Journal of Organic Agriculture Research and Innovation (JOARI)

# DEVELOPMENT OF A SIMPLE AGRO-WASTE SHREDDER

ADEDIPE, J.O.*, ROBERTS, A.E., OYELEKE, O.S, ADETUNJI, A.S.

Forestry Research Institute of Nigeria (FRIN)

*Corresponding Author: crowndipe04@gmail.com; Phone: +2348066208261

**Abstract**

The conventional method of agro-waste disposal, which involves dumping and burning, leads to significant environmental pollution; to mitigate these issues, the study designed and fabricated a low-cost, electrical motor shredding machine capable of converting large particle-sized agricultural waste into small particle-sized easily decomposable forms. The machine has key components such as electric motor, shredding chamber, and collector. The parameters considered in evaluating the machine are, workability, material loss, throughput, efficiency and cost. It was able to shred wet and dry waste materials at an efficiency of 96.01% and 98.1% respectively. The machine performed better with dry agro-waste as against the wet ones; the average throughput for the dry weeds and the wet weeds were 11.05 and 5.83kg/hr respectively. This implies that dry weeds tend to get shredded faster than wet ones. The cost of production of the machine was ₦45,000 and this was assumed economical when compared to similar existing machines. It was recommended that the machine could be optimized, automated and customized in the future. Overall, this research contributes to the broader efforts of enhancing agricultural productivity and environmental conservation through innovative waste management solutions.

**Keywords:** Agro-waste, Shredder, Efficiency, Throughput

## INTRODUCTION

Agricultural waste is defined as the residues from the growing and processing of raw agricultural products. They are the by-product outputs of production and processing of agricultural products that may contain materials that can benefit man (Obi et al., 2016). It was estimated that about 9.054 x 1011 kg of agricultural waste are produced yearly (Agamuthu, 2009). Organic wastes can amount up to 80 percent of the total solid wastes generated in any farm (Brown and Root, 1997).

Waste generation has become a major concern to the government and the environmental regulatory bodies, and it is worse with the current population, economic and social pressures in Nigeria. (Obi et al., 2016). A large part of this population is faced with the problem of managing waste before and after harvest (Adewumi and Omoresho, 2002). Agro-waste shredding machines also present a management process.

Pavankumar et al. (2018) stated that as manual cutting is a time-consuming process, developing a shredding machine that satisfies our requirements is important. Khope and Modak (2013) proposed the design of experimental set-up for establishing empirical relationship for chaff cutter energized by human powered flywheel motor. Nithyananth (2014) developed a design of waste shredder machine. The Assembly consists of one fixed blade and five rotating blades, while Abdulkadir et al., (2020) developed a shredding machine for cowpea stalk and evaluated its performance by investigating the shredding efficiency and throughput capacity.

Like any other equipment, they may require regular maintenance to ensure optimal performance, However, the machine would address key issues such as uniform shredding, high throughput and ease of operation. This study aims to contribute to waste management, improve resource utilization and potentially provide added value to shredded wastes, by using local materials to develop a low-cost shredding machine that uses electric power to ease labor and reduce cost. The shredded materials can further be managed by composting it, used to produce biogas or biochar, for mulching and also for feeding animals. While designing the machine safety factor also was considered.

## MATERIALS AND METHODS

The machine was constructed in the metal workshop of the Federal College of Forestry Ibadan; while testing and performance evaluation was carried out on the farm of the Agricultural department of the college.

### Shredder prototype

The shredding machine (see figure 1) consists of the following key units:

i. **Electric motor**: this converts electrical energy to mechanical energy and this comes in the form of rotational motion (torque) through the electric motor, to power the machine.

ii. **Hopper:** this is the input component where agricultural waste materials are fed into the shredder. It also serves a safety barrier and a material quantity control for the machine to ensure safe, controlled and efficient feeding of materials into the shredding machine.

iii. **Shredding chamber:** this is the core component of the machine, where the actual cutting, tearing or grinding takes place. It protects the operator from flying debris.

iv. **Shredding Mechanism:** these consist of series of curved blades mounted on a central shaft. These blades spin at high speed to chop agro-materials for easier disposal.

v. **Collector:** it gathers and contains the shredded agro-waste materials exiting the shredding chamber. It enhances quick removal, emptying and replacement of materials.

vi. **Frame:** The frame of the shredding machine is a crucial component that provides structural support and houses various parts of the machine shredding unit.

