



Development of an Agro-Waste Diesel Engine Powered Shredding Machine

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Abstract

A key goal of agro-waste management is to convert agro-waste into useful products such as compost and other agro-allied applications. This study aimed to develop an agro-waste diesel engine powered shredding machine to thresh agro-wastes. A safe design approach was adopted by carefully calculating the dimensions of each part and applying appropriate engineering formulations. Material selection was based on key factors such as availability, durability, cost-effectiveness, and ease of fabrication. Factors considered to enhance the machine's functionality and efficiency were cost consideration, load capacity, material selection, power source reliability, and maintenance strategy. The developed machine threshes the wastes into usable sizes using sharp rotating and stationary blades, which apply mechanical impact, shearing, and cutting action to break down the agro-wastes into smaller particles. The diesel-powered shredding machine with a 5-hp, 850 rpm engine achieved a throughput capacity of 92,400 m³, operating with a maximum shear force of 254,418 N and a shredding efficiency of 93.73%. The shredded agro-waste showed a particle size reduction ranging from 50% to 99.09% within the 0.01–12 mm average size group, with palm bark producing two distinct output sizes after shredding. An average fuel consumption of 1 litre/hour was recorded and there was no overheating observed during the process. The machine is suitable for small-scale farmers by offering an affordable and accessible solution. Additionally, the use of locally sourced materials highlighted its cost-effectiveness and adaptability for rural applications.

Keywords: *Agro-waste, diesel powered, shredding, size reduction, small scale, energy consumption, throughput capacity.*

1.0 Introduction

Agriculture remains a cornerstone of livelihoods and economic development in agrarian economies such as India and Nigeria. However, the management of agricultural waste, which includes crop residues, leaves, stems, and other organic matter, poses a persistent challenge for farmers [1]. The improper handling of agricultural waste has far-reaching consequences. For instance, the burning of crop residues releases harmful pollutants such as carbon monoxide, particulate matter, and volatile organic compounds, which adversely affect air quality and human health. The management of agricultural waste is a critical issue that demands innovative and practical solutions. In many cases, the lack of efficient waste management systems leads to the improper disposal of these materials, often through open burning. This practice contributes to environmental degradation, including air pollution and greenhouse gas emissions, and results in the loss of valuable organic matter that could otherwise be repurposed into beneficial products [2].

Agricultural waste is an inevitable by-product of farming activities, representing both a challenge and an opportunity for sustainable resource management [3]. The burning of agricultural residues in India contributes significantly to the country's air pollution crisis, exacerbating respiratory illnesses and reducing visibility [4]. Similarly, in Nigeria, the widespread practice of burning farm waste has been linked to environmental and health challenges, particularly in rural areas where alternative disposal methods are limited. These practices highlight the urgent need for sustainable solutions to manage agricultural waste effectively.

The design and fabrication of a diesel-powered shredder machine represent a significant step toward addressing this challenge, offering a sustainable and accessible tool for farmers in resource-constrained settings. By converting agricultural waste into valuable products, the shredder machine contributes to resource conservation, environmental protection, and economic development [1, 5, 6]. Furthermore, the adoption of such technology can empower small-scale farmers, enabling them to improve their livelihoods while contributing to broader sustainability goals. The recovery of resources from waste is a critical step toward achieving sustainable development and reducing the environmental footprint of agricultural activities [7].

However, agricultural waste is not merely a problem to be disposed of; it is a potential resource that can be harnessed for various applications [8]. When managed properly, agricultural waste can be transformed into valuable products such as compost, mulch, biochar, and biofuels [1]. Composting, for example, is a well-established method of converting organic waste into nutrient-rich fertilizer, which can enhance soil fertility and reduce the need for chemical fertilizers [9]. Mulching, on the other hand, helps conserve soil moisture, suppress weeds, and improve soil structure. Additionally, agricultural waste can serve as a feedstock for bioenergy

production, offering a renewable alternative to fossil fuels. Using agricultural residues for bioenergy has the potential to reduce reliance on non-renewable energy sources while mitigating environmental pollution [10]. Therefore, the shredder was developed considering the physical properties of agricultural wastes like length, top width, root/stem diameter, moisture content, bulk density, chopped density etc. were determined [11].

The development of agro-waste shredding machines has evolved significantly over time, with various researchers and engineers working to improve efficiency, throughput capacity, and overall machine performance. One such advancement was made by Abdulkadir *et al.* [1], who designed and evaluated a shredding machine specifically for processing bean stalks. Khope *et al.* [13] proposed an innovative approach to mechanized chaff cutting by designing an experimental setup powered by a human-powered flywheel motor. The primary objective of this system was to provide an efficient and sustainable means of chopping forage into small pieces for easy consumption by animals, particularly in regions where conventional power sources may not be readily available. The design concept presented by Khope *et al.* [13] highlights a sustainable and energy-efficient method of operating chaff-cutting machines, particularly in rural and off-grid agricultural settings. Hande and Padole [14] conducted research on the design and fabrication of a portable organic waste chopping machine, aiming to create an efficient system for processing organic waste into smaller, manageable pieces. The machine operates on a uniform feeding mechanism, where organic waste is introduced through a feeding drum and tray. Naik *et al.* [15] focused their project on the fabrication of an area fiber extraction machine, which is specifically designed to separate fiber from areca husk efficiently. By developing this mechanized coconut fiber extraction machine, Prashant *et al.* [16] provide a cost-effective and efficient solution for small-scale coir industries. The automation of fiber extraction reduces labor costs and improves productivity, making it an ideal solution for rural entrepreneurs and small business owners. This machine not only enhances the utilization of agricultural by-products but also contributes to sustainable waste management and eco-friendly product manufacturing. Nithyananth *et al.* [17] developed a waste shredder machine designed as an attachment for tractors, similar to a ploughing attachment. This machine was specifically engineered to assist farmers in shredding agricultural waste efficiently, reducing the bulkiness of organic matter and preparing it for further use, particularly for vermicomposting. The design integrates a power take-off (PTO) mechanism, which enables the shredder to derive its power directly from the tractor's engine. The waste shredder machine developed by Nithyananth *et al.* [17] provides an innovative and practical solution for modern farming. By shredding crop residues and other organic materials into smaller particles, the machine facilitates faster decomposition and enhances the efficiency of composting processes [14]. Moreover, the shredded material can be used as a raw material for other sustainable agricultural practices, such as biofuel production or soil amendment. The importance of optimizing organic waste management systems to produce nutrient-rich fertilizers [18], further emphasizing the value of shredding technologies.

