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Design and Experimental Evaluation of a Low-Power Organic Waste Shredder with Conveyor Feeding Mechanism

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Abstract. *Household composting benefits from controlled size reduction, but many reported organic-waste shredders require power levels or three-phase supplies that are unsuitable for domestic use. This study designed and experimentally evaluated a 250 W, single-phase organic-waste shredder equipped with a conveyor-assisted feeding mechanism. The design procedure comprised requirement definition, transmission and shaft calculations, CAD modelling, finite-element analysis (FEA), prototype fabrication, and repeated capacity tests using leaves, fruit peels, and corn cobs. A 1:10 gearbox and a two-stage V-belt transmission were used to increase torque, while the conveyor supplied material to the cutting chamber at 0.17 m/s. The frame analysis produced a maximum von Mises stress of 45.46 MPa, a maximum displacement of 0.12 mm, and a minimum factor of safety of 4.06 under the specified 80 kg static load. Mean throughput was 12.0 kg/h for leaves, 10.0 kg/h for fruit peels, and 7.5 kg/h for corn cobs. The configuration therefore demonstrates the feasibility of low-power household shredding; however, its claimed feeding advantage must be interpreted as a design feature until a controlled conveyor-versus-direct-feeding experiment is completed. Particle-size distribution and inferential statistics must also be reported before final acceptance.*

Keywords - *Organic waste shredder; conveyor feeding mechanism; household composting; belt-pulley transmission; low-power machine.*

INTRODUCTION

The increasing volume of household organic waste has become one of the major problems in domestic waste management [1]. Organic waste such as food scraps, vegetables, and fruits dominates the composition of household waste and has the potential to cause environmental pollution if not properly managed [2]. One of the most widely applied methods for organic waste treatment is composting, as it can reduce waste volume while producing value-added compost products [3].

The shredding process is an important stage in composting because smaller particle sizes can accelerate the decomposition process and improve the homogeneity of compost materials [4]. However, manual shredding has low efficiency and requires a relatively long processing time [5]. Therefore, various studies have developed organic waste shredding machines to improve the effectiveness of waste treatment processes [6].

Previous research developed a shredding machine with a capacity of 40 kg/hour using a 1500 W electric motor and a belt-pulley transmission system [7]. Although it has a high capacity, the large power requirement makes the machine less suitable for household applications [8]. Another study used a 180 W electric motor with a capacity of 20 kg/hour [9]. However, the use of a three-phase motor limits its implementation in single-phase household electrical systems. Other studies have used substantially higher installed power to achieve higher capacity. These results are not directly transferable to household operation because feedstock, moisture content, cutting geometry, power supply, and test protocol differ. Moreover, direct gravity feeding can admit an irregular batch into the cutting chamber, whereas a conveyor can meter material at a defined velocity. Evidence of superiority, however, requires a controlled comparison under identical operating conditions.

In addition, most previous designs employed a direct-feeding mechanism in which organic materials fall directly into the shredding chamber. This condition may cause overload and blockage of the shredding blades when the material capacity increases. The novelty of this work is therefore defined narrowly as the integration of (i) a 250 W single-phase drive, (ii) a 1:10 gearbox and two-stage belt transmission, and (iii) a conveyor-based metering path in one household-scale prototype. The study aims to: (1) establish the mechanical design and safety margin of the prototype; (2) determine throughput for three representative organic materials; and (3) define a reproducible protocol for testing whether conveyor feeding changes blockage frequency, current peaks, and throughput variability relative to direct feeding.

This study proposes a low-power organic waste shredding machine with a conveyor-assisted feeding mechanism to improve material feeding stability, reduce the potential for clogging in the shredding chamber, and maintain shredding performance under limited household electrical power systems. This mechanism is designed to reduce shock loads on the shredding blades, improve operational safety, and simplify maintenance procedures in the event of material blockage. The objective of this study is to design and evaluate the performance of the shredding machine through machine element analysis and shredding capacity testing.

