



# Development of a Hold-On Pedal-Operated Paddy Thresher

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## ABSTRACT

Paddy threshing is a very tedious, less efficient and expensive operation that is carried out manually by most small-scale farmer in Nigeria. To assist in addressing some of these problems, a hold on type pedal-operated paddy thresher was developed at U-SAF Technology Fabrication Academy, Bauchi, and constructed using locally available material and a performance test carried out. The thresher was found to suitably thresh between 55 and 73 kg of paddy per hour with an average threshing efficiency of 92%, about 5% percent threshing losses and 4% of broken grains. The developed machine was found to be cheap and effective and can be adopted by local farmers to improve rice production at a reduce cost and stress.

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## Introduction

Rice (*Oryza spp*) is a staple food with rich cultural identity, in Nigeria its consumption has no cultural, religious, ethnic or geographical boundary [1]. Consequently, its demand and consumption have continued to witness momentous changes with increasing population across all socio-economic classes [2]. The annual consumption of rice in Nigeria is estimated at about 5.5 million metric tonnes which exceeds the local production which stands at 3.3 million metric tonnes with the deficit of 2.2 million metric tonnes been bridged by importation from other countries [3 and 4].

Reports indicates that most consumers in the country prefer the imported rice to the locally produced rice, because the local rice is not entirely stone free, is not well polished, takes longer cooking time, contains a lot of broken kernels and not appealing when compared to the imported rice [5]. These and others factors are having dire effects on the local production. Some of the factors that have been attributed to the low quality of the locally produced rice include poor agronomic practices, poor postharvest handling, low standard rice processing equipment and methods among others [6].

Majority of rice farmers in Nigeria are small scale, who lack enough capacity to acquire appropriate equipment such as planters and combine harvesters to be used for rice production. They therefore resort to manual methods which is limiting their production. Harvesting, threshing and other post-harvest operations are entirely carried our manually.

In Nigeria, rice threshing is predominantly accomplished by the traditional method, by beating harvested rice panicles against wooden logs or metal barrel or by beating cut panicles

with sticks on hard floor to detach grains. Such method has been reported to be major sources of contamination of the rice with stones and other foreign materials as well as breakages of the rice kernels [7]. According to [8], the output of the manual threshing methods ranges from 0.01 kg to 30 kg of grain per man-hour depending on the variety of rice, condition of rice, the method applied and rice losses recorded. [9] reported that the manual threshing method is popular due to its associated low cost; however, quantitative and qualitative losses can be as high as 20-30%. [10] reported that this qualitative post-harvest loss of rice could reach as high as 50% of the production, while [8] stated that threshing losses account for 30% of rice post-harvest loss.

In order to improve the quality of the locally produced rice, to make it attractive to consumers and to reduce the losses associated with post-harvest handling, there is the need to adopt modern and improve agronomic practices in its production as well employ machines in carry out some of the post-harvest operations and handling of the products.

[11] and [12] reported that mechanization of threshing operation in rice production is very vital if the quality of locally produced rice is to be improved, due to which several researchers devoted a lot of efforts in the development of paddy threshers among which include a pedal powered paddy rice thresher developed in 2018 by [13] which is capable of threshing 90 kg of paddy per hour at an efficiency of 92% with a total power requirement of 84 W.

**Material and Method**

**Design Consideration**

This work focuses on producing a thresher that will be cheap, light in weight and durable. To achieve this some factors were considered among which include: components parts easily dismountable for replacement and repairs, safety of operation, light in weight for safe transportation, ease of operation, low cost of maintenance, use of locally available materials and simplicity in design and construction making it reproducible by local artisan and ease of operation.

**Development of the Machine**

The design and fabrication of the hold on paddy thresher was done under the following phases: design of the individual components, drawing the individual components using Solid-works Premium 2019 software, assembling the components and animating the operation of the machine in Solid-works 2019, construction of the individual components, assembling the components of the machine and testing the operation of the developed machine.

