



Design and Fabrication of an Okra Threshing Machine

Adejumo, Akinfoye O.D¹, Ajav, Emmanuel A², Igeka, Joseph C² and Komolafe, Clement A³

¹Agricultural Engineering Department, Federal College of Agriculture, Ibadan, Nigeria.

²Agricultural and Environmental Engineering Department, University of Ibadan, Ibadan, Nigeria.

³Mechanical Engineering Department, Landmark University, Omu-Aran, Kwara State, Nigeria.

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ABSTRACT

A simple Okra threshing machine was designed, fabricated and tested to alleviate the problems associated with Okra processing in Nigeria. It consists mainly of five units namely, the feeding assembly, the threshing unit, separation unit, power transmission unit. The overall mean threshing and cleaning efficiencies obtained were 93.95 and 99.56% respectively. Drum speed 500rpm combine with 55mm concave clearance gave the highest Threshing efficiency of 99.99%. All speeds, concave clearance combinations gave clearing efficiency above 98%. The machine threshing and cleaning efficiencies increased with increase in drum speed and decrease with increase in concave clearance. The machine is simple to operate and maintain without formal training.

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Introduction

Okra (*Abelmoschus esculentus*(L)Moench) is a herb of the family of Malvaceae. It is one of the most important vegetables widely grown throughout the tropics especially West Africa for its tender fruits, young leaves and seeds. Okra seed (dry seed) has high potential as a good source of oil and protein for human diets, which is one of the problems in diets in most developing countries of the world, like Nigeria.

Recent works have shown that okra seed (dry seed) is a good source of high quality oil and protein for both the temperate regions and tropics (Oyelade *et al.*, 2003). The seed is free from undesirable components such as protease inhibitors in soybean, and tannin and gossypol content is found to be below FAO recommended tolerance (Martin *et al.*, 1979). The potential use of okra seed for the development of weaning foods in West Africa was investigated. Addition of okra seed meal into blends increased protein and fat contents of the blends and was found suitable in terms of flavour, taste and texture (Kalra *et al.*, 1982, Jideani and Adetula 1993). Also, okra cheese prepared from okra seed proteins and milk protein precipitated with limejuice was both attractive and good tasting (Martin and Ruberte, 1979 and Martin *et al.*, 1979). Even though there has been a great global desire for meat products, the world, especially the developing countries, cannot supply the much needed protein in form of animal products to satisfy the nutritional needs of ever increasing population. According to Deshpande *et al.*, (2000), approximately 20 % of the protein currently available is derived solely from food legumes in the developing world. Therefore, the global trend and encouragement on plant protein (i.e. such as pulses, seeds and cereals) which are cheap and of high calory than insisting on animal products is recommendable (Ritchie, 1983).

Okra seed oil is rich in unsaturated fatty acids such as linoleic acid, which is an essential fatty acid in human nutrition (Savello *et al.*, 1980). The oil has a similar fatty acid composition with cottonseed oil and can be used for cooking and for the production of margarine (Karakoltsidis and Constantinides 1975, Martin and Ruberte, 1979). Okra seed contains about 7.8 % moisture, 19.2 % crude protein, 13-21 %

crude fat, 4-5 % ash, 60-61 % carbohydrate, 34-35 % crude fibre and the residue meal had a protein content of 42% (Savello *et al.*, 1980, Karakoltsidis and Constantinides 1975, Rao *et al.*, 1992). Okra can be planted all the year round depending on availability of water. It tolerates most soils and cultural practices. The yield of okra (287-612 kg/ha) is higher than that of soybean (Telek and Martin, 1981).

However, there are very few reported works and literature sources on okra seeds as a source of high quality fats and oils. This could be as a result of little awareness of its high potentials and difficulty of mechanical processing of the seeds prior to the oil extraction.

Processing of dry okra pod involves many operations, among which is threshing. In Nigeria, okra pod threshing is mainly traditional. Traditionally, okra pods are opened by hand, beating with sticks in sacks on hard surfaces like (rocks, concrete, tarpaulin, mat and so on) or trampling by animal. The first method is tedious and time consuming while the last two methods cause severe damage to the seed without the consideration of basic requirement for preserving quality of agricultural product(s) (okra) and also the control of moisture content during pre-processing storage (Igbeka, 2013) resulting in low germination and quality reduction in industrial usage. Moreover, these methods do not encourage large scale seed production. The ability to purchase foreign machinery for the threshing of okra pod becomes a mirage. Therefore, it is imperative that if the country is to be self sufficient in food (oil and protein) and raw material for industries, it must be based largely on indigenous engineering initiative and researches to design, adapt, develop and manufacture locally most of the machines for agricultural processes (Odigboh, 1992). Therefore, the justification for the design and fabrication of a threshing machine which will provide solution to the problem of dry okra processing (threshing) prior to the seed utilization.