Before the advent of shredding machines, agricultural waste was primarily managed through burning, open dumping, or manual cutting using machetes and other handheld tools. These methods had significant drawbacks, including air pollution, inefficient waste decomposition, and the loss of valuable organic material that could have been reused for composting or mulching [19]. Despite the potential benefits, the adoption of sustainable waste management practices is often hindered by the lack of appropriate technology and infrastructure, particularly in developing countries [20, 21]. Small-scale farmers, who constitute a significant portion of the agricultural workforce in this region like Sub-Saharan Africa and South Asia, often lack access to affordable and efficient machinery for processing agricultural waste. This gap in technology limits their ability to convert waste into useful products, perpetuating the cycle of environmental degradation and resource loss. To address these challenges, the design and development of an agro-waste shredding machine has emerged as a promising solution. Such a machine is designed to reduce the volume of agricultural waste, making it easier to handle, compost, or recycle [22, 23]. The choice of a diesel engine ensures that the machine remains operational in off-grid areas, thereby increasing its accessibility and practicality for rural farmers [24]. Hence, this study aims to develop a diesel engine powered shredding machine, specifically tailored to meet the needs of small-scale farmers in regions where electricity supply is unreliable or unavailable.

2.0 Materials and Methods/Methodology

2.1 Design Considerations

While designing the agro-waste shredding machine, certain assumptions were considered to ensure that its components met standard requirements. A safe design approach was adopted by carefully calculating the dimensions of each part and applying appropriate engineering formulations. Material selection was based on key factors such as availability, durability, cost-effectiveness, and ease of fabrication. The shredding process aims to reduce the size of agricultural waste into smaller particles, making it more manageable for applications like composting, mulching, handicrafts and textiles. The agricultural waste used in this process is collected from various sources, including farms and agro-processing industries. The waste is sorted based on its type and characteristics, ensuring effective shredding performance. Once these preparatory steps are completed, the waste is cut into smaller fragments through a mechanical shredding process.

This agro-waste shredder was designed with small-scale waste managers and farmers in mind. Several factors were carefully considered to enhance the machine's functionality and efficiency:

- i. **Cost Consideration:** Since the machine is intended for small-scale agricultural waste management, affordability was a key factor in its design. The use of locally available materials and simple fabrication techniques ensures that the shredder remains cost-effective for users.
- ii. **Load Capacity:** The shredder was designed to process a wide variety of agricultural waste materials with varying levels of toughness, including crop residues, leaves, husks, and stems. The machine's cutting mechanism ensures efficient shredding regardless of the material's thickness.
- iii. **Material Selection:** The primary material used for fabrication is mild steel due to its affordability, corrosion resistance, and durability. Mild steel is also readily available and easier to work with compared to stainless steel, making it the preferred choice for structural components of the shredder.
- iv. **Power Source Reliability:** The shredder is powered by a diesel engine, ensuring reliable operation in rural areas where electricity may be scarce or unreliable. Diesel engines are widely used in agricultural machinery due to their efficiency and easy availability.
- v. **Maintenance Strategy:** The design allows for easy dismantling and reassembly, making it simple to clean, maintain, and repair when necessary. Basic tools, such as a spanner, can be used to loosen and tighten the nuts securing the machine's components. This ensures that users can perform routine maintenance without requiring specialized skills or equipment.

2.2 Design Theory

Design calculations for the locally made agro-waste shredding machine typically involve several key parameters and considerations.

i). Design of Hopper

The capacity of the diesel engine powered shredding machine hopper was determined using equation 1.

$$V = \frac{1}{3}(A_1 + A_2) + \sqrt{(A_1 \times A_2)} \times h \quad (1)$$

where:

V = Volumetric capacity of the hopper (mm³),

A₁ = Top area of upper base of hopper (mm²), (L + W)

A₂ = Lower base area of hopper (mm²), (L + W)

h = Height of Hopper (mm)

Total surface area (TSA) of hopper = (Area of upper and lower base) + (Area of the four trapezoidal faces)

$$T_{SA} = (A_1 + A_2) + \frac{1}{2}(a + b)h \quad (2)$$

Where; 'a' and 'b' are the opposite parallel sides of the trapezoid

$$\text{Area of trapezoid} = \frac{1}{2}(a + b)h \quad (3)$$

A₁ = Top base area = L x B = 754.88 x 549.89 = 415,100.96mm²

A₂ = Bottom base area = L x B = 330 x 549.89 = 181,463.7mm²

H = height of hopper = 410mm

$$\begin{aligned} (V) &= \frac{1}{3}(415,100.96 + 181,463.7) \sqrt{415,100.96 + 181,463.7} 400 \\ &= 1.874 \times 10^{10} \text{mm}^3 \end{aligned}$$

ii). Torque Transmitted by Shaft: The torque transmitted by the shaft is the twisting force required to rotate the blades to shred the agro-waste material. This was determined using equation 4.

$$T = P \times \frac{2\pi N}{60} \quad (4)$$

where:

T = Torque Transmitted by Shaft in Nm,

P = Motor Power (KW), and

N = Rotational Speed (rpm)

$$T = 3.7285 \times \frac{2\pi \times 850}{60} = 89.012 \text{ N.m}$$

iii). Shear Force: The shear force is the force required to cut through the agro-waste material. It was determined using equation 5.

$$F = \tau \times A \quad (5)$$

$$A = t \times L \quad (6)$$

where:

F = shear force (N),

τ = Shear Strength of the agro-waste material (N/mm²),

A = Cutting Area (mm²),

t = Thickness of the agro-waste (mm),

L = Length of the agro-waste (mm).

Shear Force: From Equation (4)

$$A = t \times L$$

$$F = \tau \times A$$

$$F = \tau \times t \times L$$

Using these agro-wastes

Wood bark

Where: t = 70mm, L = 225mm, τ = 8.30

$$F = 70 \times 225 \times 8.30 = 130,425\text{N}$$

Sugarcane bagasse

Where: t = 35mm, L = 180mm, τ = 3.20

$$F = 35 \times 180 \times 3.20 = 20,160\text{N}$$

Fruit palm bunch

Where: t = 30mm, L = 100mm, τ = 19.50

$$F = 30 \times 100 \times 19.50 = 58,500\text{N}$$

Palm bark

Where: t = 70mm, L = 220mm, τ = 16.53

$$F = 70 \times 220 \times 16.53 = 254,418\text{N}$$

With a 5 hp motor and blade yield strength of 250 MPa, palm bark has the highest shear force so we would use the material for testing and demonstration.