**Design of the individual components**

The designed machine as shown on Figure 1 consists of the following components: main frame, threshing cylinder, power transmission unit (Bevel gear, pinion, link rod, Drive shaft and Treadle pedal) and collection unit each of which was designed independently as follows:

**Design of the main Frame**

The frame is the skeleton of the threshing machine; it is design to be constructed from strong material (45 × 45 × 5 mm mild steel angle iron) which can support all other components as well can withstand the vibration of the machine during operation. The frame was designed to have a width of 704 mm, wide enough to accommodate material from a single operator; the height of the thresher was made to be 775 mm so that the thresher can be fed without any stress of bending by the operator while the length of the frame is designed to be 1067 mm. In the design of the frame, the total weight the frame shall carry was calculated and the bending moment the frame shall experience was also calculated and the material was selected appropriately.

**Design of the threshing cylinder**

The threshing cylinder as shown on Figure 2 consists of threshing drum, threshing fingers and the shaft. The threshing drum was design to be constructed from two circular plates of diameter 200 mm and a thickness of 10 mm place 584 mm apart on to which six 584 × 30 × 10 mm MS metal bars are mounted

60 degree apart on to each of which 10 wire loop threshing fingers of height 63.5 mm are securely fixed.

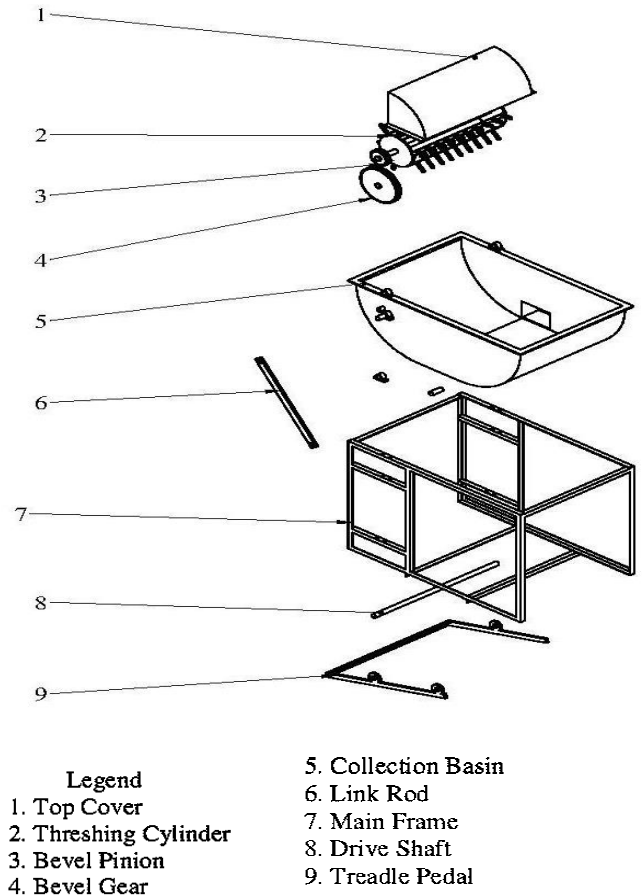


Figure 1: Exploded View of the Developed Paddy Thresher

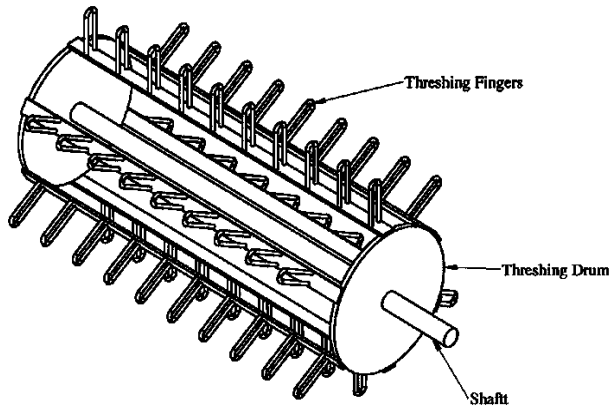
The threshing cylinder has a diameter of 330 mm and a height of 584 mm mounted firmly to a 762 mm long, 25 mm diameter shaft which will drive it through spur gear power transmission assembly from the pedal.