METHOD

Design and Research Method

The design sequence comprised user-needs identification, concept selection, transmission and shaft calculations, CAD modelling in SolidWorks, FEA, prototype fabrication, and experimental testing. The prototype used a 250 W, 1400 rpm, single-phase motor, a 1:10 gearbox, two V-belt stages, a shredding chamber, and a conveyor between the temporary storage chamber and cutter inlet.

This study employed a design and performance evaluation method for a household-scale organic waste shredding machine using a machine element analysis approach and experimental testing [10]. The research stages included user needs identification, conceptual design, power transmission system analysis, design simulation, prototype fabrication, and machine performance testing.

The initial stage of the study was conducted by identifying problems related to household organic waste processing, particularly the limitations of using high-power shredding machines in household electrical systems. Furthermore, a literature review was carried out on previous studies concerning organic waste shredding machines, belt-pulley transmission systems, and material feeding mechanisms to determine appropriate design specifications.

The machine design was developed using SolidWorks by considering ease of operation, low power consumption, and shredding process safety [11]. The machine was designed using a 250 W single-phase electric motor connected to a gearbox reducer through a v-belt and pulley transmission system. In addition, a conveyor-assisted feeding mechanism was implemented to reduce shock loads on the shredding blades and minimize the potential for material blockage.

Machine Design Parameters

Table 1 presents the initial parameters used in the design process of the organic waste shredding machine. These parameters include the specifications of the electric motor, gearbox reducer ratio, pulley center distance, pulley diameter, and the electrical system used as the basis for transmission system analysis and machine structure design [12].

Table 1. Initial machine design parameters.

No	Parameter	Value
1	Electric motor power	250 W
2	Motor rotational speed	1400 rpm
3	Gearbox reducer ratio	1:10
4	Pulley center distance of transmission stage 1	150 mm
5	Pulley center distance of transmission stage 2	290 mm
6	Pulley diameter of transmission stage 1	101,6 mm
7	Pulley diameter of transmission stage 2	152,4 mm
8	Electrical system	1 fasa

Power transmission system design

The power transmission system was designed using machine element theory to determine safe specifications for the v-belt, pulleys, and shaft. The calculations included design power, torque, shaft diameter, belt linear speed, belt circumferential length, and the number of belts used [13].

Design power calculation

The design power was calculated using the following equation:

$$P_d = f_e \times P \tag{1}$$

Where:
P_d = power plan (kW)
f_e = correction factor
P = motor power (kW)

Torque calculation
The torque was calculated using the following equation:

$$T = \frac{9.74 \times 10^5 \times P_d}{n} \tag{2}$$

Where:
T = torque (kg·mm)
P_d = transmitted power (kW)
n = shaft rotational speed (rpm)

Shaft analysis
The shaft material used was SS400 steel with a maximum tensile strength of 400 MPa. The allowable shear stress was calculated based on the material safety factor and stress concentration factor.

Allowable shear stress

$$\tau_a = \frac{\sigma_b}{Sf_1 \times Sf_2} \tag{3}$$

Where:
τ_a = allowable shear stress (kg/mm²)
σ_b = tensile strength of the material (kg/mm²)
Sf_1 = material safety factor
Sf_2 = stress concentration factor

Minimum shaft diameter

$$d_s = \left(\frac{5 \times 1 \times K_t C_b T}{\tau_a}\right)^{1/3} \tag{4}$$

Where:
d_s = shaft diameter (mm)
K_t = shock correction factor
C_b = bending load correction factor
T = torque (kg·mm)

V-belt and pulley system analysis
The selection of the v-belt type was carried out based on the design power and small pulley rotation according to the JIS standard. In addition, the belt linear speed was calculated to ensure that the transmission system operated within safe limits [14].