Recall;

Where: t = 70mm, L = 220mm, τ = 16.53

$$F = 70 \times 220 \times 16.53 = 254,418\text{N}$$

$$\text{So, } F_{\text{palm bark}} = 254,418 \text{ N}\cdot\text{mm}$$

iv). Blade Design

Blade thickness: This was determined using equation 7.

$$t = \frac{F}{\sigma} \quad (7)$$

where:

t = Thickness (mm),

F = Shear Force (N),

σ = Yield Strength of blade material (MPa)

Where: $F_{\text{palm bark}} = 254,418\text{N}$, $\sigma = 250\text{MPa}$ (for Mild Steel) $\cong 250 \text{ N/mm}^2$

$$t = \frac{254,418}{250} = 1017.672\text{mm}$$

Blade speed: This determined using equation 8.

$$\text{Blade speed}(\omega) = \frac{2\pi N}{60} \quad (8)$$

where:

ω = Angular Velocity of the Blade (rads/sec),

N = Blade RPM

$$= \frac{2\pi \times 850}{60} = 89.01 \text{ rads/sec}$$

Cutting speed

$$s = \pi \times d \times \frac{N}{60} = w \times r \quad (9)$$

where:

s = Cutting Speed (m/sec),

d = Blade Diameter (mm), and

N = Blade RPM

$$S = \pi \times 200 \times \frac{850}{60} = 8901.18\text{mm/s}$$

The cutting speed (V) of the shredder blade was calculated using the formula:

$$V = \omega \times r$$

Where: V = Cutting speed (mm/s), ω = Angular speed (rad/s), r = Blade radius (mm), the angular speed (ω) of the blade was obtained at 89.01 rad/s.

$$\text{Shear force } F_{\text{palm bark}} = 254,418\text{N}$$

Blade material yield strength $\tau_y = 250 \text{ N/mm}^2$

Cutting speed $V = 8901.18 \text{ mm/sec}$

Blade radius $r = 100 \text{ mm}$ cutting speed $(V) = 89.01 \times 100 = 8901 \text{ mm/s}$

The Rotational Speed (N)

$$N = \frac{V}{2\pi r} = \frac{w \times r}{2\pi r} \quad (10)$$

$$= \frac{8901}{2\pi \times 100} = 14.17 \text{ mm/s}$$

$$Q = \frac{v}{t}$$

Using the hopper

Length = 330mm

Width = 280mm

Height of loaded material = 250mm

Permissible loaded volume of shredded materials = $330 \times 280 \times 250 = 23,100,000 \text{ mm}^3$

Throughput = Permissible loaded volume of shredded materials x Number of discharges per hour

Where: $\text{mm}^3 = 23,100,000 \text{ mm}^3$ $d = 4$

$Q = \text{mm}^3 \times d = 23,100,000 \times 4 = 92,400,000 \text{ mm}^3 \text{ per hour}$

v). Shredding capacity: The shredding capacity of the diesel engine powered shredding machine was determined using equation 9.

$$S_c = \frac{M_s}{t} \quad (11)$$

where:

V_s = Mass of shredded agro-waste (kg),

t = operating time (hr.)

vi). Material Feed Rate: The material feed rate is estimated based on the shredding capacity, particle size distribution, and material density.

$$\text{Material Feed Rate} = \frac{\text{volume of agro-waste to be shredded}}{\text{operating time}}$$

$$f = \frac{m}{t} \quad (12)$$

Where: f = Material Feed Rate (vol/hr.), v_1 = volume of agro-waste to be shredded (vol), t = operating time (hr.)

$m_1 = 23,100,000 \text{ mm}^3$, t = 1hour

$$f = \frac{23,100,000}{1} = 23,100,000 \text{ mm/hr.}$$

vii). Structural Integrity: Performed structural calculations to ensure the integrity and stability of the shredder's frame, rotor assembly, and other structural components.

Shear Stress on blades: It was determined using equation 13.

$$\tau_{blade} = \frac{F}{A} \quad (13)$$

where:

τ_{blade} = Shear Stress on blades (N/mm^2),

F = Shear Force (N), and

A = Area of blade (mm^2)

$$\tau_{blade} = \frac{254418}{18900} = 13.46 \text{ N/mm}^2$$

Bending stress: The bending stress was determined using equation 14:

$$\sigma = \frac{M.y}{I} \quad (14)$$

where:

σ = Bending Stress (MPa),

M = Bending Moment (N.mm),

y = Distance from the neutral axis to the outer fiber (mm), and

I = Second Moment of Inertia (mm^4)

$$M = F_{\text{palm bark}} \times \frac{D}{2} = 254,418 \times \frac{200}{2} = 25,441,800 \text{ Nm}$$

$$y = \frac{200}{2} = 100 \text{ mm}$$

$$I = \frac{\pi \times D^4}{64} = \frac{\pi \times 200^4}{64} = 78.54 \times 10^6 \text{ mm}^4$$

From equation 12

$$\sigma = \frac{M \cdot y}{I}$$

Where: $M = 25441800 \text{ Nm}$, $y = 100 \text{ mm}$, $I = 78.54 \times 10^6 \text{ mm}^4$

$$\sigma_{\text{shaft}} = \frac{25441800 \times 100}{78540000} = 32.39 \text{ MPa}$$

Torsional stress: It was determined using equation 15.

$$\tau_{\text{shaft}} = \frac{T \times r}{J} \quad (15)$$

where:

τ_{shaft} = Torsional Stress (MPa),

T = Torque Transmitted by the Shaft (N-m),

r = Radius of the Shaft (mm),

J = Polar Moment of Inertia (mm^4)

$$J = \frac{\pi}{32} \times D^4 = \frac{\pi}{32} \times 200^4 = 157079632.7 \text{ mm}^4$$

$$r = \frac{D}{2} = \frac{200}{2} = 100 \text{ mm}$$

$$T = 89.012 \text{ N.m} \cong 89012 \text{ N.mm}$$

vii). Energy Consumption: The energy consumption of the shredder is estimated from the motor power rating and the duration of operation using equation 16.

$$E = P_{\text{motor}} \times t \quad (16)$$

Where:

E = Energy Consumed (kWh),

P_{motor} = Motor Power (KW), and

vii). Shredding Efficiency: The shredder efficiency is evaluated by determining how effectively the shredding machine processes the raw material into usable shredded material. This was determined by using equation 17.

