on the triangular bars of the frame was determined using equation 16 and is given by:

$$S_r = \frac{S_e}{F_s} - \frac{S_e}{S_{yp}} \times S_m \quad (16)$$

S_r = Superimposed alternative stress

$$S_r = \frac{(Maximum\ Stress - Minimum\ Stress)}{2} \quad (17)$$

Where;

Where the minimum stress is the weight of the machine components on the frame, and the maximum stress is the combined weight of the machine components, the weight of the waste material filling the hopper, and the force exerted by the electric motor on the machine members.

2.5 Description of the Machine

The agricultural waste shredder and mixer is a specialized machine designed to process agricultural waste by shredding and mixing it. The main components of the machine are the cutting blade, mixing blade, machine frame, hopper, and belt drive as illustrated in Figure 1(a and b)



Figure 1a: Waste Shredder-Mixer Machine

2.5.1 Shaft Assembly

Two shafts, each with a diameter of 25mm, were machined down to 20mm in diameter and cut to a length of 215mm. These shafts are essential for attaching and supporting the cutting and mixing blades. Two angle irons, each 307.25mm in length and 2mm in thickness, were used to construct both the shredder and mixer sections.

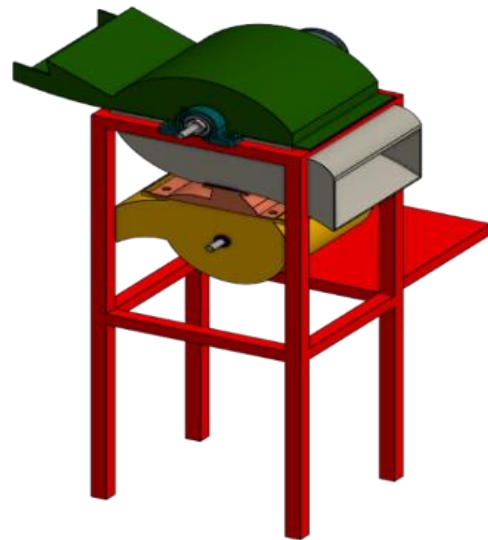


Figure 1b: Waste Shredder-Mixer Machine Assembly

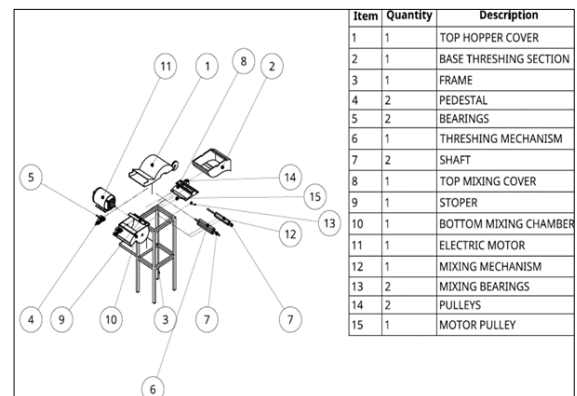


Figure 1c: Working Drawings for Multipurpose Agriculture waste shredder and Mixer

The major parts of the machine are;

- Cutting Blade
- Mixing Blade
- Machine Frame
- Hopper
- Belt Drive

The cutting blades are fixed onto the shaft using bearings that are mounted on the angle irons. Similarly, the mixing shaft passes through the mixing chamber with a blade mounted on it to perform the mixing action. The mixing shaft is concentrically placed within the chamber. There is an outlet on the side of the machine where the mixed feed is expelled. The cutting shaft is spaced 30mm apart, and the driven shaft is centrally positioned on the angle iron to drive both the shredder and mixer. The assembly and working drawings are illustrated in figure 1b and 1c respectively.

2.5.2 Machine Frame

The construction of the machine frame is made of mild steel with a rectangular cross-section, designed to support the entire machine. This includes the cutting and mixing mechanisms, the pulley system, and the prime mover. The frame's function is to provide structural support and stability, ensuring that all components remain securely attached and

properly aligned during operation, which is crucial for the machine's efficiency and longevity.

2.5.3 Hopper, shredding and mixing chambers

The shredder hopper is a crucial component of the machine, featuring a combination of a trapezoidal shape and a shortened rectangular-based pyramid, and is positioned above the chamber that houses the shredder shafts. Below the shredder chamber is the cylindrical mixing hopper. The primary function of these hoppers is to facilitate the feeding and processing of waste materials. The shredder hopper has an opening at the top where waste materials are fed into the machine. These materials slide down into the cutting blade assembly, where they are shredded. The shredded materials then pass through a cylindrical hole that connects the shredder chamber to the mixing chamber. The mixing chamber collects the shredded waste and thoroughly mixes it, ensuring a consistent and homogenous output.

