DEVELOPMENT AND OPTIMIZATION OF FERMENTED CASSAVA MASHING AND SIEVING EQUIPMENT FOR AKPU AND FUFU PASTE PRODUCTION

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ABSTRACT
One of the hardest and slowest stages in the processing of cassava into akpu and fufu is the mashing and sieving of fermented cassava to get the paste which is manually done using plastic, metal or calabash sieves. Drudgery, inefficiency, limited output and low quality are major problems encountered during processing. A faster method of loosening and sieving the fermented cassava led to the need for the development, using finite element modelling and optimization of machine for production of akpu and fufu paste, thereby eliminating the problems associated with the manual operation. The machine was developed using SOLIDWORKS 2021 3D Computer Aided Design (CAD), and imported to ANSYS 2021 software. The machine had a capacity, 140-160 kg/hr, average sieving speed, 415 rpm, torque, 17.42Nm, minimum and maximum stress of 0.000e+00N/m^2 and 8.933e+05N/m^2 respectively, minimum and maximum strain of 0.000e+00 and 3.195e-06 respectively, with minimum and maximum factor of safety, 3.638e+02 and 1.000e+16 respectively. While the average speed of shaft and axial speed of feeder were found to increase with the speed of motor. There is urgent need to work towards mechanizing the processing of cassava into akpu and fufu paste to make its production effective, efficient and timely, leading to products availability, accessibility, affordability and storability – a step towards HiTech Agriculture and food security and sustainability in the face of Pandemic.

Keywords: Finite, Modelling, Optimization, Cassava, Mashing, Sieving, Akpu, Fufu

1.0 INTRODUCTION

Nigeria is the leading producer of cassava (*Manihot esculenta Crantz*) globally, accounting for about one-fifth (21%) of total production worldwide with an annual production of about 60 million tonnes PWC (2020). Cassava has been put to use in various ways IITA (2005). Communities in Nigeria and beyond consume cassava leaves as vegetable in soup preparation or dried and fed to livestock as protein feed supplement. It is known globally as a cheap source of calorie in human diet and animal feeds especially in Africa where it accounts for 60% of root crops consumption. Cassava is primarily a source of carbohydrate and contains very little protein or fat. The approximate composition of the cassava tuber is starch, 20-30%; protein, 2-3%; water, 75-80%; fat, 0.1%; fibre, 1.0%; ash, 1-1.5% El-Sharkawy (2006); Kolawole and Agbetoye (2007); Kolawole *et al.* (2010); Uthman (2011).

Cassava is the second most consumed staple food in Nigeria after maize, and has become a food security crop due to its increased significance in the country Asante-Pok (2013); KPMG (2019) and Ani *et al.* (2020). Cassava crop can be processed into many food items such as Gari, Akpu, Fufu, Lafun, Cassava chips, Abacha, Starch, Cassava Baking Flour and others Ovat and Odey (2019). According to Owolarafe *et al.* (2018) the quality of fufu has been known to vary from one location to another due to processing technique. Akpu and Fufu contains moisture, 6.50, protein, 1.68, fat, 1.32, ash, 1.84, crude fibre, 1.42 and carbohydrate, 87.24% respectively.

Oyewole and Isah (2012) reiterated that fermented cassava mashing into akpu and fufu manually is accompanied with problems of drudgery and inefficiency, and was the only method identified, and it is one of the hardest and slowest stages. Owolarafe *et al.* (2018) further reported that Cassava mashing by hand was observed to be the dominant method of mashing in Abeokuta agricultural zone and its environs. Kolawole *et al.* (2010) reported that several efforts have been made to develop suitable indigenous machines for cassava processing; this attempt was made to make the cassava mash process more energy-efficient and to meet the Millennium Development Goals (MDGs), aimed at poverty reduction over a stipulated period of time. Kudabo *et al.* (2012) recorded that, constraints to cassava processing include the absence of efficient equipment; appropriate processing technologies, machines, and tools. These are not easily affordable and sometimes unavailable at the farm level. Currently, the equipment available are the grater, sieving, dryer and dewatering machines in the processing of gari. Whereas equipment for processing cassava into akpu and fufu paste are scarce.