$$\text{Shredding Efficiency} = \frac{\text{Useful output energy}}{\text{Input energy}} \times 100 \quad (17)$$

$$\text{Useful output energy} = P_{\text{motor}} \times \text{time}(\text{hr}) \times 3600(\text{s/hr}) \quad (18)$$

$$\text{Input energy} = \text{Fuel consumption}(\text{litre}) \times \text{Energy content of diesel} \quad (19)$$

2.3 Description of the Diesel Engine Powered Agro-Waste Shredding Machine

The developed engine powered shredding machine consists of the following components as shown in Figures 1 to 2:

i. Shaft

A shaft is a rotating machine element, usually circular in cross section and which is used to transmit power from one part to another part or from a machine which is power producer to power machine, which absorbs power. The various members such as cutting blades, gears and pulley are mounted on it. Circular shaft is used with one keyway (square) has a circular cross section for cutting system. Material used for shaft is steel.

ii. Cutting Blades

Cutting system consists of the shafts, cutting blades, washers and gears. The cutting blade is round-shaped blade with three cutting edges, given circle-shaped hole in the middle with keyway, mounted on the main shaft and main shaft move together. We design the cutting system in such a way that angle between keyway of each cutter blade is 40 degrees. And cutting blades are placed in such a manner that after first blade apart 40 degrees from second blade. This concept used in shredder machine. Because of that, power which was required to rotate the shaft was large. Now that power to rotate the shaft is lesser than previous. Material used for cutting blade is mild steel.

iii. Motor

Diesel engine motor is a mechanical device that converts chemical energy into mechanical energy. In certain applications, such as in the transportation industry with traction motors, diesel motors can operate in both motoring and generating or braking modes to also produce chemical energy from mechanical energy.

Selection of Pulleys and Determination of their Speeds

Power is transferred from a driving shaft to a driven shaft using a pulley and belt system. The relationship expression provided by Kurmi and Gupta [25] is utilized to calculate the transmission speed.

The equation below is used to determine the transmitted speed:

$$N_1 D_1 = N_2 D_2 \quad (20)$$

Where:

$$N_1 = \text{Speed of motor shaft} = 850 \text{ rpm}$$

D_1 = Diameter of driver pulley = 180mm
 N_2 = Speed of shredding machine shaft = 480rpm
 D_2 = Diameter of driven
Hence,
 $D_2 = 850 \times 180 / 480 = 320mm$

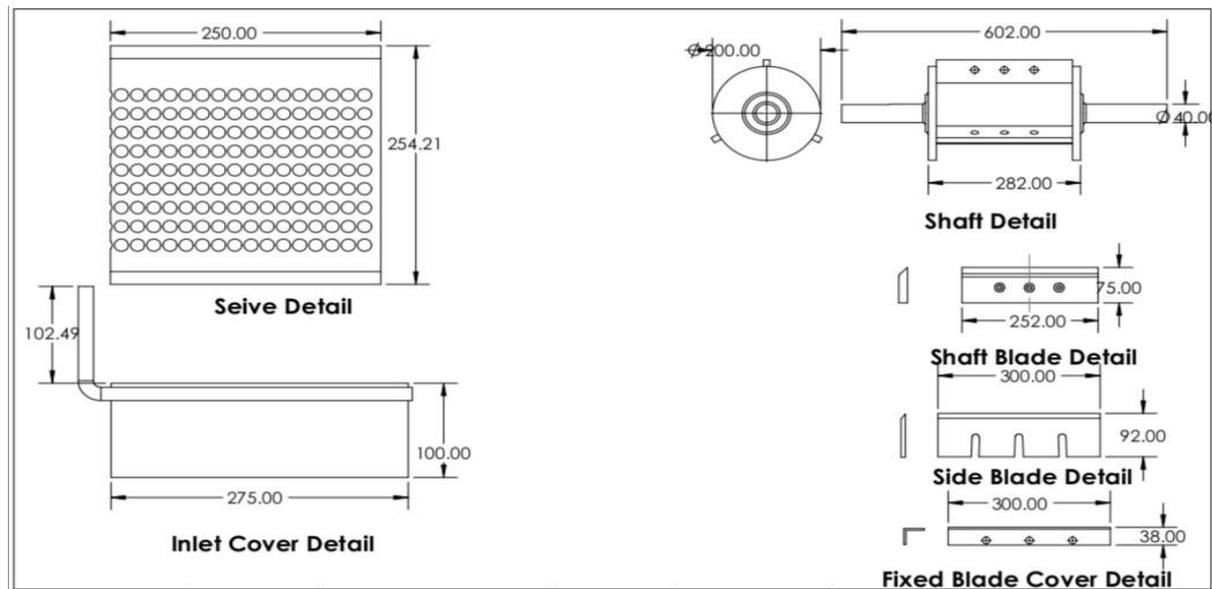


Figure 1: Sieve, shaft, blade, inlet

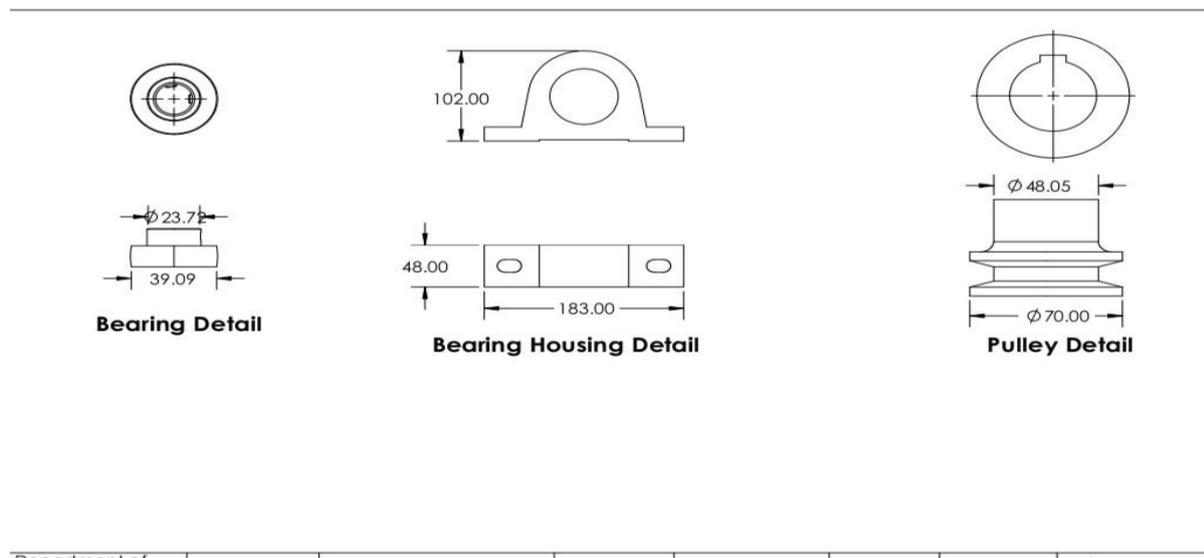


Figure 2: Bearing, housing, and pulley

2.4 Principle of Operation

As the Diesel engine is switched on, the shaft starts rotating and therefore the blades also rotate. This rotation movement of blades shred the agro-waste. Agro waste is fed to the cutter through the hopper. The shredded agro-waste material then falls on the mesh. Smaller pieces pass through the mesh and larger ones are again fed in through the hopper. The size of the shredded agro-waste particles can be adjusted by changing the size of the screen or mesh, which controls the size of the openings through which the shredded agro waste passes.