2.5.4 Belt Drive

The machine operates using a Vee belt drive system, which consists of rotating belts that engage when the machine is in operation. This system includes two key pulleys: a drive pulley and a driven pulley. The drive pulley is connected to the power source, transmitting motion and power through the Vee belt to the driven pulley. This setup facilitates the rotation and efficient functioning of the machine's components, ensuring synchronized and smooth operation of the shredding and mixing processes. The belt drive system is essential for the mechanical coordination and energy transfer within the machine.

2.5.5 Machine Assembly

This section details the assembly procedure for the multipurpose agricultural waste threshing machine. The first step in the assembly process involved constructing the frame, which serves as the base structure supporting all other components. Once the frame was completed, the cutter shaft and mixer shaft were installed according to design specifications to ensure proper alignment and

functionality. Each shaft was suspended by two bearings, one at each end, to provide stability and support during operation. Following this, a pulley was attached to both the cutter shaft and the free transmission shaft connected to the engine. This setup was crucial for transmitting power from the engine to the cutter shaft via a belt. The mixer shaft was similarly suspended by two bearings at each end, ensuring smooth and efficient operation.

Next, the top cutting chamber and the input chamber case were placed onto the frame and securely bolted in place to ensure stability and proper alignment with the shafts. The bottom chamber case was then assembled and bolted to the top chamber case, completing the main body of the machine and providing the necessary enclosure for the shredding and mixing processes. The GX 160 gasoline engine was mounted onto the frame, and a V-belt was positioned on the free pulley connected to the cutter shaft, establishing the power transmission link between the engine and the cutter shaft.

Throughout the assembly process, careful attention was given to ensure all components were correctly aligned and securely fastened. Bearings were checked for proper fit and lubrication to minimize friction and wear during operation. The pulley and belt system were adjusted for optimal tension and efficient power transmission from the engine to the shafts. After assembly, the machine underwent a series of tests to ensure all components functioned correctly and efficiently. Necessary adjustments were made to fine-tune alignment, tension, and overall performance, ensuring the machine's optimal operation.

2.6 Cost of machine production

A total cost of Fifty-Nine Thousand Seven Hundred Naira (₦101,500.00) was spent in the Construction of the Shredder as indicated in table 1. The breakdown is as follows. Cost is a critical factor for consumers when selecting materials from various options that can serve the same purpose. This project analyzed the costs associated with the materials used in constructing the agricultural waste shredder and mixer.

Table 1. Cost analysis of a multipurpose agriculture waste shredder and mixer.

S/N	Component	Material description	Quantity	Unit price (₦)	Total price (₦)
1	Petrol engine		1	15,000	15,000
2	Cutter shaft	Carbon steel	1	5,000	5,000
3	Mixer shaft	Carbon steel	1	1,000	1,000
3	Plane sheet	Mild steel	1	18,000	18,000
4	pulley	Cast iron	2	1,500	3,000
5	belt	Fabric	1	1,500	1,500
6	Flat bar	Mild steel	1	2,500	2,500
7	Angle iron	Mild steel	2	5,200	10,400
8	Goseth plate	Mild steel	6	400	2,400
9	Iron rod	Mild steel	1	3,000	3,000
10	Bolt and nut	stainless steel	8		2,000
11	Bearing	stainless steel	4	2,500	10,000
12	paint	Organic coating		1,500	1,500
13	labour				20,000
14	miscellaneous				6,200
Total					101,500

2.7 Machine Performance Evaluation

The Multifunctional Agricultural Waste Shredder-Mixer Machine was tested to evaluate its performance based on throughput capacity (kg/h). After constructing and assembling the machine, a two-way factorial design of experiments was used to test throughput capacity, focusing on operation speed and time. The analysis was conducted using MINITAB software version 19. The experiment was performed on dry Guinea corn stalks and Napia Grass, with operational speeds set at 150 rpm, 300 rpm, 450 rpm, and 600 rpm. The time intervals tested were 15 minutes, 20 minutes, 25 minutes, and 30 minutes.

2.8 Throughput capacity

The throughput capacity of the shredding machine was tested at the three different speeds of operation namely; 325rpm, 650rpm, and 975rpm respectively. The throughput capacity was calculated using the following equation 18

$$TP_c = \frac{W_T}{T} \quad (18)$$

Where W_T = total weight of the shredded waste (kg) and T = time of operation(s).