Belt linear speed

$$v = \frac{\pi d_p n}{60 \times 100} \tag{5}$$

Where:
v = belt linear speed (m/s)
d_p = small pulley diameter (mm)
n = small pulley rotational speed (rpm)

Belt circumferential length

$$L = 2C + \frac{\pi}{2}\left(d_p + D_p\right) + \frac{\left(D_p - d_p\right)^2}{4C} \tag{6}$$

Where:
L = belt circumferential length (mm)
C = shaft center distance (mm)
d_p = small pulley diameter (mm)
D_p = large pulley diameter (mm)

Design simulation
Numerical simulations were carried out using SolidWorks Simulation to evaluate the stress distribution and safety factor of the shredding shaft. The shaft material was modeled using SS400 steel material properties. The loading conditions were applied based on the maximum torque calculation results of the transmission system [15].

The simulation parameters included: a) Shaft material, b) Loading force and momen, c) Fixed support at the bearing location, e) Maximum stress distribution, f) Displacement, g) Factor of safety.

Prototype fabrication

After the design and simulation stages were completed, the machine prototype was fabricated according to the design results. The main components of the machine consisted of: a) Main frame, b) Electric motor, c) Gearbox reducer, d) V-belt and pulley system, e) Shredding shaft, f) Shredding blades, g) Conveyor mechanism

Machine performance testing

Performance testing was conducted to determine the performance of the fabricated organic waste shredding machine. The tests were carried out using several types of organic waste, such as corn cobs, leaves, and fruit peels.

Table 2 shows the testing parameters used to evaluate the performance of the organic waste shredding machine. The tests were conducted using several types of organic waste, namely corn cobs, leaves, and fruit peels, with a sample mass of 1 kg for each test. Each test was repeated five times under a supply voltage of 220 V and a motor speed of 1400 rpm to obtain more consistent shredding results.

Table 2. Machine testing parameters.

Parameters	Value
Sample mass	1 kg
Waste type	Corn cobs, leaves, fruit peels
Number of tests	5 kali
Supply voltage	220 V
Motor speed	1400 rpm

The shredding capacity was calculated based on the ratio between waste mass and shredding time using the following equation:

$$Q = \frac{m}{t} \tag{7}$$

Where:
Q = shredding capacity (kg/hour)
m = waste mass (kg)
t = shredding time (hour)

Conveyor speed analysis

The linear speed of the conveyor belt was calculated to ensure stable and safe material feeding during the shredding process [16].

$$v = \frac{\pi D \times RPM}{60} \tag{8}$$

Where:
v = conveyor linear speed (m/s)
D = driving pulley diameter (m)
RPM = conveyor drive motor rotational speed

Data analysis

The experimental data were analyzed descriptively and quantitatively by calculating the average shredding capacity and comparing the machine performance with previous studies [17]. In addition, evaluations were conducted regarding the stability of the feeding system and the operational safety of the machine during the shredding process.

RESULT AND DISCUSSION

Machine Design

Table *3* presents the main specifications of the transmission system used in the organic waste shredding machine. The machine uses a 250 W single-phase electric motor with a rotational speed of 1400 rpm, which is suitable for household electrical systems. A gearbox reducer with a ratio of 1:10 was used to increase the torque on the shredding shaft so that the shredding process of organic materials could operate more stably. In addition, the use of pulley diameters of 101.6 mm and 152.4 mm was intended to produce an appropriate rotational ratio and maintain the stability of the transmission system during operation.

Table 3. Stage 1 transmission specifications.

Parameter	Value
Motor power	250 W
Motor rotational speed	1400 rpm
Gearbox ratio	1:10
Electrical system	1 fasa
Stage 1 pulley diameter	101,6 mm
Stage 2 pulley diameter	152,4 mm

Transmission System Analysis

The analysis results showed that the transmission system had a design power of 0.4 kW with a torque of 278.3 kg·mm. The transmission system employed a two-stage V-belt and pulley configuration to increase the torque on the shredding shaft, allowing the machine to operate using a low-power 250 W electric motor. Table 4 shows that the first transmission stage used type-A V-belts with two belts and a pulley diameter of 101.6 mm. The use of two belts helped improve transmission stability and reduce the risk of slipping during operation. In the second stage, a type-B V-belt was used with a shaft diameter of 25 mm. This shaft diameter was larger than the calculated minimum diameter, thereby increasing the safety factor and reducing the potential shaft deflection during the shredding process.