Materials and Methods

The materials such as metal sheet, angle iron, iron rod etc. for the fabrication of the designed okra thresher were obtained from Ogunpa and Araromi spare parts markets both in Ibadan, Nigeria.

Machine features and description

The thresher consists of five main units namely; the feeding assembly, the threshing unit, separation unit, power transmission unit and the main frame labeled (A-G) as in plate 1 and Fig. 1. The design enables the utilization of various power sources i.e. electric motor, ic engine and P.T.O. etc.

Feeding unit

The feeding unit(A) (hopper and its cover) is mounted on top of the concave (cylinder housing) of the thresher. The hopper holds the dry okra pods prior to their introduction into the threshing unit and has a volume of about 0.003792 m^3 to hold about 1500 g of okra pods at a time. The base is so designed to enhance the pods enter the threshing unit lengthwise. The cover helps to prevent throwing out of pods and seeds from the hopper.

Threshing unit

The threshing unit (B) consists of the concave (or cylinder housing) and the cylinder or drum. The concave is made of 300 mm diameter, 480 mm long and 3mm thick (rolled mild steel sheet). This is spitted into two equal halves viz top and bottom parts. Three rows of nine M10 nuts are welded on drilled holes allowing screw in and out of M10 bolt on the top part. An opening of 460 mm by 80 mm is made on the bottom part to allow threshed produce out of the threshing unit. The two halves are bolted together using 8-M8 bolts and nuts.

The cylinder or drum was made of 190 mm diameter, 460 mm long and 3mm thick closed at both ends (rolled mild steel sheet). Four rows of 10 mm diameter pegs were welded (10 pegs per row) along the length. A ring and a M8 bolt were wedded on both ends for securing the cylinder on the main shaft of 42mm diameter. Impact, shear and slight compression of pod induced by pegs on the drum passing in between those on the concave, breaks the pod thereby releasing the seeds. The seeds and chaff fall by force of gravity into the sieve.

Separation unit

The separation unit(C,D and F) consists of a reciprocating sieve, seed outlet and a blower. The sieve(C) is made of 2 mm (gauge 16) metal sheet, 495 mm by 325 mm, perforated with 8 mm drill bit covering surface area of about 45 %. Thus, airflow through the sieve is considered an open area in accordance with Donald *et al.*, (1975), who stated that any surface area that has 10 % openings or more is considered an open area. The sieve is connected to the reciprocator shaft carrying a cam of 30 mm travel with linkages and a bearing (6306). The sieve is inclined at an angle of 10 degrees to the horizontal so as to allow for free flow of the seed and chaff.

The seed trough (D) is made of gauge 16 (2 mm) mild steel sheet. This is inclined at an angle of 15 degrees to the horizontal so as to allow free flow of the seeds.

The blower (F) is designed to generate airflow rate very close to the terminal velocity of the seed (2-3 m/s). It consists of the fan and its housing. The fan housing is made of 1.5 mm thick (gauge 18) sheet metal with 160 mm air inlet opening of on both sides. Four fan blades of 495 mm by 115 mm and 2 m thick were welded on a fan shaft of 32 mm diameter and mounted on two bearings (6306).

Frame

The frame (E) is cubic in shape. This serves as the load bearing for all other parts viz feeding assembly, threshing unit, separation units, pulley and belts arrangements, bearings, seed trough. Attached to the main frame is engine seat and supports. These are constructed with (mild steel) 45 mm Angle Iron.

Power transmission unit

The power transmission unit(G) consists of a 0.75 kw, 1400 rpm, single phase a.c motor, control panel, a set of belts and pulleys. The desired speed was obtained by belt and V-groove pulley arrangements on the main shaft, fan shaft and reciprocator shaft.