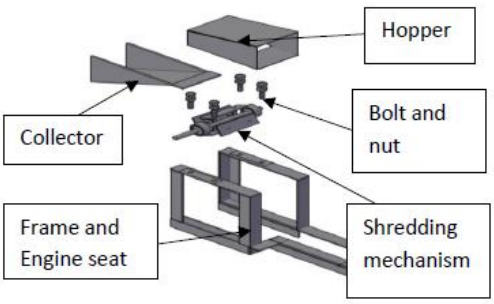


**Figure 1: Exploded view of machine**

**The Design and Fabrication:**
The electric motor was a single-phase induction motor with 230 V, 50/60 Hz a 2 Hp and runs at a maximum speed of 1300 rpm.

**Shredding mechanism:** To determine the mass (m) of the shredding mechanism;

$$m = \rho x V \quad (1)$$

where: m = mass, V = volume
The volume was evaluated as
$$V = l x B x t \quad (2)$$

**Determination of angular velocity, ω**
Angular velocity (ω) is given by:
$$\omega = 2\pi N/60 \quad (3)$$
where: $N$ = speed of the shaft in rpm

**The radius (r) of the shredding blade**
radius of shredding blade (r) = 9cm (assumed)
thickness (t) = 0.4cm, distance between blades (d) = 4.5cm

**Determination of shredding torque**
The torque ($T$) is given by:
$$T = F x r \quad (4)$$
where:
$F$ = Force available along shredding bar; r = shredding radius.

**Determination of power delivered by shredding shaft**
The power is given by
*power* = *force* x *velocity*,
$$linear\ velocity = \omega r \quad (5)$$
where: ω = angular velocity; r = radius.
Therefore,
$$power = F\omega r \quad (6)$$

**Shaft**
The following presentation is based on shafts of ductile materials and circular cross-section. The length of the shaft has been pre-determined at 13cm;

**Power delivered by shaft**

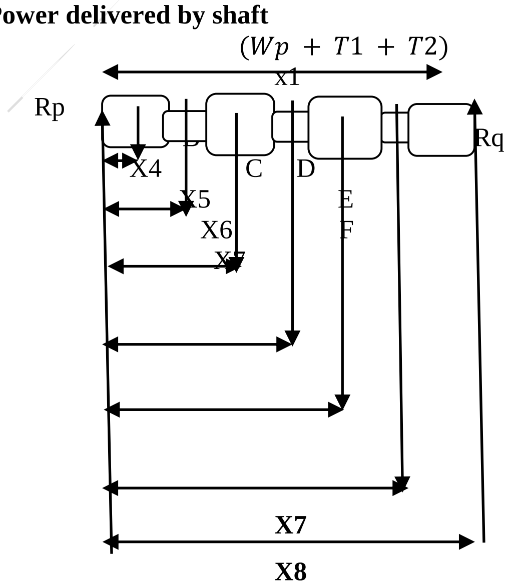


**Figure 2: Distributed weights acting on the shaft at different sections of the shaft**

Taking moment about *Rp*:
sum of clockwise moments equal = sum of anticlockwise moments,
$$(WP + T1 + T2)\,x1 + Fx7 + Ex6 + Dx5 + Cx4 + Bx3 + Ax2 = Rqx8$$
$$Rq = (WP + T1 + T2)x1\ Fx7 + Ex6 + Dx5 + Cx4 + Bx3 + Ax2)/x8$$
But sum of upward forces = sum of downward forces:
$$Rp + Rq = WP + T1 + T2 + A + B + C + D + E + F + G$$

$Rp = (WP + T1 + T2 + A + B + C + D + E + F + G) - Rq$

The weights A, C and E were 1 kg each, weights B, D and F were 0.5 kg each. The forces acting upwards (Rp and Rq) were determined to be 20 N each.

**Force required to shred on the shredding shaft**

The shredding blades, which are attached to the shaft rotates with the shaft, giving rise to centripetal force. From study, an optimum force of and velocity 500 N and 30 m/s are required to shear *Impereta cylindrica.*

$F = m\, \omega 2\, r$ (7)

where: $F$ = centripetal force; $m$ = mass of threshing bars; $w$ = angular velocity;
$r$ = radius of the arm of the threshing bar.