An agro-waste shredding machine operates based on a systematic process that ensures efficient shredding of agricultural waste. Its effectiveness depends on the power transmission system, structural strength, operational procedures, and energy consumption. In this case, A dual-belt system which distributes the load between two belts, reducing wear and increasing durability was used. Though it required precise alignment, this is due to its ability to handle higher loads efficiently. Similarly, the mainframe and hopper walls must be robust enough to withstand mechanical stress. Optimizing the plate thickness ensures the machine remains durable and resistant to breakdowns. For optimal operation, the machine must be running before waste is loaded. This prevents clogging

and mechanical strain on the system. Attempting to start the engine with a loaded chamber increases diesel consumption and risks damaging the cutting mechanism. Ensuring a smooth start-up process enhances efficiency and prolongs the machine's lifespan.

2.5 Fabrication Process

The fabrication process involves using the selected materials and constructing the product based on the design and the desired dimension. The various methods used during the fabrication of the machine from start to finish include; measuring, marking, cutting, joining, drilling and finishing.

This was done part by part before assembly of each component.

- i. Measurement: Materials were measured according to the desired dimensions of the design.
- ii. Marking: All measured materials were marked in the main sheet or full material to give precise dimensions before cutting.
- iii. Cutting: Marked materials are then cut into pieces.
- iv. Joining: Materials were joined together by the arc welding for permanent joint and temporary joint by bolting.
- v. Drilling: Marked holes are then drilled to make holes for bolts.
- vi. Finishing: Any rough surface or sharp edge was grinded to give smooth and safe surface.

However, most agro-waste shredding machines share some common components, which include:

i. Top Layer (Hopper)

Top layer is made on 2.50 mm thickness plate of mild steel. This is the part of shredder where the waste is stored while the shredding procedure. The shape of top layer is rectangular and covered with an outlet/opening at the top right used to input the agro-waste into the middle layer/shredding chamber with a dimension of 330mm by 300mm.

ii. The Shredder Inlet

The shredder inlet was fabricated using mild steel. It is rectangular in shape with a dimension of 299.54mm by 255mm, and it connected to the top layer of the shredder with a dimension of 330mm by 300mm.

iii. The Shredder outlet

The shredder outlet was fabricated from mild steel with the dimension of 299.54mm by 255mm it was extended to the base of the shredder with dimension of 255mm by 330mm.

iv. Shredder Stand

The Shredder stand was fabricated from mild steel bars. It has a height of 750mm and a square base of 480mm. The stand was constructed with four legs for proper balancing.

v. Rotating shaft:

The shaft has a rod of radius 20mm and length 602mm, which connects the entire shaft to the gear box and the bearing, which holds the blades. The blades are welded to the rod, it has a dimension of 252mm in length by 75mm.

vi. The pulley system

The pulley which connects the shredder to the diesel engine has a radius of 25m.

vii. The Prime Mover:

This is the power source for the machine and provides the necessary torque and speed to rotate the blades. A diesel engine is preferred for this project because it provides a higher torque and speed to rotate the blades. A 5hp diesel engine was purchased from the local market to power the equipment. A belt is being used to connect the engine to the pulley system.

viii. Middle Layer (Shredding Chamber)

The middle layer is where the actual cutting process takes place. This middle layer is made of a thick plate of mild steel with dimension of 300mm by 330mm. All the plates of the chamber are joined by arc welding except a plate is kept bolted for ease of coupling and decoupling. This facilitates easy maintenance and servicing of blades. A mesh is attached below the chamber to regulate the size of shredded pieces.

ii. Mesh (Sieve)

The mesh is placed at the bottom of the shredding chamber with dimension 254mm by 250mm. The function of mesh is to separate the small particles from larger ones. The small particles pass through the mesh and remaining larger ones are again shredded till the desired size is achieved. The mesh is made of steel wire.

ix. Blade (Stationary and Movable Blade)

In this project, the blade is used as a cutter for cutting the agro-waste. Blade is the tool that is used to cut the agro-waste into fine pieces. The blade is made using steel with dimension 252mm by 75mm. There can be blades with two, three or five cutters. Depending on the application and type material to be shredded, suitable blade is to be chosen.