Experimental Preliminary Survey

Rc_1 = Inner radius of threshing cylinder = 92 mm
 Rc_2 = Outer radius of threshing Cylinder = 95 mm
 Dc = Diameter of cylinder = 190 mm
 H = Length of cylinder = 475 mm
 Zs = Number of spike = 48
 Ls = Length of spike = 50 mm
 r_s = Radius of spike = 7.5 mm
 Mp = Mass of pulley = $Mp_1 = 0.6 \text{ kg}$, $Mp_2 = 2.4 \text{ kg}$, $Mp_3 = 2.0 \text{ kg}$
 Rp = Radius of pulley $Rp_1 = 22.5 \text{ mm}$, $Rp_2 = 100 \text{ mm}$, $Rp_3 = 70 \text{ mm}$
 = maximum impact force to rupture the pod = 88.86 N

Components Design

$$\text{Threshing Power}(P_{TH}) = \frac{I \times \pi^2 N_T^2 (2N^* - N^{*2})}{108 \times 10^3} \text{ (watt)} \quad (1)$$

where I = Total moment of inertial of threshing head(), N_T = Threshing speed (rpm), N^* = Deceleration of angular speed, X = Constant

$$I = I_c + I_p + I_s \quad (2)$$

Where I_c = Moment of Inertial of Cylinder, I_p = Moment of Inertial of Pulley, I_s = Moment of Inertial of Spike ()

$$I_c = Mc(Rc_2^2 - Rc_1^2) \quad (3)$$

Where Mc = Mass of cylinder, Rc_1 = Inner radius of threshing cylinder, Rc_2 = Outer radius of threshing Cylinder

$$Mc = \rho v = \rho(\pi Dc \times t \times h) \quad (4)$$

Where ρ = Density of mild steel = 7.85 g/cm^3 (Kenyon, 1980), Dc = Diameter of cylinder, t = Thick of metal sheet = 3 mm (gauge 14), h = Length of cylinder

$$I_s = MsZs [(Rc_2 \times \frac{Ls}{2})^2 + \frac{Ls^2}{12}] \quad (5)$$

Where Ms = Mass of Spike, Zs = Number of spike, Ls = Length of spike

$$Ms = \rho Vs = \rho \pi r_s^2 Ls$$

Where r = Radius of spike

$$I_p = Mp \frac{Rp^2}{2} \quad (6)$$

Where Mp = Mass of pulley, Rp = Radius of pulleys

Design Threshing Force

Grain thresher works on the principle of shearing (impact force) and puppy (gentle compression). According to Ryder (1988) and Khurmi (2002), the stress induced by sudden (impact) load is twice the stress induced when the same load is applied gradually (compression). Therefore, the maximum impact force to rupture the pod is designed for, which is 88.86 N (preliminary survey).

The theoretical equation is given as:

$$T = \frac{P_{TH}}{W} \quad (7)$$

Where T = Torque, W = angular velocity

$$W = \frac{2\pi Nc}{60} \quad (8)$$

where

Nc = Cylinder speed = 450 rpm (preliminary survey)

$$F_{TH} = \frac{T}{Rc + Ls} \quad (9)$$

Design Threshing Capacity

The capacity of the thresher (C_{TH}) is controlled by the flow of pods into the threshing chamber. It is assumed a flow of three pods (length 103.18 mm, preliminary survey) lengthwise

from hopper of length 430 mm per second into the threshing chamber.

$$\text{Mass of seed per pod (M}_{sp}) = M_s \times N_{sp} \quad (10)$$

Where M_s = Mass of seed, N_{sp} = Number of seed per pod

$$C_{TH} = M_{sp} \times N_p \times 60 \times 60 \quad (11)$$

Where N_p = Number of pods

Cylinder Belt Design

There are three belts on the machine. The main belt transmit power from an electric motor or I c engine to the main shaft; while the other two, transit power from the main shaft to drive a fan and a reciprocator. For a chosen 2.238 kW, 1400 rpm electric motor

The cylinder pulley; diameter (D_1)

$$D_1 = \frac{Nm d_1}{N_{th}} \quad (12)$$

Where Nm = Speed of the electric motor, d_1 =Diameter of driving pulley, N_{th} = Cylinder speed

The minimum centre distance

$$C_{d1} = \frac{D_1 + d_1}{2} + d_1 \quad (13)$$

The pitch length of belt

$$L_{approx} = 2C_{d1} + \frac{\pi d_1 + D_1}{2} + \frac{D_1 - d_1}{4C_{d1}} \quad (14)$$

Determination of Tensions in Belt

The angle of wrap

$$\alpha = 180 \pm 2 \sin^{-1} \{(R - r)/c\} \quad (15)$$

Where R = radius of the larger pulley, r = radius of the smaller pulley, c = centre distance = 550mm According to Hall *et al.*, (1983),

$$(T_1 - T_2)V = P \quad (16)$$

and

$$\frac{T_1 - Mv_1}{T_2 - Mv_2} = e^{\mu \alpha / \sin(\theta/2)} \quad (17)$$

Where T_1 = tension in the tight side, T_2 = tension in the slack side, M = bte, b = belt width = 12 mm = 0.012m, t = belt thickness = 9.5 mm = 0.0095, e = belt density = 970kg/m³ for leather belt

$$M = 0.012 \times 0.0095 \times 970 = 0.11 \text{ kg/m}$$

μ = Coefficient of friction between belt = (0.15 for leather belt on steel)

Shaft Design

The main shaft transmits power from electric motor or IC engine to the threshing cylinder, fan and reciprocator. Therefore, the shaft is design based on strength and rigidity criteria.