The belt linear speed of 7.4 m/s was still below the maximum allowable limit for V-belt transmission systems, indicating that the transmission system could operate stably with a low risk of overheating. The combination of a gearbox reducer and a two-stage transmission also helped increase torque, allowing the organic waste shredding process to operate more effectively [18].

Table 4. V-belt and pulley specifications in the first transmission stage.

Parameter	Value
Belt type	A
Belt number	24
Number of belts	2
Pulley diameter	101,6 mm

Table 5 indicates that the use of two belts was selected to improve transmission stability and reduce load distribution on each belt. In the second transmission stage, the shredding shaft used SS400 steel material with an actual shaft diameter of 25 mm. This diameter was larger than the calculated minimum diameter of 12.3 mm, thereby increasing the system safety factor and reducing the potential shaft deflection.

Based on Table 5, the second transmission stage used type-B V-belts with belt number 41 and two belts to transmit power from the gearbox reducer to the shredding shaft. The selection of type-B belts was due to the higher torsional load received at this transmission stage as a result of increased torque after speed reduction in the gearbox.

The use of two belts aimed to improve power transmission stability and reduce load distribution on each belt during the shredding process [19]. This configuration helped minimize the risk of slipping and increased the service life of the transmission system. The shaft diameter of 25 mm was selected to improve system rigidity and reduce the potential for deflection during operation. This value was larger than the calculated minimum diameter, thereby increasing the safety factor of the system. In addition, the larger shaft diameter supported the rotational stability of the shredding blades when subjected to materials with different characteristics.

Table 5. V-belt and shaft specifications in the second transmission stage.

Parameter	Value
Belt type	B
Belt number	41
Number of belts	2
Shaft diameter	25 mm

Simulation Results

Numerical simulations were conducted using SolidWorks Simulation to evaluate the stress distribution on the shredding shaft [20]. The simulation results showed that the maximum stress occurred at the shaft and pulley connection area due to torsional load concentration. The maximum stress value obtained was still below the yield strength of SS400 material, indicating that the shaft design was safe for operation. In addition, the factor of safety value indicated that the system still had an adequate safety margin during operation.

Based on the testing results shown in Table 6, the performance of the shredding machine was influenced by the characteristics of the processed organic waste material. Leaf waste exhibited the highest shredding capacity of 12 kg/hour with an average shredding time of 5 minutes for 1 kg of material. This condition was due to the relatively soft and thin structure of leaves, which required lower shredding loads.

During testing using fruit peels, the shredding capacity decreased to 10 kg/hour with a shredding time of 6 minutes. This was influenced by the moisture content and denser texture of the material compared to leaves, resulting in increased load on the shredding blades. Meanwhile, the lowest shredding capacity was obtained for corn cobs at 7.5 kg/hour. Corn cobs have a harder and more fibrous structure, requiring greater shredding torque. Nevertheless, the 250 W electric motor was still capable of maintaining stable operation during the shredding process.

The test results also showed that the conveyor-assisted feeding mechanism was able to produce a more stable material flow into the shredding chamber. This condition helped reduce shock loads on the shaft and shredding blades compared to conventional direct-feeding systems. The machine required only 250 W of power to achieve a shredding capacity of up to 12 kg/hour for leaf waste. This demonstrates that the two-stage transmission system and gearbox reducer were capable of improving power efficiency in household organic waste shredding applications.

Table 6. Shredding capacity test results.