**Design of the power shaft**

The thresher contains 2 main shafts: the threshing cylinder drive shaft and the pedal shaft. In the design of those shafts the weight of the threshing cylinder, the weight of the gears and the speed of operation and the effect of torsion and bending during the operation of each of the shafts were considered and used in Equation 1 and 2 to select the size of the shafts [14].

$$d^3 = \frac{16}{\pi \tau_{max}} [(M_B)^2 + (M_t)^2]^{\frac{1}{2}} \tag{1}$$

Where d is diameter of the shaft (m),  $\tau_{max}$  is allowable stress (MN/m<sup>2</sup>) = 42 MPa for shafts with allowance for keyways,  $M_t$  is twisting moment (Nm) and  $M_B$  is Bending moment (Nm).



**Figure 2: Isometric View of threshing cylinder**

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

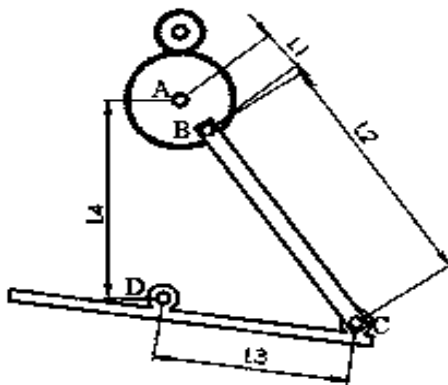
Where  $M_t$  is the twisting moment (Nm), P is power transmitted by shaft (W) and N is angular speed (r.p.m.).

**Design of the power transmission unit**

The power transmission unit consist of a treadle assembly and a flat bar connected through a spur gear assembly to produce a rotary motion that operates the threshing drum as a result of the reciprocating motion of the pedal.

**Design of the treadle unit**

The aim of designing the treadle unit is to obtained a link of correct length and to ensure rigidity for satisfactory performance. The treadle unit operates on the principle of 4 – bar linkage mechanism. Figure 3 illustrates the 4 – bar linkage mechanism as described by [15].



**Figure 3: Illustration of the 4 – bar link system.**

The four bars are AB, BC, CD and DA. Point B is the crank point, and D is the pivot for the treadle. [15] stated that the equation governing the principles of operation of a 4 – bar linkage system is as presented in Equation 3.

$$(L_1 + L_2)^2 \leq L_3^2 + L_4^2 \quad (3)$$

Where  $L_1$  is length between the centre of the driving gear and the link point on the gear (84 mm),  $L_2$  is length of the link bar to be determined (mm),  $L_3$  is centre distance between the pivot and point of contact of the link bar on the treadle (406 mm), and  $L_4$  is distance between the centre of the driving gear and the pivot point (463 mm). Therefore, the length of link  $L_2$  should be equal to 531.8 mm.

**Design and selection of spur gear**

The aim of designing and proper selection of the spur gear and pinion is to increase the speed to obtain the required speed of the threshing cylinder without straining the operator.

The gear design and selection were done by using the velocity ratio of the gears and calculating the number of teeth on the pinion to avoid interference as presented on Equation 4 and Equation 5 [14].

$$V.R. = \frac{T_G}{T_P} = \frac{D_G}{D_P} \quad (4)$$

Where V. R. is velocity ratio,  $T_G$  is number of teeth on the gear,  $T_P$  is Number of teeth on the pinion,  $D_G$  is diameter of gear (mm) and  $D_P$  is diameter of pinion (mm).

$$T_P = \frac{2AW}{G \left[ 1 + \frac{1}{G} \left( \frac{1}{G} + 2 \right) \sin^2 \phi - 1 \right]} \quad (5)$$