Strength Criterion

The required diameter for a solid shaft having combine bending and torsional loads is obtained from ASME code equation (hall, *et. al.*, 1983) as:

$$D_s^3 = \frac{16}{\pi S_s} \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (18)$$

Where at the section under consideration, S_s = Allowable combined shear stress for bending and torsion = 40 N/m² for steel shaft with keyway, k_b = Combined shock and fatigue factor applied to bending moment = 1.5 to 2.0 for minor shock, k_t = Combined shock and fatigue factor applied to torsional moment = 1.0 to 1.5 for heavy shock, M_b = Bending moment (Nm), M_t = Torsional moment (Nm) = 0.0161 Nm, D_s = Diameter of solid shaft (m)

Torsional Rigidity criterion

The design of shaft for torsional rigidity is based on the permissible angle of twist. This is 3 deg/m for steel shaft.

$$\theta = \frac{584 M_t L}{G d^4} \quad (19)$$

Where θ = angle of twist deg, L = Length of shaft, = 0.68 m, M_t = torsional moment = 0.0161 Nm, G = torsional modulus of elasticity = 80 GN/m², D = shaft diameter = 0.042 m

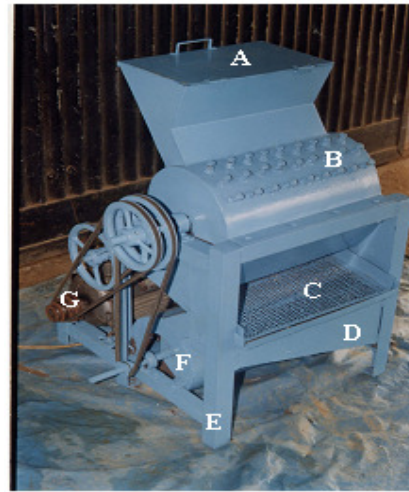


Plate 1: The Pictorial view of the Developed Okra Thresher

- A-The Hopper
- B-The Threshing Chamber
- C-The Sieve Unit
- D-The Seed Outlet
- E-The Frame
- F-The Blower
- G-The Power Drive

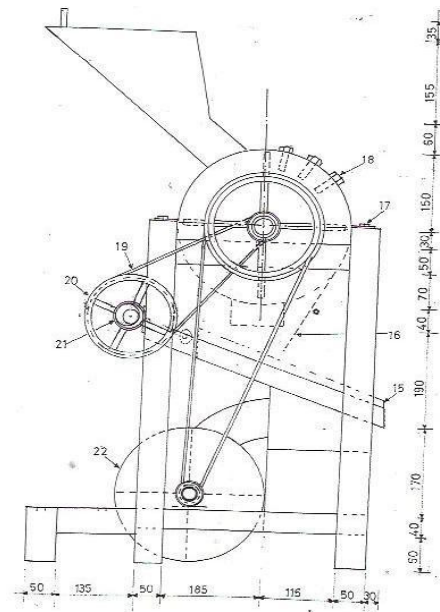


Fig 1. Side View of the Developed Okra Thresher

Testing and Evaluation

The components of the threshing machine (Plate 1) were measured, machined, welded, bolted and assembled as shown in the sectional side view (Fig. 1) according to the design specifications. The threshing machine was then test run to effect all necessary adjustment, alignment, tensioning, greasing etc. where necessary.

Testing

The electric motor was switched on, and allowed to idle run for half a minute, while a tachometer was attached to the cylinder shaft and noted. A known mass of dry okra pods were poured into the hopper and the threshing time recorded using

stop watch. The threshed product from the seed outlet, those blown from the sieve and other outlet were collected separately and each sample separated manually into threshed, unthreshed, damage, chaff and their weight taken using an electric weighing machine (± 0.01 g). The experiment replicated 3 times.

Evaluation

Evaluation of the developed okra thresher was carried out on yield and quality of the threshed seed on mass bases. The quality of these seeds was determined in terms of visible damage. Dependent variables viz: threshing efficiency, cleaning efficiency and percentage of damaged grains. were determined using test code by National Agricultural Technology Information Centre, INDIA (Mehta *et.al.*, 1995).