3. Result and Discussion

3.1 Operating speed and time of operation

The Analysis of Variance (ANOVA) Table 2 shows the throughput capacity of the agricultural waste shredding and mixing machine. The table reveals a significant effects of operation time, speed, and their interaction on performance. The operation time shows a significant influence with a P-value of 0.0001 and an F-value of 9.6154 (degrees of freedom (DF) = 3, adjusted mean square (Adj MS) = 125.00). Similarly, the speed of operation has a significant impact, indicated by a P-value of 0.0001 and an F-value of 18.862 (DF = 3, Adj MS = 245.00). The interaction between time and speed is also significant, with a P-value of 0.0001 and an F-value of 0.6410 (DF = 9, Adj MS = 8.333).

Table 2 Analysis of Variance table for throughput capacity of shredding and mixing machine

Source	df	Adj SS	Adj MS	F-Value	P-Value
Time (min)	3	375	125.00	9.6154	0.0001
Speed (rpm)	3	735	245.00	18.862	0.0001
Time (min)*Speed (rpm)	9	75	8.333	0.641	0.0001
Error	32	4.16	0.13		
Total	47	1189.16			

The significant effects may include the inherent characteristics of the shredding and mixing process. Longer operation times allow the machine to process more material, increasing throughput capacity. Higher speeds enhance the efficiency of the cutting and mixing mechanisms, leading to greater throughput. The significant interaction effect suggests that the benefits of increased time and speed are not simply additive; instead, they amplify each other. For example, at higher speeds, longer operation times may allow the machine to reach its optimal processing rate, thereby significantly boosting throughput. The error term,

with DF = 32 and Adj MS = 0.13, represents the unexplained variability in the data. Overall, the total sum of squares for the model is 1189.16, underscoring the substantial contributions of time, speed, and their interaction to the machine's throughput capacity.

3.2 Operating time on throughput capacity

The effect of operating time on throughput capacity of shredding and mixing machine using Tukey method with 95% confidence is shown in Figure 1.

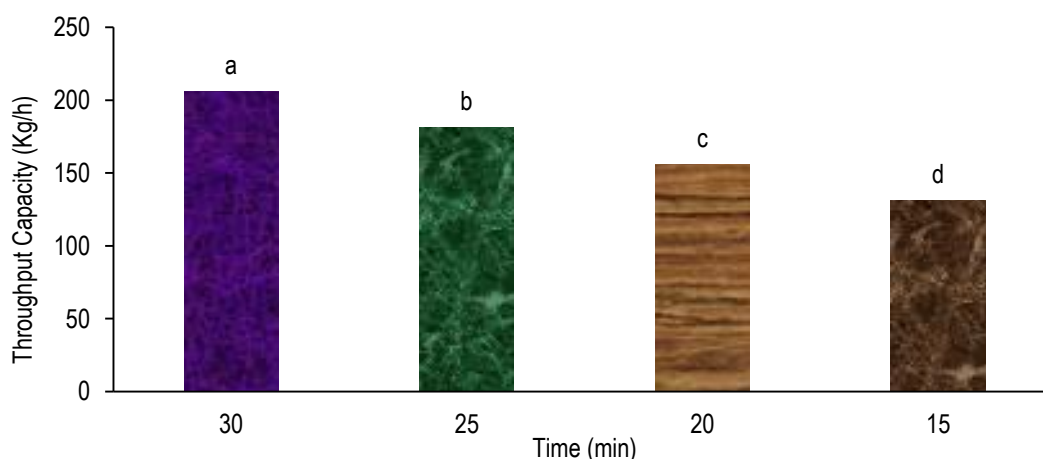


Figure 1: Effect of machine throughput capacity on operating time.