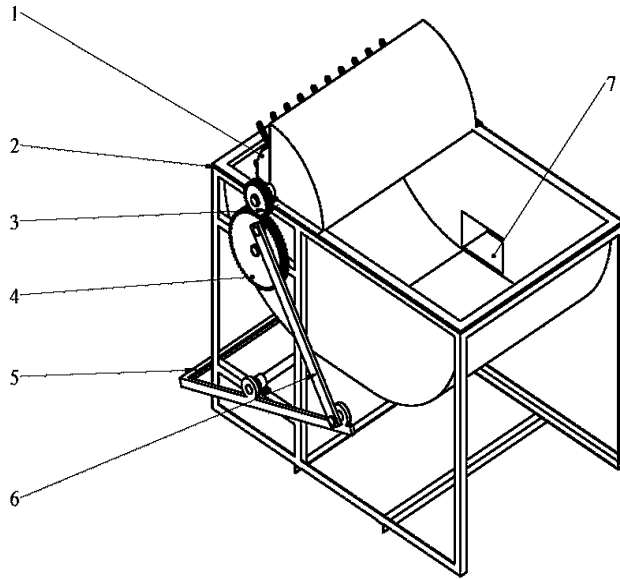
Where  $T_P$  is the number of teeth on the pinion, G is gear ratio and  $\theta$  is pressure angle.

**Construction of the Machine**

The construction of the machine was carried out at the workshop of U-SAF Technology Fabrication Academy located at shops No. 2 and 3 Nasarawa Gate by AMSAD Clinic Junction, Bauchi, Bauchi State. The construction of the thresher was done part by part through the process of cutting, forming and welding and later assembled together using bolt and nut.

**Mode of Operation of the Pedal Operated Thresher**

The developed thresher as shown on Figure 4 is designed to be powered by the human foot, as the treadle pedal (5) is operated by the operator, power is transmitted through the link rod (6) which rotates the bevel gear (4) which in turn rotates the pinion (3) in the opposite direction, the pinion is firmly connected to the threshing cylinder (1). As the pinion rotates, it rotates the threshing cylinder (1) which threshers the rice fed by the operator to it and the grains of the rice will be falling to the ground through the grain outlet (7).



Legend

- |                       |                  |
|-----------------------|------------------|
| 1. Threshing Cylinder | 5. Treadle Pedal |
| 2. Main Frame         | 6. Link Rod      |
| 3. Bevel Pinion       | 7. Grain out let |
| 4. Bevel Gear         |                  |

Figure 4: Isometric View of the developed Pedal-Operated Paddy Thresher.

**Performance Evaluation of the developed pedal- operated Paddy Thresher**

After constructing the pedal operated paddy thresher, its performance was evaluated by threshing Faro 44 and Jamila varieties of rice and following parameters were recorded: moisture content of the rice, weight of material fed, weight of rice collected, time taking to thresher the fed material, weight of broken kernels and weight of un-thresher kernels.

The collected data were then used to calculate the through put capacity, threshing efficiency, percentage spilt grain and percentage un-thresher grain using the following relations as reported by [11]:

$$C_{th} = \frac{W_{ma}}{T_{th}} \quad (6)$$

Where  $C_{th}$  is through put capacity (kg/hr),  $W_{ma}$  is weight of material fed (kg) and  $T_{th}$  is threshing time (hr).

$$Th_{Eff} = \frac{W_{gc}}{W_t} \times 100 \quad (7)$$

Where  $Th_{Eff}$  is the threshing efficiency (%),  $W_{gc}$  is weight of grain collected (kg) and  $W_t$  is total weight of grain fed (kg).

$$Sg = \frac{W_s}{W_{gc}} \times 100 \quad (8)$$

Where  $Sg$  is percentage split grain (%),  $W_s$  is weight of split grains (kg) and  $W_{gc}$  is weight of grain collected (kg).

$$Th_{un} = \frac{W_{ut}}{W_t} \times 100 \quad (9)$$

Where  $Th_{un}$  is percentage un-threshed grain (%),  $W_{ut}$  is weight of un-threshed grain (kg) and  $W_t$  is total weight of grain (kg).