**Determination of shaft diameter**

Shafting is usually subjected to torsion, bending and axial loads. For a solid shaft having little or no axial loading, the ASME code equation is given as (ASME 1995):

$d\, 3 = [16/(\pi Ss)]\, x\, [(KbMb)2 + (KtMt)2]1/2$ (8)

where: $d$ = diameter of the shaft; $Mt$ = torsional moment; $Mb$ = bending moment;
$Kb$ = combined shock and fatigue factor applied to bending moment;
$Kt$ = combined shock and fatigue factor applied to torsional moment;
$Ss$ = Allowable Stress. = 40MN/$m^2$. (A shaft with key-way was used for this work).
For rotating shafts, when load is suddenly applied (minor shock):
$Kb$ = 1.5 to 2.0; $Kt$ = 1.0 to 1.5.

**Pulley/belt**

The horsepower rating of the electric motor determined the diameter of the driver pulley, while for the driven pulley**,** the spindle speed and the speed of the prime mover are related by the expression: N1D1 = N2D2 (speed x diameter of driver = speed x diameter of driven)

**Weight of pulley**: this was determined using the equation: Weight (Wp) = mg

Where: $m = \rho\, x\, v = \rho\, (A\, x\, L)$ (9)

Therefore;

$Wp = \rho g\, (A\, x\, L)$ 10)

Where: L is the length of pulley

**Belt:** This transmits torque from one moving body to another.

Effective pull-on belt:

$(T) = T1 - T2$ (11)

Where T1 is tension on tight side, T2 is tension on slack side

Torque on shaft:

$(Ts) = F\, x\, r$ (12)

**Power Transmitted by Belt**

According to Hannah and Stephens (1970), the power transmitted by belt is given by:

$P = (T1 - T2)\, V$ (13)

**Parameters used in evaluating the shredding machine**

The following parameters were assessed in the evaluation of the shredding machine:

i. **Functionality test** … a machine passes the "functionality test" if it runs smoothly at idle loading and comfortably shreds agro-waste when loaded. This was by physical assessment. The effectiveness of its functionality was further evaluated with using other parameters.
ii. **Material loss (%) …** is the ratio of the difference in the initial weight of the waste material and the final weight, to the initial weight, in percent;
(%) $= ((Initial\ weight - final\ weight)\, x\, 100)/ Initial\ weight$
iii. **Throughput …** these measures how much material the machine can shred per time (in seconds). The weight of agro-waste shredded was measured before the operation. A timer was used to record the the time for complete shredding.
Throughput = Material weight (g)/time (s)
iv. **Machine efficiency (%) …** these measures how efficiently the machine shreds agro-materials with minimum loss of material.
Machine processing efficiency = (Shredded material weight /Initial material weight) x 100

**Performance test**

A performance test was carried out on the farm of Agricultural Technology Department, Federal College of Forestry Ibadan. The agricultural waste under study was spear weed (I*mperata cylindrica*) after they were harvested. The machine was tested idle to ensure it worked perfectly before been subjected to loading and shredding operations. The initial and final weight of shredded materials were measured and replicated five (5) times. Data collected from the tests was used for evaluations and conclusions were drawn.

## RESULTS AND DISCUSSION

### Functionality

Table 1 suggests that the machine worked satisfactorily at idle operation without component failure. Subsequently, it also worked comfortably well when loaded; i.e. it was able to shred both wet and dry weeds completely at permissible noise level. It performed well at very good efficiencies both for wet and dry weeds.

The quantity of material loss differed for the shredding of both wet and dry (at 70% and 17% moisture content respectively) agro-waste materials. Wet materials tend to lose more materials during shredding operations. Figure 3 shows the respective percentage weight loss for wet and dry shredding operations; the average percentage loss was 3.09% and 1.41% respectively; it was observed that weight in materials loss was more when wet weeds were shredded for most operations. This could be because the wet weeds had moisture and they clog, leading to clumping and residue build up, while dry weeds allow for cleaner cuts and reduces wear on the shredder.