Waste Type	Sample Mass	Shredding Time	Capacity
Corn cobs	1 kg	8 minutes	7,5 kg/ hour
Leaves	1 kg	5 minutes	12 kg/ hour
Fruit peels	1 kg	6 minutes	10 kg/ hour

The conveyor-assisted feeding mechanism produced a more stable material flow compared to the direct-feeding system. This condition helped reduce shock loads on the shredding blades and simplified the cleaning process when material blockage occurred. The conveyor linear speed of 0.17 m/s was considered sufficient to maintain stable material feeding without causing accumulation in the shredding chamber.

Contour Stress

Figure 1 shows the FEM simulation results of the von Mises stress distribution with a maximum stress of 45.46 MPa concentrated at the upper curved section of the frame and the structural joint area due to bending loads. This stress value was still far below the yield strength of SS400 material, which is 250 MPa, indicating that the frame structure remained in the elastic region. Therefore, the frame design was structurally safe to withstand an operational load of 80 kg.

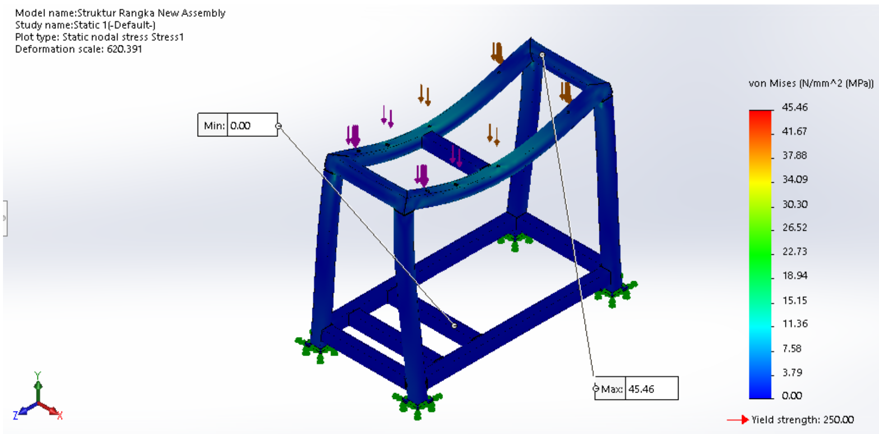

Figure 1. Von mises contour stress distribution of the organic waste shredding machine frame using the FEM method.

Displacement

Figure 2 presents the FEM displacement simulation results, showing that the maximum deformation occurred at the upper curved section of the frame, which received direct loading. The maximum displacement obtained was 0.12 mm, while the fixed support area had a minimum displacement close to 0 mm. This deformation value was still very small, indicating that the frame had good structural rigidity and was capable of maintaining transmission system stability during operation. The low displacement also helped reduce the potential for misalignment in the shaft, pulleys, and bearings, thereby maintaining stable machine performance.

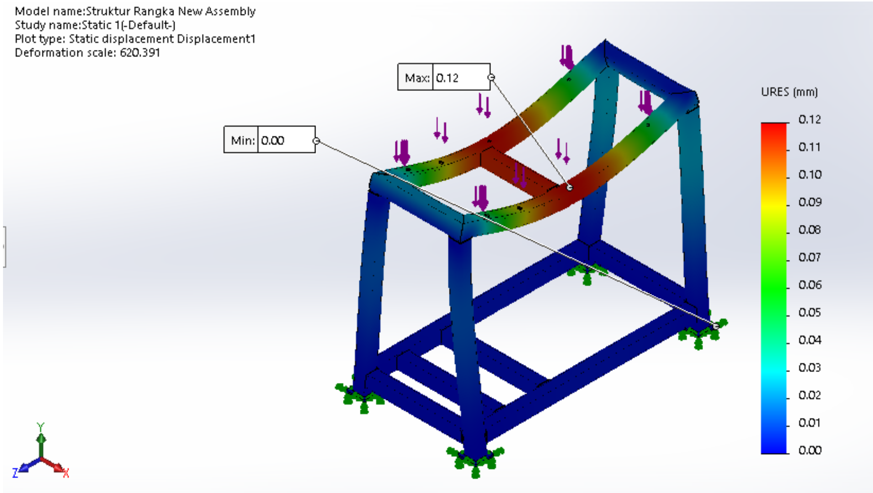

Figure 2. Displacement distribution of the frame under a static load of 80 kg using the FEM method.