**Results and Discussion**

The pictorial view of the developed pedal operated paddy thresher is shown in Plate 1.



Plate 1: Pictorial View of the Developed Pedal Operated Rice Thresher

The result of the performance evaluation of the developed pedal operated paddy thresher which include: moisture content of the rice, weight of material fed, weight of rice collected, time taking to thresher the fed material, weight of broken kernels and weight of un-thresher kernels is presented on Table 1, while that of through put capacity, threshing efficiency, percentage spilt grain and percentage un-thresher grain is presented on Table 2.

**Table 1: Result of Measured Performance Evaluation of the Developed Pedal-operated Rice Thresher**

Variety	Moisture Content of the rice (%)	Weight of Material fed (kg)	Weight of Rice Collected (kg)	Time Taken to Thresh the fed Material (min)	Weight of Broken Kernels (kg)	Weight of Un-Threshed Kernels (kg)
Faro 44	15.8	20	12.7	17.13	0.43	0.58
	15.8	20	14.8	21.47	0.31	0.47
	15.8	20	13.7	18.24	0.45	0.61
Average	15.8	20	13.7	18.95	0.40	0.55
Jamila	14.7	20	13.6	16.42	0.75	0.62
	14.7	20	12.7	16.87	0.43	0.81
	14.7	20	14.1	17.21	0.61	0.42
Average	14.7	20	13.5	16.83	0.60	0.62

**Table 2: Result of Calculated Performance Evaluation of the Developed Pedal-operated Rice Thresher**

Variety	Through Put capacity (kg/hr)	Threshing Efficiency (%)	Percentage Spilt Grain (%)	Percentage Un-Threshed Grain (%)
Faro 44	70.05	92.63	3.39	4.42
	55.89	94.79	2.18	3.24
	65.79	92.82	3.28	4.31
Average	63.91	93.41	2.95	3.99
Jamila	73.08	90.85	5.51	4.32
	71.13	91.10	3.39	6.17
	69.73	93.19	4.33	2.86
Average	71.31	91.72	4.41	4.45

The moisture content of Faro 44 at the time of threshing was found to be 15.8% while that of Jamila was 14.7%, the average weight of rice collected were 13.7 kg and 13.5 kg for Faro 44 and Jamila respectively. The time taken for threshing 20 kg of Faro 44 and Jamila were 18.95 and 16.83 minutes respectively, while an average of 0.4 and 0.6 kg grains of Faro 44 and Jamila respectively got broken during threshing with the developed rice thresher and 0.55 kg of Faro 44 grains and 0.62 kg of Jamila grains were not threshed.

The throughput capacity of the developed thresher was found to be 63.91 kg/hr with Faro 44 and 71.31 kg/hr with Jamila which closely agrees with that obtained by [16], an average threshing efficiency of 93.41 and 91.72% while threshing Faro 44 and Jamila Varieties respectively which is in agreement with the result obtained by [15]. The average percentage split grains and that of un-threshed grains were found to be 2.95 and 3.99% with Faro 44 Variety and 4.41 and 4.45% with Jamila Variety which falls within the range obtained by [15] and [16].

### Conclusion

A hold-on pedal-operated paddy thresher was developed and constructed using locally available material with the tools and techniques available to the local artisans to improve rice production and reduce the cost and drudgery associated with the local method used by small scale farmer in Nigeria.

The developed thresher consists of the following components: a threshing drum, spur gear power transmission mechanism, a treadle powering mechanism and a frame which are assemble such that the machine can be fed and powered by a single person. The throughput capacity of the machine ranges between 55 and 73 kg/hr with an average threshing efficiency of 92%. The average quantity of un-threshed grains is 5% and an average 4% of broken grains.

The developed machine is found to have a suitable performance and can be adopted by local farmers to improve production at a reduce cost and stress.

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