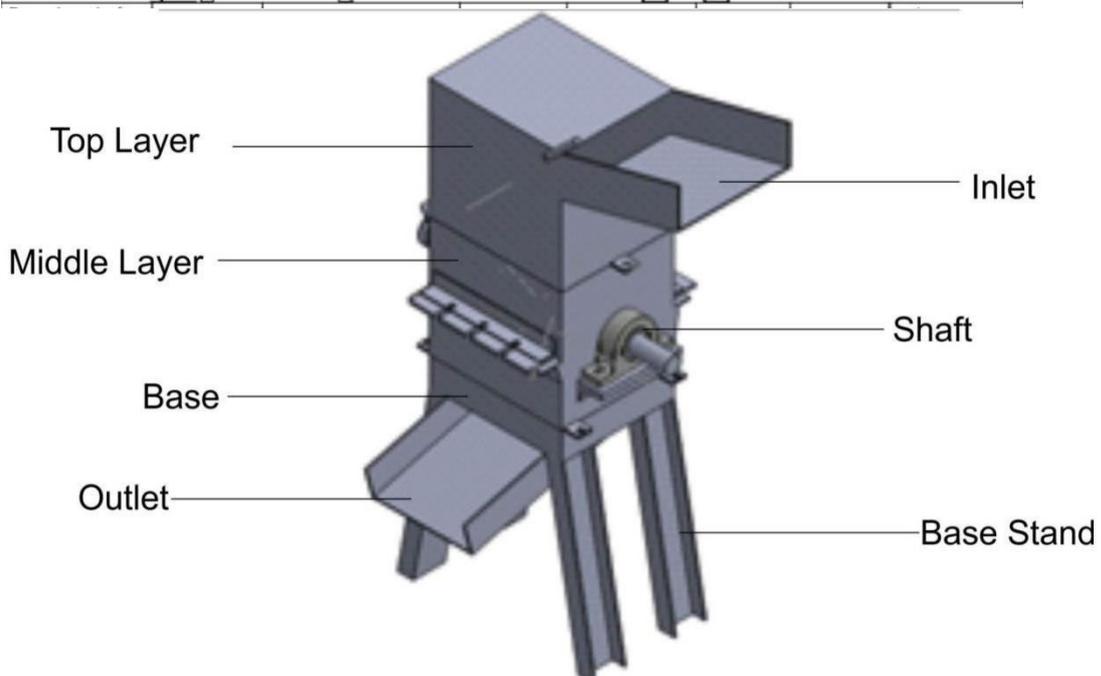
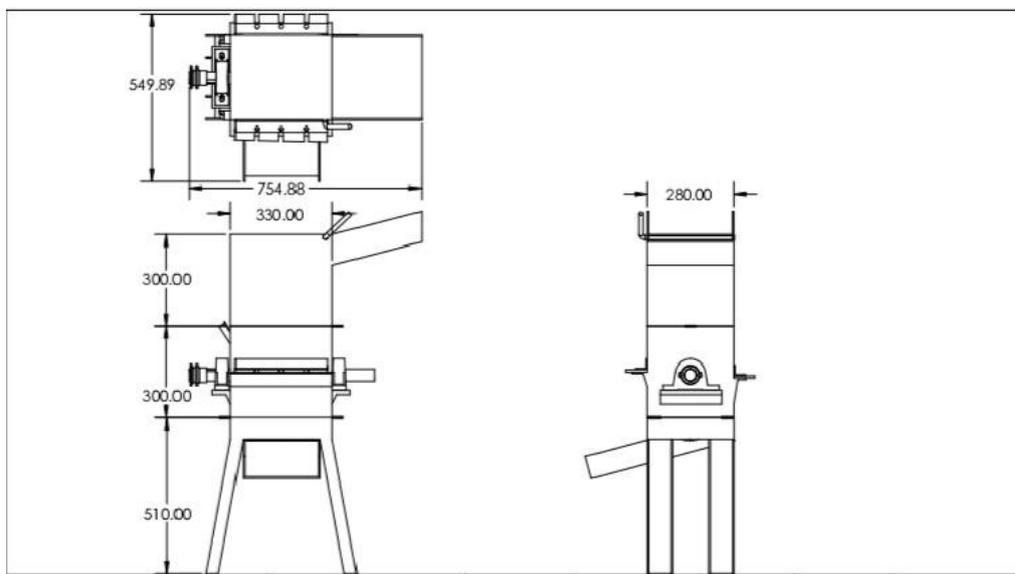
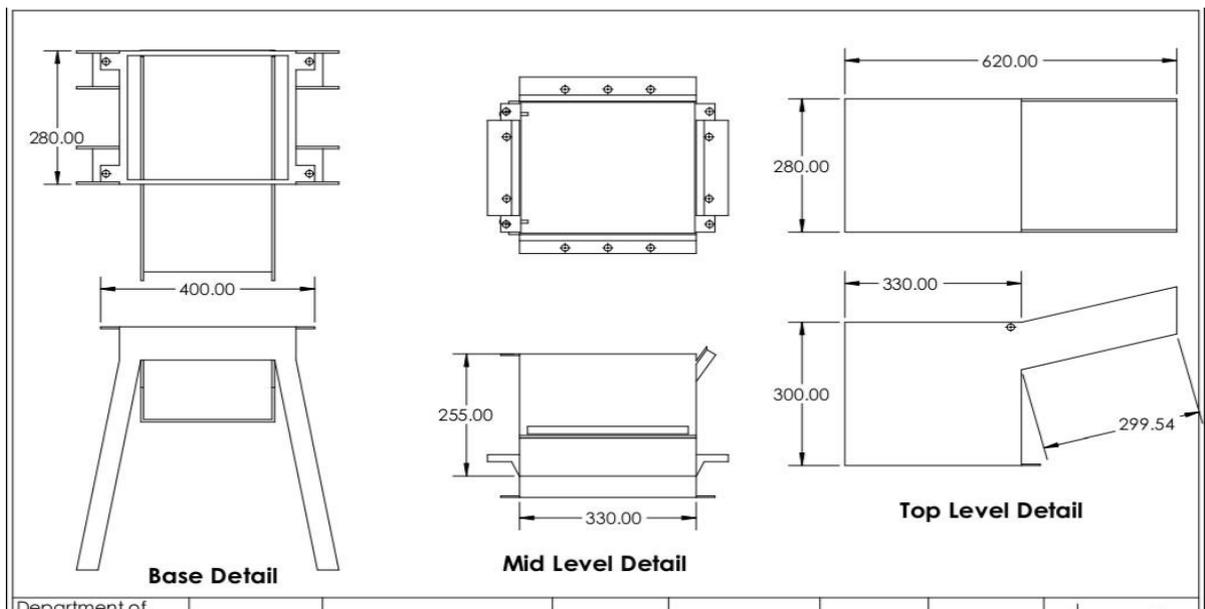


Figure 3: Assembly drawing of the shredding machine

2.6 Performance Evaluation

Performance evaluation of the shredding machine was conducted to ascertain the working ability and efficiency. Shredding was randomly carried out on different agricultural wastes, including coconut husks, palm bark, empty palm bunch, maize stalk, and empty coconut bunch in the Production Engineering Department Workshop of University Benin, Benin City Nigeria. The following parameters (feed rate, time, fuel used, size of agro-waste before and after shredding) were measured. In addition, the percentage reduction was calculated using equation 19.

$$\text{Percentage Reduction (\%)} = \frac{M_b - M_a}{M_b} \times 100 \quad (21)$$

M_b = Mass of agro-waste before shredding,

M_a = Mass of agro-waste after shredding

Materials, methods and equipment used for the work should be expressly described in this section. All prescribed formatting styles must be followed, to avoid delay in processing of the manuscript.

3.0 Results and Discussion

3.1 Designed Diesel Engine-Powered Shredding Machine

Quite a few input parameters were used in designed of diesel engine-powered agro-waste machine. These parameters are shown in Table 1.