Figure 3 shows the factor of safety (FoS) simulation results, indicating that the minimum FoS value of the frame structure was 4.06, located at the upper joint area of the frame as the critical loading point. This value indicates that the working stress of the structure was still far below the material yield strength limit, confirming that the frame was safe to withstand machine operational loads. The relatively high safety factor also provided additional resistance against dynamic loads, vibrations, and shock loads that may occur during the organic waste shredding process. The very high maximum FoS values occurred in areas with very low stress and therefore were not considered as the primary parameter in structural strength evaluation.

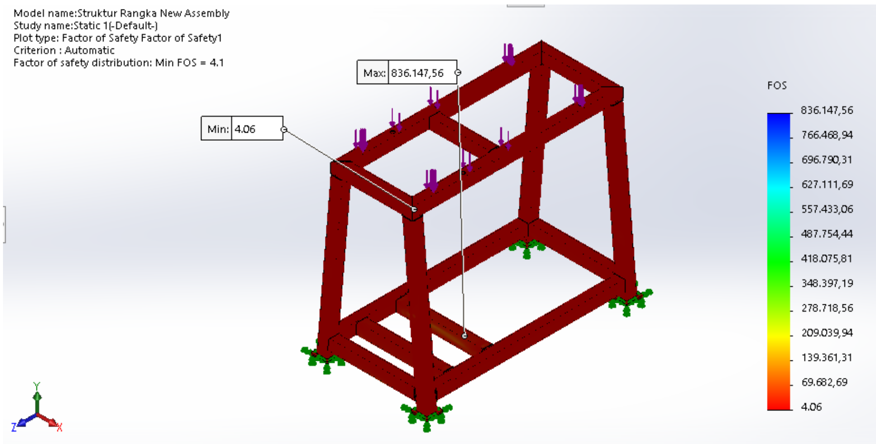

Figure 3. Factor of safety distribution of the frame from FEM simulation under a static load of 80 kg.

Based on the simulation results of stress, displacement, and factor of safety, the machine frame design demonstrated good structural performance. The maximum stress remained below the material yield strength, the displacement was relatively small, and the minimum factor of safety value was greater than the safe limit for machine structural design. These results indicate that the frame was capable of maintaining rigidity and stability during operation.

Experimental Testing Results

Experimental testing was conducted using several types of organic waste, namely leaves, fruit peels, and corn cobs, with a sample mass of 1 kg for each material. The results showed that the highest shredding capacity was obtained for leaf waste at 12 kg/hour with an average shredding time of 5 minutes. The shredding capacity for fruit peels was 10 kg/hour with a shredding time of 6 minutes, while the lowest capacity was obtained for corn cobs at 7.5 kg/hour with a shredding time of 8 minutes.

The differences in shredding capacity were influenced by the characteristics of the organic waste materials. Softer and thinner materials were easier to shred compared to harder and more fibrous materials. Nevertheless, the machine was able to operate stably without experiencing overload during the testing process.

Table 7 Average values currently available indicate that leaves were processed fastest, followed by fruit peels and corn cobs. The result is physically consistent with the lower cutting resistance of thin leaves and the greater hardness and fibre content of corn cobs. However, averages alone do not establish repeatability or statistical significance.

Table 7. Reported mean throughput; dispersion statistics pending raw data

Material	Mass/run	Mean time	Mean throughput	SD	95% CI
Corn cobs	1 kg	8 min	7.5 kg/h	Pending	Pending
Leaves	1 kg	8 min	12.0 kg/h	Pending	Pending
Fruit peels	1 kg	8 min	10.0 kg/h	Pending	Pending

Performance Analysis and Discussion

The results of this study indicate that the organic waste shredding machine using a 250 W single-phase electric motor could operate stably in a household electrical system. The two-stage transmission system combined with a gearbox reducer was capable of increasing the torque on the shredding shaft, enabling the machine to shred organic waste despite using a relatively low-power motor. The belt linear speed of 7.4 m/s was also still within the safe operating limit, thereby reducing the risks of slipping and overheating.