Finite Element (FE) is one of those methods used for evaluation of a structure under static and dynamic loads before proceeding with the model. Finite element analysis (FEA) is a computerized method for predicting how a product reacts to real-world forces, vibration, heat, fluid flow, and other physical effects Jagota *et al.* (2013). Finite element modelling (FEM) permits complex analysis of multilayered complex shape structures, including stress–strain, dynamic, thermal, or electro-magnetic loading, and even combinations of the above. FEM applications include stress analysis, slope stability analysis, soil structure interactions, seepage of fluids in soils and rocks, analysis of dams, tunnels, bore holes, propagation of stress waves and dynamic soil structure interaction. ANSYS is a general-purpose software package based on the finite element analysis, allowing full 3-dimensional simulation without compromising the geometrical details Hughes (2000) and Madenci and Guven (2007). ANSYS is used to determine how a product will function with different specifications, without building test products or conducting crash tests Nakasone (2006).

Universal model design is a near impossible work due to ambiguous conditions of the working environment. Jayasuriya and Salokhe (2001) suggested the use of computer aided method for creating the supporting database of model parameters in order to utilise them for any specific condition or design purpose. Computer integrated design software helps in development of complete system design processes, especially the use of three dimensional (3D) solid modelling and finite element analysis (FEA) applications, now forming a branch of software known as computer aided engineering (CAE). The act of obtaining the best results under given circumstances, is very necessary for modern day development of effective equipment for application in various fields. Use of these techniques for the design of agricultural machine systems is inevitable and now a commonplace. Structural optimization of agricultural machines and equipment is a sure way towards getting the right shape of component parts for effective delivery Mehmet *et al.* (2010). The main objective of the study was development using finite element modelling and optimization of fermented cassava mashing and sieving equipment in the production of akpu and fufu paste.

2.0 METHODOLOGY

2.1 Design Consideration

Finite Element Modelling and design of fermented cassava mashing and sieving machine considered a number of factors such as: Strength of materials for the fabrication, durability of the machine, moisture content of the materials that is to be processed on the machine, cost of the required materials, expected life span of the design, cost of maintenance of the design and availability of replaceable parts. The design also considered ability to loosen, sieve and convey unfermented cassava roots parts and fibre to the outlet through. The design looked at provision of water jacket for adequate circulation of water within the mashing and sieving chamber. The design of the fermented cassava mashing and sieving machine reviewed the work of the following authors among others in the design of agricultural processing machines: Olugboji (2004) as and utilized by Sharma and Aggarwal (2006); Olugboji and Jiya (2014); Gbasouzor (2015); Amare *et al.* (2015); Caringal *et al.* (2016); Adisa *et al.* (2016); Ruekkasaem and Sasananan (2018); Okunola *et al.* (2018); Ajis and Lanya (2018); Bariya *et al.* (2019); Adetola and Akindahunsi (2020); Ohwofadjeke (2020); and Ani *et al.* (2020).

2.2 Design Materials and Components of the Sieving Machine

Materials selection for the design model and optimization of the fermented cassava mashing and sieving machine included the following amongst others; mild steel, stainless steel, cast iron, cast aluminium, plastic piping, and a host of others. These were: mainframe, hopper, water tank/jacket, shaft -auger mashing and conveyor**,** mashing and Sieving chamber**,** pulleys and v-belt, shafts**,** bearings and variable speed electric motor.

2.3 Finite Element Design and Modelling of the Mashing and Sieving Equipment

Finite element design and modelling of the fermented cassava mashing and sieving equipment for the production of akpu/fufu paste was carried out using SOLIDWORKS 2021 3D Computer Aided Design (CAD) software, and imported to ANSYS 2021. SOLIDWORKS is a solid modeling computer-aided design (CAD) and computer-aided engineering computer program. It is an auxiliary tool, which helps to obtain simple analysis results quickly in the design process. ANSYS software is dedicated to the developments of Computer-Aided Engineering (CAE) and multi-physics engineering simulation for product design, testing and operation. The software was utilized in the design, modelling and simulation of the machine parts and steps Jagota *et al.* (2013); Gbasouzor (2015) and Nam *et al.* (2018).