Table 1: Input parameters

Parameter	Dimension
Hopper Dimension	
i. Top base cross-section, mm ²	415,100.9
ii. Bottom bases cross-section, mm ²	181,463.7
iii. Height of hopper, mm	410
iv. Volume of hopper, mm ³	1.874
Blade thickness, mm	1017.672
Blade radius, mm	100
Diameters of large pulley, mm	100
Diameters of small pulley, mm	85
Centre distance between the pulleys, mm	154
Weight of belt per meter length, N	2136

3.2 Performance Evaluation of Shredding Machine

Figures 4 to 8 showed the various agro-waste used to evaluate the performance of the developed shredding machine. The agro-wastes include coconut husk, tree bark, empty palm bunch, maize stalk, and empty coconut bunch. These Figures (4 – 8) also pictorial shapes of the studied agro-wastes after shredding. The average sizes of the different agro-waste were presented graphically in Figure 9. Table 2 showed the numerical values of the tests of the shredder. These showed the differences before and after shredding the studied agro-wastes with the shredder.

In addition, the extent of agro-waste shredded were subjected to percentage reduction (Table 2). Various agro-waste materials demonstrated significant differences in size reduction highlighting both material properties and the efficiency of the shredding machine (Figure 2). Palm bunch recorded the highest percentage reduction at 99.09%, while palm bark _{particles} showed the lowest reduction at 50%. Palm bunch, initially measuring 11 mm, was shredded down to 0.1 mm, indicating that the machine performed with excellent efficiency on loose, fibrous materials. This extremely high percentage reduction emphasizes the machine's strong shredding action, capable of converting bulky agro-waste materials into very fine particles suitable for further processing. This similar to Kumar and Kumar [22] and Adil et al. [23] that designed to reduce the volume of agricultural waste, making it easier to handle, compost, or recycle. In contrast, the palm bark _{particles}, although starting at a similar size of 11 mm, were only reduced to 4 mm. Other wastes such as palm bark _{fibers} (98.75%), coconut frond (98%), corn stalk (98%), and coconut husk (95.83%) also experienced very high size reductions, reinforcing the shredding machine's overall efficiency.



Figure 4: Coconut husk before shredding and after shredding



Figure 5: Tree bark before and after shredding



Figure 6: Empty oil palm bunch before and after shredding



Figure 7: Maize stalk before and after shredding



Figure 8: Empty coconut bunch before and after shredding

Table 2: Average size of different agro-waste

S/N	Agro- waste	Average size before shredding (mm)	Average size after shredding (mm)	Percentage Reduction (%)
1	Coconut husk	12	0.5	95.83
2.	Palm bark fibres	8	0.1	98.75
3	Palm bark particles	11	4	50
4	Palm bunch	11	0.1	99.09
5	Corn stalk	0.5	0.01	98
6	Coconut frond	5	0.1	98

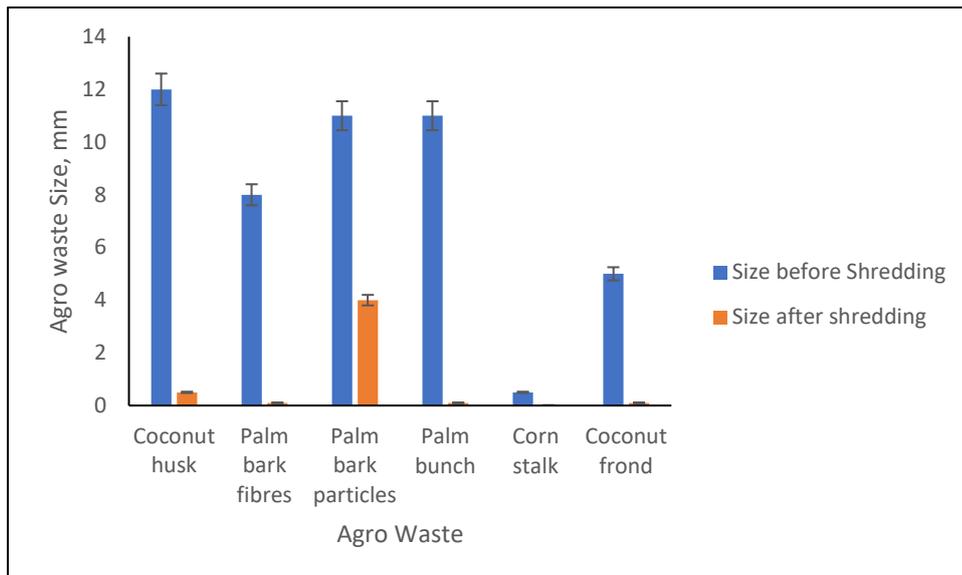


Figure 9: Sizes of different agro-wastes before and after shredding

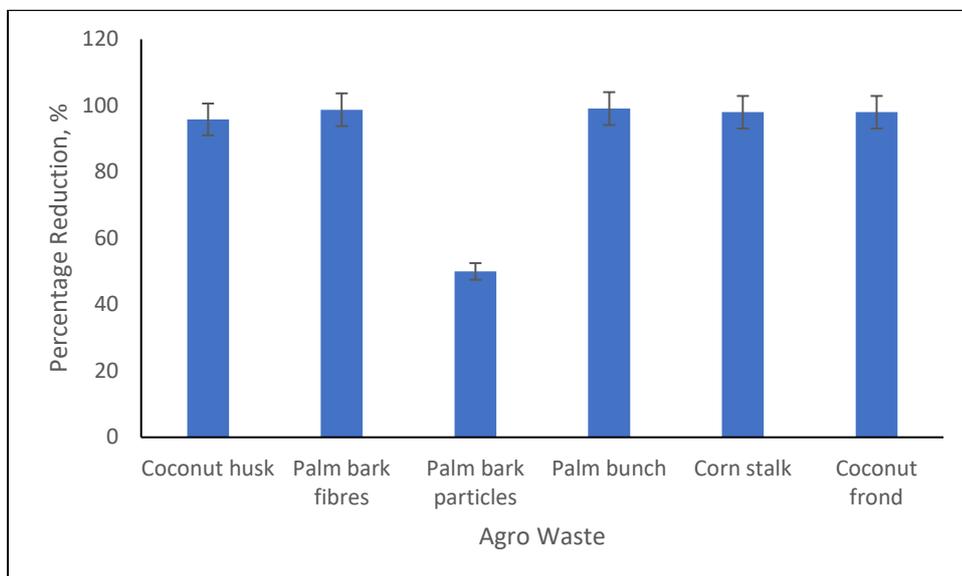


Figure 10: Percentage reduction of agro-waste

4.0 Conclusion

The agro-waste diesel engine powered shredding machine developed in this study met the key goals of being affordable, efficient, and practical for small-scale agricultural use. The evaluation of the performance of the machine showed the differences before and after shredding the studied agro-wastes with the shredder. Various agro-waste materials demonstrated significant differences in size reduction highlighting both material properties and the efficiency of the shredding machine. This extremely high percentage reduction emphasizes the machine’s strong shredding action, capable of converting bulky agro-waste materials into very fine particles suitable for further processing. In contrast, the all the agro-waste tested experienced very high size reductions, reinforcing the shredding machine’s overall efficiency.