**Table 1 Data obtained from machine performance test**

| | Wet waste materials (70%) | | | | | Dry waste materials (17%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **S/N** | **Initial weight (g)** | **Final weight (g)** | **T (s)** | **Throughput (g/s)** | **Efficiency (%)** | **Initial weight (g)** | **Final weight (g)** | **T (s)** | **Throughput (g/s)** | **Efficiency (%)** |
| 1 | 600 | 580 | 360 | 1.67 | 96.67 | 300 | 300 | 100 | 3.00 | 100 |
| 2 | 580 | 570 | 355 | 1.63 | 98.28 | 300 | 290 | 95 | 3.15 | 96.67 |
| 3 | 558 | 530 | 345 | 1.62 | 94.98 | 290 | 290 | 93 | 3.11 | 100 |
| 4 | 540 | 503 | 337 | 1.60 | 93.15 | 270 | 260 | 87 | 3.10 | 96.30 |
| 5 | 535 | 520 | 335 | 1.59 | 97.20 | 240 | 240 | 80 | 3.00 | 100 |
| **Mean** | **562** | **541** | **346** | **1.62** | **96.01** | **280** | **276** | **91** | **3.07** | **98.6** |

### Material loss (%):

The quantity of material loss differed for the shredding of both wet and dry (at 70% and 17% moisture content respectively) agro-waste materials. Wet materials tend to lose more materials during shredding operations. Figure 3 shows the respective percentage weight loss for wet and dry shredding operations; the average percentage loss was 3.09% and 1.41% respectively; it was observed that weight in materials loss was more when wet weeds were shredded for most operations. This could be because the wet weeds had moisture and they clog, leading to clumping and residue build up, while dry weeds allow for cleaner cuts and reduces wear on the shredder.

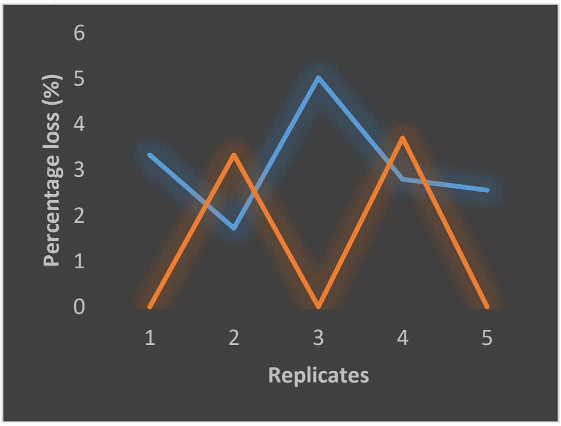


**Figure 3: Percentage shredded materials**

### Throughput (kg/hr)

Figure 4 shows the difference in throughput values of the shredding machine when wet and dry weeds were shredded. It revealed that the machine performed better when used to shred dry weeds as against the wet ones; the average throughput value for the dry weeds and the wet weeds were 11.05 and 5.83kg/hr respectively. This could be because dry plant materials are more brittle and easier to break apart, while wet weeds are more fibrous and can clog equipment due to their moisture content.

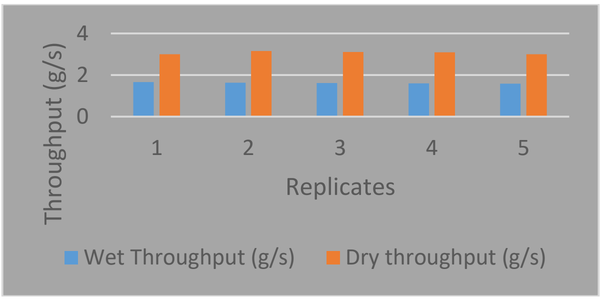


**Figure 4: Throughput between wet and dry weeds**

**Machine efficiency (%):**
Figure 5 shows the difference in the efficiency values of the shredding machine when wet and dry weeds were shredded. It showed that the mean efficiency for the wet and dry shredding operations were 96.01% and 98.6% respectively. This suggests that the machine was more efficient when shredding dry weeds to wet weeds. This could be as a result of the moisture content present in wet weeds that makes them clog to shredding blades and slows down shredding process. It was also observed that wet weeds lead to frequent bluntness of shredding blades.