Figure 1 highlights the significant differences in throughput capacities of the shredding and mixing machine across different operation times. The graph presents the mean throughput capacities for four operation times: 30

minutes (T4), 25 minutes (T3), 20 minutes (T2), and 15 minutes (T1). The mean throughput capacity at 30 minutes (T4) is the highest at 20.6 kg/h, denoted by the letter "a," indicating it is significantly greater than the throughput

capacities at all other tested times. The throughput capacity at 25 minutes (T3) is 18.1 kg/h, marked by the letter "b," showing it is significantly lower than T4 but higher than T2 and T1. The 20-minute operation time (T2) has a mean throughput capacity of 15.6 kg/h, grouped under the letter "c," signifying it is significantly different from T4, T3, and T1. Finally, the 15-minute operation time (T1) has the lowest throughput capacity at 13.1 kg/h, labeled with the letter "d," indicating it is significantly lower than all other times. The grouping letters (a, b, c, d) denote that the mean throughput capacities at different operation times are statistically distinct from one another, with no overlap in their confidence intervals. This means that increasing the operation time results in a significant increase in throughput capacity, and

each time increment (from 15 to 30 minutes) leads to a statistically notable improvement in performance. The significant differences suggest that the shredding and mixing process benefits greatly from longer operation times, which allows more material to be processed, thereby increasing the throughput capacity.

3.3 Operating speed on throughput capacity

Figure 2 illustrates the post hoc Tukey method table with 95% confidence reveals significant differences in the throughput capacities of the shredding and mixing machine at various operational speeds.

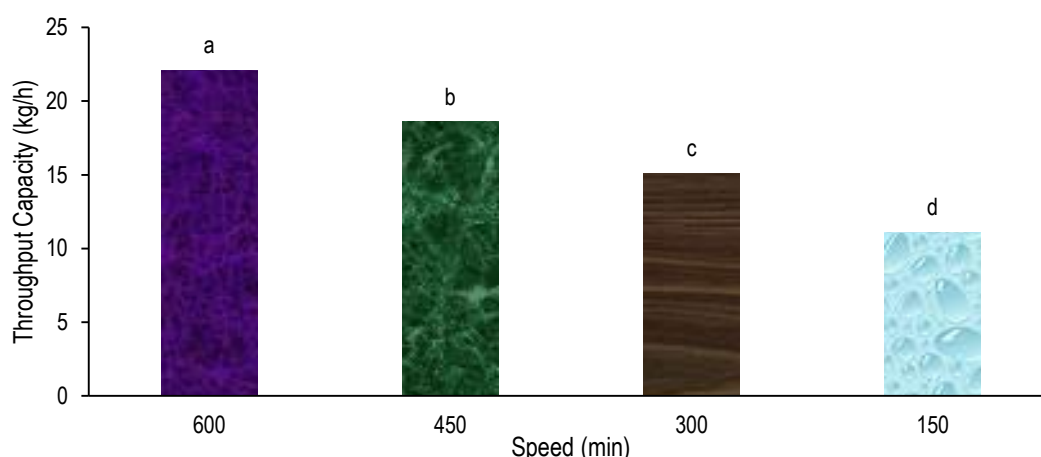


Figure 2: effect of Machine throughput capacities on operating speed

Figure 2 shows that the highest throughput capacity of 22.1 kg/h is achieved at 600 rpm (S4), significantly surpassing the capacities at lower speeds. At 450 rpm (S3), the throughput is 18.6 kg/h, which is notably lower than S4 but higher than the capacities at 300 rpm (S2) and 150 rpm (S1). The throughput at 300 rpm is 15.1 kg/h, lower than both S4 and S3 but higher than S1. The lowest throughput capacity of 11.1 kg/h is recorded at 150 rpm. Each speed setting is assigned a unique group (a, b, c, d), indicating statistically significant differences between them. These results underscore that increasing the operation speed

significantly enhances the machine's throughput capacity, highlighting the importance of optimizing speed for maximizing efficiency in processing agricultural waste.

3.4 Operating Speed and Time of Operation

The post hoc Tukey method table with 95% confidence reveals significant variations in the throughput capacities of the shredding and mixing machine across different combinations of operation time and speed is shown in Figure 3.