2.3.1 Design of Belt

Speed ratio of belt drive is given by

$$\frac{N_2}{N_1} = \frac{D_1}{D_2} \quad \text{--} \quad 1$$

Diameter of the driver $D_1 = 75mm$
Diameter of the follower $D_2 = 200mm$
Speed of the driver $N_1 = 1800rpm$
Speed of the follower $N_2 =?$

$$N_2 = \frac{D_1 \times N_1}{D_2} = \frac{75 \times 1800}{200} = 675rpm$$

Velocity of Belt

Assuming a center-to-center distance of 400mm

$$v = \frac{d_2}{2} \times \frac{2\pi N_2}{60} \quad \text{--} \quad 2$$

$$= \frac{0.2}{2} \times \frac{2\pi \times 675}{60}$$

$$= 7.07 m/_{s}$$

Length of V-belt (L)
Radius of driver pulley, $r_1 = 0.0375m$
Radius of follower pulley, $r_2 = 0.1m$
center-to-center distance $c = 0.4m$
$L = \pi(r_2 + r_1) + 2c + \frac{(r_2 - r_1)^2}{c}$ -- 3
$= \pi(0.1 + .0.0375) + (2 \times 0.4) + \frac{(0.1 - 0.0375)^2}{0.4}$
$L = 1242mm$

Cross Sectional Area of Belt
Taking the width and height of the V-belt to be 13mm and 8mm respectively.
$A = {}^1/_2\,(x + y)H$ -- 4
$x = width$
$H = Height$
$Q = tan\,15 \times 8 = 1.92$
$y = x - 2(Q) = 9.16$
$A = {}^1/_2\,(13 + 9.16) \times 8 = 88.64mm^2$

2.3.2 Design of Pulleys
Angle of Contact on Small Pulley
$\theta_1 = \pi - \frac{D_2 - D_1}{C} = \pi - \frac{(200-75)}{400}$ --- 5
$\theta_1 = 2.83rad = 162.15^0$

Angle of Contact on Large Pulley
$\theta_2 = \pi + \frac{D_2 - D_1}{C} = \pi + \frac{(200-75)}{400}$ -- 6
$\theta_2 = 3.45rad = 197.67^0$

2.3.3 Design of Shaft
Torque Transmitted to shaft from motor
$T_n = \frac{P \times 60}{2\pi N}$ -- 7
Power generated by 2 horsepower motor is 1491.4W.
$T = \frac{1491.4 \times 60}{2\pi \times 1800} = 7.91N$

Centrifugal Force
$F = {}^T/_r$ -- 8
$F = \frac{7.91}{0.0375} = 210.9N$

Minimum Diameter of the Shaft
$\frac{T}{J} = \frac{G\theta}{L} = \frac{\tau}{r}$ --- 9
Length = 1050 mm = 1.05m
G= Modulus of rigidity for mild steel = 78GN/m^2
$\theta = angle\ of\ twist = 0.05$
T = Torque

J = Second Polar Moment $= \pi \frac{(d)^4}{32}$

$$d = \sqrt[4]{\frac{32TL}{\pi G\theta}} = 0.0407m = 40.7mm$$

Stress acting on Belt

$\sigma = {}^{F}\!/_{A}$ -- 10

$$\sigma = \frac{210.9}{88.64} = 2.38\, N\, /\, mm^2$$

Maximum Tension

$T_{max} = \sigma bt$ -- 11

b = width of belt = x

t = thickness of belt = H

$T_{max} = 2.38 \times 13 \times 8 = 247.52N$

Tension on Tight Side, T_1

$T_1 = T_{max} - T_c$ -- 12

$T_c = Mv^2$ -- 13

$m = AL\rho = 88.64 \times 1.242 \times 1100 = 0.121Kg$

$T_c = 0.121 \times 7.07^2 = 6.05N$

$T_1 = 247.52 - 6.05 = 241.47N$

Belt Tension

$\overline{T_1}\!/_{T_2} = \ e^{u\theta_1 cosec\frac{\alpha}{2}}$ -- 14

Coefficient of Friction $\mu = 0.22$

$\propto = 32^0$

$T_{1}/_{T_2} = 12.18$

Tension on Slack Side T_2

$$T_2 = \frac{241.47}{12.18} = 19.83N$$

Power Transmitted by V-belt

$P = (T_1 - T_2)V$ -- 15

$$P = (T_1 - T_2)V = 7.07 \times (241.47 - 19.83) = 1231.4W$$

Torque on Shaft T_n

$P = \frac{T_n}{W}$ -- 16

$T_n = 17.42Nm$

2.3.4 Design of Feed Layer

Feed Layer Cross Sectional Area

$A = \pi({r_1}^2 - {r_2}^2)$ --- 17

$r_1 = 0.135m$

$r_2 = 0.075m$
$A = 0.04m^2$

Volume of Feed Layer

$V = \pi h(r_1 - r_2)$ -- --- 18

h = 0.5m = $0.094m^3$

Filling Coefficient (φ)