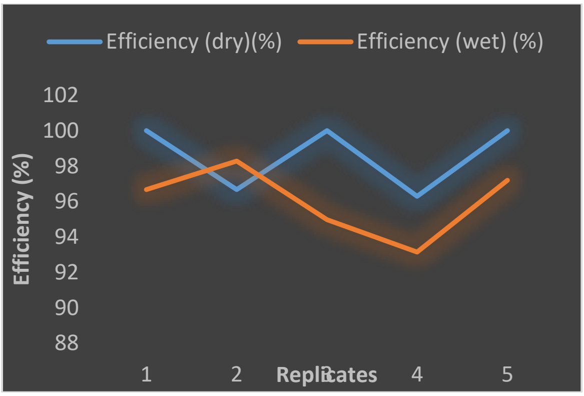

**Figure 5: Efficiency for wet and dry shredding operations**

## CONCLUSION

The development and implementation of an agro-waste shredding machine present a practical and economical solution to the persistent problem of agricultural waste management. This study demonstrated that the shredding machine effectively converts various types of agricultural waste into smaller, decomposable forms, facilitating their use as organic fertilizer. The performance tests revealed that the machine operates efficiently with both wet and dry materials, although it performs better with dry waste, achieving a mean efficiency of 98.6%. It is considered more economical and with a better efficiency when compared to the report of Abdulkadir *et al.*, (2020) whose machine cost N 59,700 and a lower efficiency of 93%. The throughput was higher for dry materials, indicating that dry waste processes more smoothly through the shredder, minimizing clogs and improving productivity.

The fabricated machine was found to be cost-effective, with an estimated total cost of ₦45,000, making it affordable for local farmers. This cost can be justified by the long-term savings in labor and increased efficiency, as well as the added value from producing high-quality organic manure.

Overall, the shredding machine not only enhances waste management practices but also promotes environmental sustainability by reducing pollution and enriching soil quality. This innovation holds great potential for widespread adoption, contributing significantly to agricultural productivity and economic benefits in the long term.

**Recommendations**
Based on the findings and the overall success of the agro-waste shredding machine developed in this study, several recommendations are proposed to enhance the machine's efficiency and broaden its applicability:

i. Further research should focus on optimizing the blade design and material to improve the shredding efficiency.
ii. Incorporating automation and control systems, such as sensors to monitor the shredding process and adjust the motor speed accordingly.
iii. To meet the diverse needs of different agricultural operations, the machine design should be made scalable and customizable.
iv. Lastly, it is recommended that further research be conducted on the potential uses of the shredded waste beyond organic manure. Exploring possibilities such as bioenergy production or material for biodegradable products could add further value to agricultural waste, enhancing the economic benefits for farmers.

## REFERENCES

Abdulkadir, S.A, Dodo, S.M, Jahun, B.G, algwi, G.S, Vanke, I (2020): Design and construction of an agricultural waste shredding machine. *Arid Zone Journal of Engineering, Technology and Environment*. Vol. 16(3): 519-538.

Adewumi, M. and Omoresho, O. (2002). An analysis of production objectives of small-scale rural farming households in Kwara State, *Nigeria. Journal of Rural Development*, 25(2): 201-211.

Agamuthu, P. (2009). Challenges and opportunities in agro-waste management: An Asian perspective. Paper presented at the Inaugural Meeting of First Regional 3R Forum in Asia, Tokyo, Japan.

Brown and Root Environmental Consultancy Group (1997). Environmental review of national solid waste management plan. Interim report submitted to the Government of Mauritius.

Khope P.B and Modak J.P (2013): Design of experimental set-up for establishing empirical relationship for chaff cutter energized by human powered flywheel motor. *Journal of Agricultural Technology* Vol. 9(4): 779-791.

Nithyananth S. Libin Samuel. (2014). "Design of Waste Shredder Machine" *International. Journal of Engineering Research and Applications*, Vol. 4, Issue 3, pp.487-491

Obi, F., Ugwuishiwu, B. and Nwakaire, J. (2016). Agricultural waste concept, generation, utilization, and management. *Nigerian Journal of Technology*, 35(4): 957–964.

Pavankumar, S.B., Sachin, K.R., Shankar, R., Thyagaraja, B. and Madhusudhan, T. (2018). Design and fabrication of organic waste shredding machine. *Int. J. Eng. Sci. Invent.,* 7(6): 26-31.