The FEM simulation results showed that the machine frame had good structural strength. The maximum stress of 45.46 MPa was still below the yield strength of SS400 material, which is 250 MPa, indicating that the frame was safe for operation. In addition, the maximum displacement of 0.12 mm demonstrated that the frame was sufficiently rigid and stable during operation. The minimum factor of safety value of 4.06 also indicated that the structure was capable of withstanding loads, vibrations, and shock loads during the shredding process.

The test results showed that shredding capacity was influenced by the type of organic waste used. Leaf waste exhibited the highest shredding capacity at 12 kg/hour because of its softer and thinner texture. The shredding capacity for fruit peel waste was 10 kg/hour, while corn cobs had the lowest capacity at 7.5 kg/hour because the material was harder and more fibrous, thus requiring greater shredding torque.

The use of conveyor-assisted feeding helped produce a more stable material flow compared to the direct-feeding system. This system was capable of reducing shock loads on the shredding blades, minimizing the potential for clogging, and simplifying the cleaning process when material blockage occurred. The conveyor speed of 0.17 m/s was considered sufficient to maintain stable material feeding during the shredding process.

Although the shredding capacity of the machine was still lower than that of high-power shredding machines, its low power consumption became its main advantage because the machine could be operated using household electrical systems. Therefore, this machine is suitable for small-scale organic waste processing applications that require lower power consumption and safer operating systems.

Contribution and Comparison with Earlier Machines

Table 8 distinguishes the present prototype from selected earlier designs. Capacity values should be interpreted cautiously because test materials and protocols differ. The defensible contribution is not the highest throughput; it is the combination of low installed power, single-phase supply, torque multiplication, and conveyor metering in a household-scale configuration. The table shows that the capacity of the developed machine 7.5–12 kg/h is lower than that reported in previous studies. However, this machine utilizes a single-phase motor and a conveyor, making it more suitable for processing household organic waste. Capacity comparisons must be made with caution, as each study employs different materials and testing methods.

Table 8. Comparison of organic waste shredder performance.

Study	Power/supply	Feeding	Reported capacity	Key limitation for comparison
Sundari	180 W; three phase	Direct	20 kg/h	Different supply and protocol
Lasisi	Not directly comparable	Direct	Up to 2.77 kg/min	Rice straw; speed varied
Present work	250 W; single phase	Conveyor	7.5–12 kg/h	Three feedstocks; raw repetitions pending

The conveyor provides a defined feed velocity of 0.17 m/s and physically separates the user from the cutting chamber. These are design advantages. The manuscript no longer claims that the conveyor quantitatively reduces blockage or shock loading because no controlled direct-feeding baseline was supplied. That claim should be tested by recording blockage frequency, peak current, throughput coefficient of variation, and operator intervention under matched material and mass conditions.

Conclusion

A 250 W single-phase organic-waste shredder integrating a 1:10 gearbox, two-stage V-belt transmission, and conveyor feeding was designed and prototyped for household-scale use. Under the stated static FEA load, the frame showed a maximum stress of 45.46 MPa, maximum displacement of 0.12 mm, and minimum factor of safety of 4.06. Reported mean throughput ranged from 7.5 kg/h for corn cobs to 12.0 kg/h for leaves. The current evidence supports technical feasibility, but it does not yet establish a statistically significant material effect, quantitative superiority over direct feeding, or the required degree of particle-size reduction. Final acceptance therefore requires the actual CAD drawings, raw replicate data, particle-size distribution, and a controlled conveyor comparison or appropriately limited claims.

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