$\varphi = \frac{F \times 4}{\pi D^2}$ --- - 19

F = Feed layer Cross-Sectional Area
D = Diameter of rotating blade = 250 mm = 0.25m
$\varphi = 0.81$

Axial Speed of Feed in the tank

$V = Sn/60$ -- 20

S = Pitch of the Spiral Blade = 95mm = 0.095m
N = rotational Speed of the shaft = 675rpm
V = 1.07m/s

Conveyor Capacity

$Q = 3600F\rho VC$ -- - 21

$\rho = density\ of\ feed\ (cassava) = 840Kg/m^3$
C = Coefficient of inclination = 1 (horizontal inclination of the shaft)
Q = 129,427.2 Kg/s
Other important design equations used for modelling and simulation of equipment are:

2.3.5 Hopper Design and Capacity

To calculate the approximate size of the hopper the following equation is used by Maynard (2013):

$$H = \frac{M}{(\rho_{avg}A)} \quad -- \quad 22$$

Where, H, is the height of the hopper, m is the mass of product (kg), ρ_{avg} is the average bulk density (kg/m^3), A is the cross-sectional area of the hopper (m^2).

Maximum Discharge Rate from the Hopper

The following equation is used:

$$M = \rho A\sqrt{\frac{Bg}{2(1+M)tan\theta}} \quad --- \quad 23$$

Where, M = mass flow rate (kg/s), ρ = bulk density (kg/m^3), A = outlet area (m^2), B = outlet size (m), θ = mass-flow angle measured from vertical (deg.).

2.3.6 Concave screens

There are two main types of concave structure: grid and punch. Selection is done based on the type of materials, hence for effective sieving of the mashed fermented cassava, the punch is preferred. The screening efficiency of concave screen depends mainly on the length and effective separation area of the concave plate. In a certain range, screening efficiency will increase with the length of the concave screen. At the same time, the larger hole ratio of concave plate screen, the higher screen efficiency of concave screen. The hole ratio of concave plate screen A is calculated by equation as used by Zhongkai *et al.* (2017) and Zhifeng *et al.* (2018).

$$A = \frac{a_1 b}{r\pi L} \times 100\% \quad \text{--} \quad 24$$

Where, A is the hole ratio of concave plate screen, a_1 is the number of sieve holes, b is the area of sieve hole, r is the roller radius, L is the roller length.

Diameter of the sieve can also be determined according to Ohwofadjeke (2020):

$$d = \sqrt{\frac{D2(D\pi - 2Co}{Co}} \quad \text{--} \quad 25$$

where, D = average effective diameter of rice grains, Co = coefficient of opening, d upper screen diameter.

2.3.7 Design of Water Jacket and Piping

Water Jacket Capacity

Volume of water jacket V = L x B x H

V = 370 mm x 370 mm x 369 mm

V = 50,516,100 mm^3

V = 0.005m^3

Volume Flow rate of the water (Q)

Volume Flow rate of the water into the feed layer

$$Q = AV \quad \text{---} \quad 26$$

$$A = \pi r^2 = \pi(\frac{d}{2})^2 = 0.0000126m^2$$

$$Q = = 3 \times 0.0000126 = 0.0000378 m^3/s$$

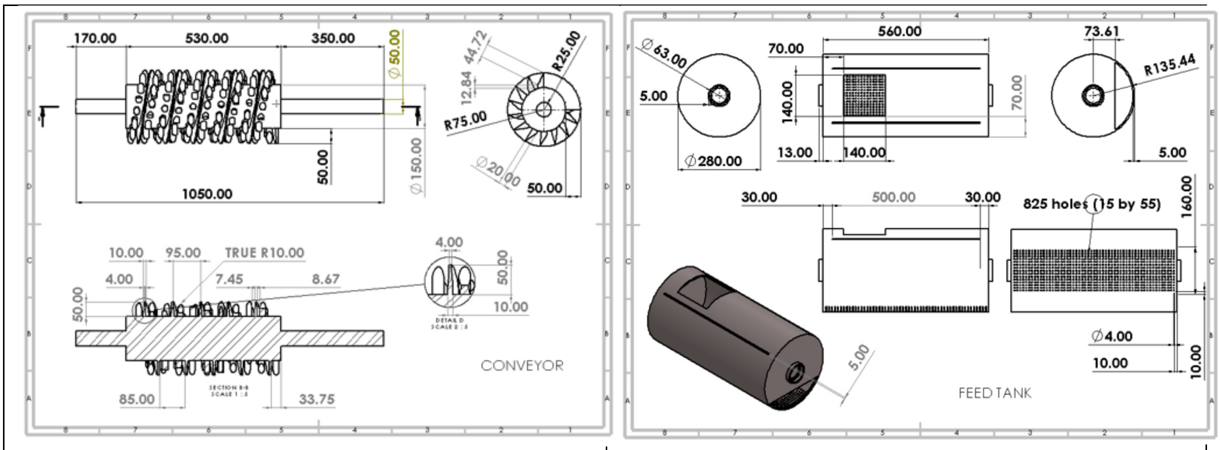
Mass Flow Rate of Water ($\boldsymbol{m}$)