The dependent variables were calculated as:

$$\text{i. Percentage of un-threshed seed (Gt)} = \frac{J}{\text{GT}} \times 100 \quad (20)$$

Where, J = Weight of un-threshed seed at all outlets per unit time (kg), GT = Total seed input (kg)

$$\text{ii. Threshing efficiency } (\eta_{\text{Thr}}) = 100 - \text{Gt} \quad (21)$$

$$\text{iii. Cleaning efficiency } (\eta_{\text{Cl}}) = \frac{K}{W_G} \times 100 \quad (22)$$

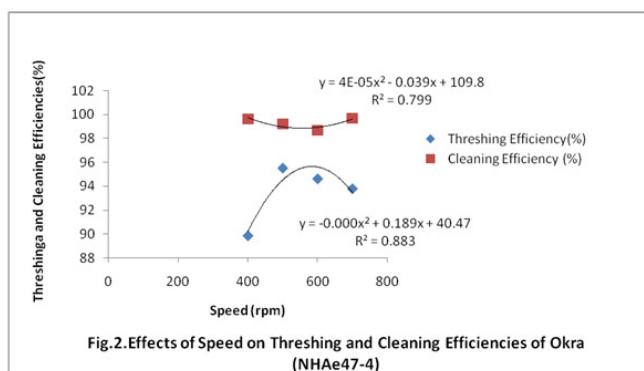
Where, K = Weight of whole seed at main seed outlet per unit time (kg), W_G = Weight of whole seed at all seed outlet per unit time (kg)

Results and Discussion

Results

The results obtained for the evaluation of the machine on okra (NHAe47-4) at 14% moisture content is shown in table 1, Fig. 2 and 3.

	Threshing Efficiencies (%)				
			Speed (rpm)		
Concave Clearance (mm)	400	500	600	700	Average
45	91.57	94.05	95.55	93.54	95.68
55	92.04	94.55	96.65	94.2	94.36
65	89.55	99.99	100	92.76	95.58
75	86.28	93.45	86.26	94.64	90.16
Average	89.86	95.51	94.62	93.79	93.95
	Cleaning Efficiencies				
45	99.91	99.84	99.79	98.79	99.83
55	99.89	99.63	99.93	99.91	99.84
65	99.3	98.52	99.71	99.7	99.31
75	99.46	98.84	99.34	99.36	99.25
Average	99.64	99.21	98.69	99.69	99.56

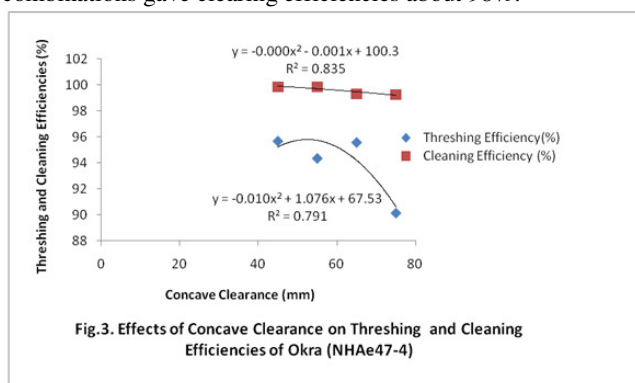


Discussion

From Table 1, Fig. 2 and 3, it is generally observed that the cleaning efficiencies is higher than the threshing efficiencies. However, in fig. 2, as the speed increases the efficiencies also increase. This trend is an indication that at high speed, there will be high impact for to thresh the pod and also to increase air

velocity for cleaning. In fig. 3, the efficiencies decrease with increase in concave clearance. This might be due to the fact that the smaller the gap between the threshing drum and concave the more the compressive force on the pod. The relationship between the efficiencies and the independent variables (threshing drum speed and concave clearance) are polynomial ($R^2 = 0.79 - 0.88$). These results are similar to mean threshing efficiency (88.2%), cleaning efficiency (99.5%) and the coefficient of determination ($R^2 = 0.58-0.89$) obtained by Adejumo, 2006.

The overall mean threshing and cleaning efficiencies are 93.95 and 99.56 percentages respectively. Drum speed 500rpm combine with 55mm concave gave the highest threshing efficiencies 99.99% and all speed and concave clearance combinations gave clearing efficiencies about 98%.



Conclusion

A designed and fabricated Okra thresher consisting mainly of five parts namely; the feeding unit, the threshing unit, separation unit, power transmission unit was tested using NHAe47-4 variety at 14% moisture content. From the results, the overall mean threshing and cleaning efficiencies were 93.95 and 99.56% respectively. The efficiencies increased with increase in drum speed and decreased with increase in concave clearance. The unit cost of the threshing machine was N90, 400.00 which is considered affordable for average Nigeria farmer.

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