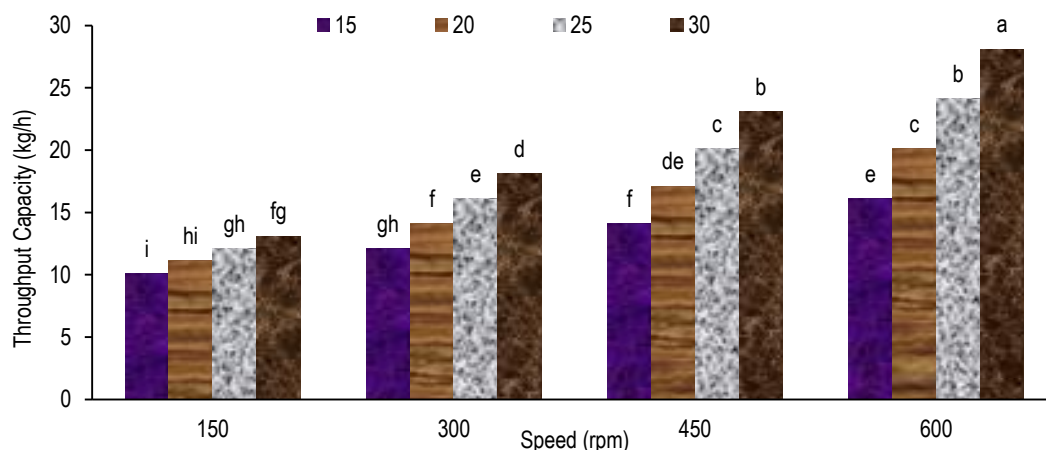


Figure 3: Effect of machine throughput capacity on machine operating time and speed

Figure 3 reveal that the highest throughput capacities are consistently achieved at 600 rpm, peaking at 28.1 kg/h at 30 minutes, while the lowest are at 150 rpm, with a maximum of 13.1 kg/h at 30 minutes. Throughput increases with both higher speeds and longer operation times, as indicated by the distinct grouping letters. These variations suggest that longer operation times allow more material to be processed, and higher speeds enhance the efficiency of the shredding and mixing mechanisms. The combination of these factors results in significantly higher throughput capacities, with the most efficient performance observed at the highest speed and longest time.

4. Conclusion

A multifunctional agricultural waste shredder-mixing machine was developed and evaluated using locally available materials, showcasing satisfactory performance and throughput capacity during test runs. The machine's throughput capacity was significantly influenced by the operation time and speed, increasing with longer operation times and higher speeds. Specifically, a maximum throughput capacity of 20.6 kg/h was achieved at an operating time of 30 minutes, while a speed of 600 rpm resulted in a throughput capacity of 22.1 kg/h. When both speed and time were optimized to 600 rpm and 30 minutes, the machine reached its peak throughput capacity of 28.1 kg/h. These results highlight the importance of optimizing operational parameters to enhance the machine's efficiency, demonstrating its potential for effective agricultural waste management and contributing to sustainable agricultural practices.

References

- [1]. Adejumo, I. O. and Adebisi, O. A., (2020). Agricultural solid wastes: Causes, effects, and effective management. *Strategies of Sustainable Solid Waste Management*, 8(10), 5772-5781.
- [2]. Obi, F., Ugwuishi, B. and Nwakaire, J., (2016). Agricultural waste concept, generation, utilization and management. *Nigerian Journal of Technology*, 35(4), 957-964.
- [3]. Lawal, A., (2019). Development and performance evaluation of a poultry feed mixer. *Journal of Agricultural Engineering and Technology (Jaet)*, 3(1), 38-43.
- [4]. Adil, B. M., Abhishek, Y., Kumar, M. and Acharya, A., (2020). Design and fabrication of agricultural waste shredder machine. *Advancement in Mechanical Engineering and Technology*, 3(1), 1-8.
- [5]. Abdulkadir, S., Dodo, S., Jahun, B., Malgwi, G. and Vanke, I., (2020). Design and construction of an agricultural waste-shredding machine. *Arid Zone Journal of Engineering, Technology and Environment*, 16(3), 519-530.
- [6]. Kumar, I. S. and Kumar, T. H., (2015). Design and development of agricultural waste shredder machine. *International Journal of Innovative Science, Engineering and Technology*, 2(10), 164-172.
- [7]. Adusei-Bonsu, M., Amanor, I. N., Obeng, G. Y. and Mensah, E., (2021). Performance evaluation of mechanical feed mixers using machine parameters, operational parameters and feed characteristics in Ashanti and Brong-Ahafo regions, Ghana. *Alexandria Engineering Journal*, 60(5), 4905-4918.
- [8]. Lindley, J., (1991). Mixing processes for agricultural and food materials: Fundamentals of mixing. *Journal of Agricultural Engineering Research*, 48, 153-170.
- [9]. Raut, P. D. and Bhalgat, S. M., (2020). Cutter blade design for shredder machine. *International Journal of Scientific and Research Publications*, 10(6), 1022-1027.
- [10]. Khurmi, R., and Gupta, J. (2005). *A Textbook of Machine Design*. S. Chand Publishing, Ram Nagar, New Delhi.
- [11]. Ghosh, N. (2014). An assessment of the extent of food processing in various food sub-sectors. Report submitted to the Ministry of Agriculture and Farmers Welfare, GOI. New Delhi, India.