$$m = \rho AV = \rho Q \quad \text{---} \quad 27$$

$$m = \rho AV = \rho Q = 1000 \times 0.0000378 = 0.0378\, Kg/s$$

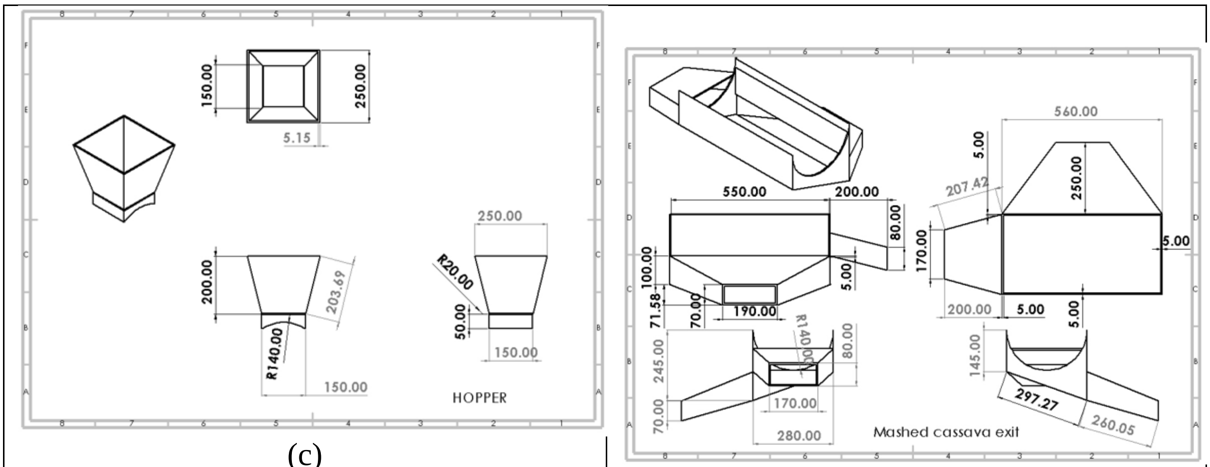
2.4 Design Drawing of the Equipment

Components design of the conceived fermented cassava mashing and sieving equipment for akpu and fufu paste production was carried out using SOLIDWORKS 2021 software, revealed the drawings as shown in figures 1 to 7.



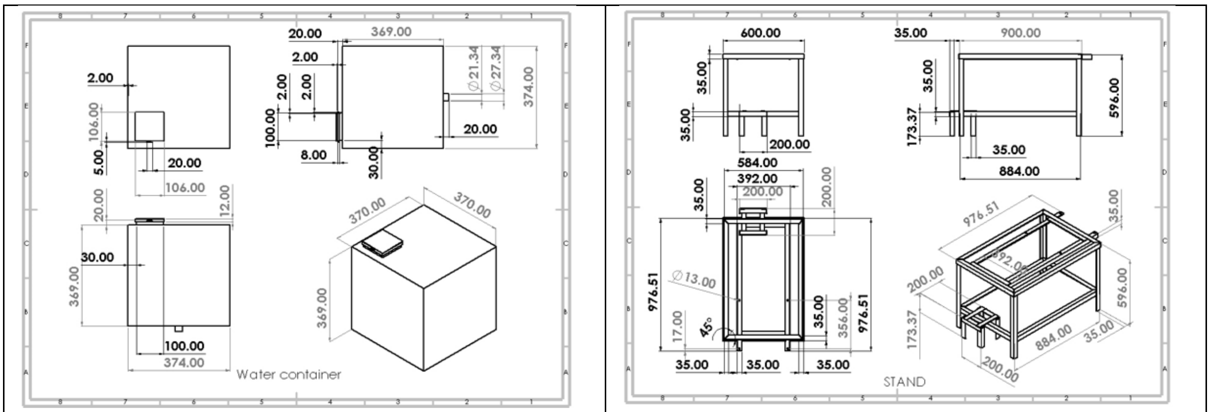
(a) (b)