References

- [1] Koul, B., Yakoob, M., & Shah, M.P. (2022). Agricultural waste management strategies for environmental sustainability. *Environmental Research*, 206, 112-285.
- [2] Babu, S., Rathore, S.S., Singh, R., Kumar, S., Singh, V.K., Yadav, S.K., Yadav, V., Raj, R., Yadav, D., Shekhawat, K., & Wani, O.A. (2022). Exploring agricultural waste biomass for energy, food and feed production and pollution mitigation: A review. *Bioresource Technology*, 360, 127-566.
- [3] Kumar, A. K., Sharma, S., Naveen, H. B., & Kumar, R. (2024), Advancements and Challenges in Agriculture Waste Management: A Comprehensive: Review, *Educational Administration: Theory and Practice*, 30(5),

7253- 7273.

- [4] Thakur, S., Sinha, A., Bag, A. G., Almalki, R. S., & Hossain, A. (2025). Challenges, solutions and policy issues for residue burning in Indian Agriculture: Searching key steps to reduce environmental pollution. *Air Quality, Atmosphere & Health*, 18, 1225. <https://doi.org/10.1007/s11869-025-01699-3>
- [5] Katiyar, A., Gaur, A., Shrivastava, A., Khan, M.A., Singh, N.P., Saini, R., & Kaur, M.G. (2019). Design and construction of a shredding machine for recycling and management of organic waste. *International Journal Trend Science Research Development*, 3, 4, 707-712.
- [6] Busari, R.A., Alabi, K.P., Adebayo, R.K., & Dada, J.O. (2024). Rapid composting using a novel agricultural waste shredder.
- [7] Haque, F., Fan, C., & Lee, Y.Y. (2023). From waste to value: Addressing the relevance of waste recovery to agricultural sector in line with circular economy. *Journal of Cleaner Production*, 415, 137873.
- [8] Rani, G.M., Pathania, D., Umapathi, R., Rustagi, S., Huh, Y.S., Gupta, V.K., Kaushik, A., & Chaudhary, V. (2023). Agro-waste to sustainable energy: A green strategy of converting agricultural waste to nano-enabled energy applications. *Science of The Total Environment*, 875, 162-667.
- [9] Singha, R., & Singha, S. (2024). Composting for a sustainable future: turning waste into nutrient-rich soil. in water-soil-plant-animal nexus in the era of climate change (pp. 279 - 297). IGI Global.
- [10] Saini, J.K., Saini, R., & Tewari, L. (2015). Lignocellulosic agriculture wastes as biomass feedstocks for second generation bioethanol production: concepts and recent developments. *3 Biotech*, 5, 337-353.
- [11] Savani, J.B., Kathiria, R.K., & Vagadia, V.R. (2004). Design and development of agricultural wastes shredder. *AMA Agric. Mech. Asia Afr. Latin Am*, 5(2), 41-46.
- [12] Abdulkadir, S. A., Dodo, S. M., Jahun, B., Malgwi, G. S., & Vanke, I. (2020). Design and construction of an agricultural waste-shredding machine. *Arid Zone Journal of Engineering, Technology and Environment*, 16(3), 519-530. Retrieved from <https://azojete.com.ng/index.php/azojete/article/view/340>.
- [13] Khope, P.B., & Modak, J.P. (2013). Design of experimental set-up for establishing empirical relationship for chaff cutter energized by human powered flywheel motor.
- [15] Naik, K., Swamy, R.P., & Naik, P. (2014). Design and fabrication of Areca fiber extraction machine. *International Journal of Emerging Technology and Advanced Engineering*, 4, (7), 860-866.
- [16] Prashant, Y., Gopinath, C., & Ravichandran, V. (2014). Design and development of coconut fiber extraction machine. *SASTech-Technical Journal of RUAS*, 13(1), 64-72.
- [17] Nithyananth, S., Samuel, L., Mathew, N., & Suraj, S. (2014). Design of waste shredder machine. *International Journal of Engineering Research and Applications*, 4(3), 487-491.
- [18] Soobhany, N., (2019). Insight into the recovery of nutrients from organic solid waste through biochemical conversion processes for fertilizer production: A review. *Journal of Cleaner Production*, 241, 118-413
- [19] Ayilara, M.S., Olanrewaju, O.S., Babalola, O.O., & Odeyemi, O. (2020). Waste management through composting: Challenges and potentials. *Sustainability*, 12(11), 44 - 56.
- [20] Ezeah, C., & Roberts, C.L., (2012). Analysis of barriers and success factors affecting the adoption of sustainable management of municipal solid waste in Nigeria. *Journal of environmental management*, 103, 9-14.
- [21] Jalalipour, H., Jaafarzadeh, N., Morscheck, G., Narra, S., & Nelles, M. (2021). Adoption of sustainable solid waste management and treatment approaches: A case study of Iran. *Waste Management & Research*, 39(7), 975-984.
- [22] Kumar, I.S., & Kumar, D.T.R.H. (2015). Design and development of agricultural waste shredder machine. *International Journal of Innovative Science, Engineering & Technology*, 2(10), 164-172.
- [23] Adil, B.M., Abhishek, Y.K., Kumar, M. and Acharya, A. (2020). Design and fabrication of agricultural waste shredder machine. *Advancement in Mechanical Engineering and Technology*, 3(1), 1-8.
- [24] Mustayen, A.G.M.B., Rasul, M.G., Wang, X., Negnevitsky, M. & Hamilton, J.M. (2022). Remote areas and Islands power generation: A review on diesel engine performance and emission improvement techniques. *Energy Conversion and Management*, 260, 115-614.
- [25] Khurmi, R. S., & Gupta, J. K. (2013). A textbook of machine design. First Multicolour Edition, Eurasia Publishing House (PVT.) LTD, New Delhi, Indian.