Figure 1. Showing (a) Conveyor shaft/Auger (b) Feed Lane



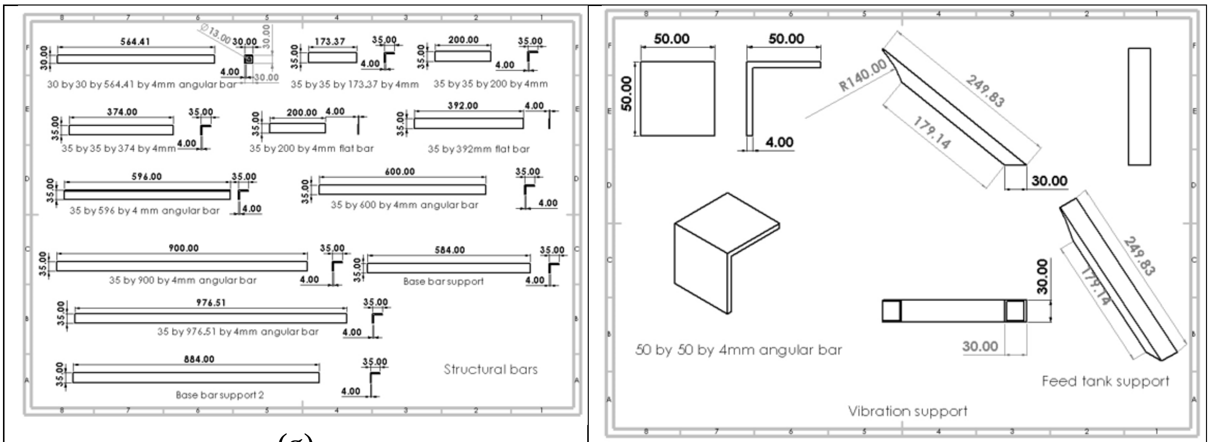
(c) (d)

Figure 2. Showing (c) Hopper and (d) Mashed Conveyor Exit



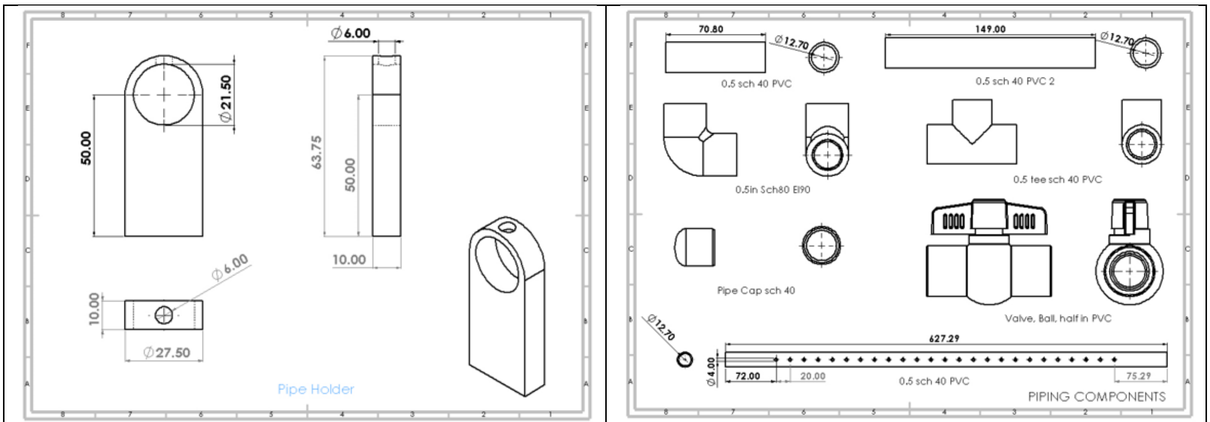
(e) (f)

Figure 3. Showing (e) Water Tank/Jacket and (f) Main Frame



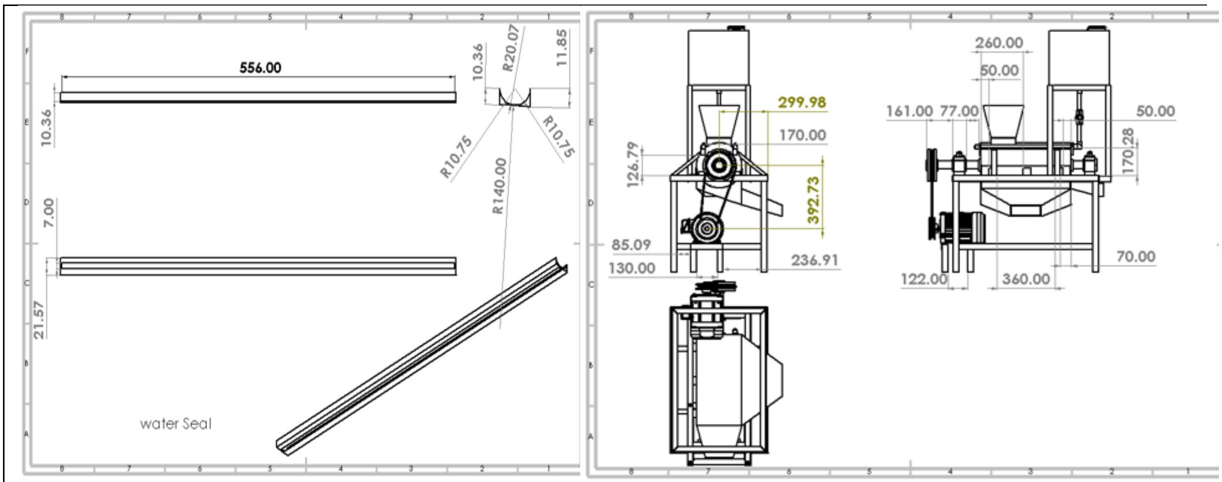
(g) (h)

Figure 4. Showing (g) Structural Bars and (h) Vibration Supports



(i) (j)

Figure 5. Showing (i) Pipe Holder and (j) Piping Components



(k) (l)

Figure 6. Showing (k) Water Seals and (l) Isometric Views of the Machine

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	35 by 600 by 4mm angular bar		2
2	35 by 596 by 4 mm angular bar		4
3	35 by 900 by 4mm angular bar		2
4	Feed Tank		1
5	Conveyor		1
6	AFBMA 20.1 - 37-50 - 40,SI,NC,40_68	Bearings	2
7	Mashed cassava exit		1
8	Hopper		1
9	Heavy Duty V-Pulley	small pulley	1
10	TECO 2HP 145T (electric motor)	TECO AEHH8P	1
11	35 by 976.51 by 4mm angular bar		2
12	35 by 392mm flat bar		2
13	50 by 50 by 4mm angular bar		6
14	Feed tank support		4
15	200mm diameter pulley	Large pulley	1
16	P0.5x10	0.5in PIPE, SCH 40, 12.70 DIA.	6
17	1_2 in	0.5in Pipe cap, welded, sch 40	2
18	Base bar support 2		2
19	User Library-0_500 tee sch 40 PVC	0.5in PVC tee sch 40	1
20	Base bar support		2
21	35 by 35 by 200 by 4mm		2
22	35 by 35 by 173.37 by 4mm		4
23	Water container		1
24	Valve, Ball, half in PVC		1
25	35 by 35 by 374 by 4mm		4
26	door hing		1
27	Pipe Holder		4
28	User Library-d5inSched80El90	90 degree elbow	2
29	30 by 30 by 564.41 by 4mm angular bar		4
30	belt		1
31	B18.6.7M - M6 x 1.0 x 8 Type I Cross Recessed PHMS --8N	M6 Screw	4
32	B18.2.3.4M - Hex flange screw, M12 x 1.75 x 20 --20N		4
33	water Seal		2

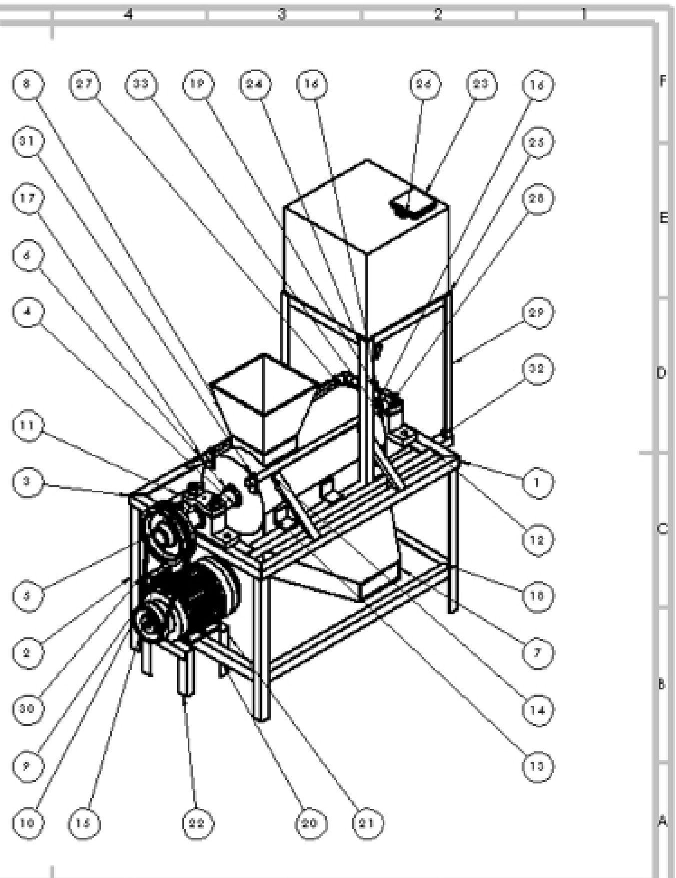


Fig. 7. Designed Drawing of the Fermented Cassava Mashing/Sieving Equipment showing its parts

3.0 RESULTS AND DISCUSSION

3.1 Description of the Equipment

Materials selected for the design and simulation of the fermented cassava mashing and sieving machine include the following amongst others; mild steel, stainless steel, cast iron, cast aluminium and others. Some of the major components of the machine included the following:

i. Main frame: This is the main unit of the machine on which all other components of the machine are supported. It is fabricated with high strength material that will withstand vibration. Mild steel was selected.

ii. Hopper: The hopper is a funnel shaped receptacle through which fermented cassava is fed into the machine. Stainless steel or aluminium plate was selected.

iii. Auger mashing and conveyor: Mild steel was selected for the design. The auger in the equipment is used for mashing and conveying the products during operation. The loosened fermented cassava passes through the enveloped sieving plate into the outlet. While the unfermented cassava root parts and fibers are retained and conveyed to the residue collecting trough as chaff (Kudabo *et al.* 2012).

iv. Sieving chamber: The sieving chamber is designed with caste aluminium to prevent corrosion and subsequent rusting. It enveloped the auger mashing and conveying device. This is designed to be replaceable and is perforated with holes of certain diameter. Different types of sieving chambers could be used to get akpu or fufu with different textures (Kudabo *et al.* 2012).

v. Pulleys and Belt: Pulleys and belt were used for transmission of power within the system.

vi. Shafts: Power within the system is transmitted using shafts made from mild steel.

vii. Bearing: Bearings of different diameters based on the sizes of shafts were deployed in the machine.

viii. Electric motor: The machine was driven by 1-1.5 hp variable speed electric motor, running at about 410 - 1400 rpm. During simulation, variable speed was used in testing the efficiency of the machine.

x: Water Jacket: Provision was made for water jacket installed above machine to ensure supply and circulation of water through gravity within the mashing and sieving chamber to enhance the process.

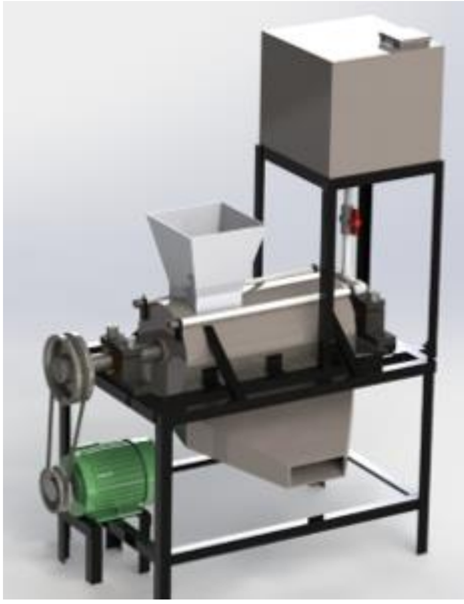


Figure 8. Developed and Optimized Fermented Cassava Mashing and Sieving Equipment

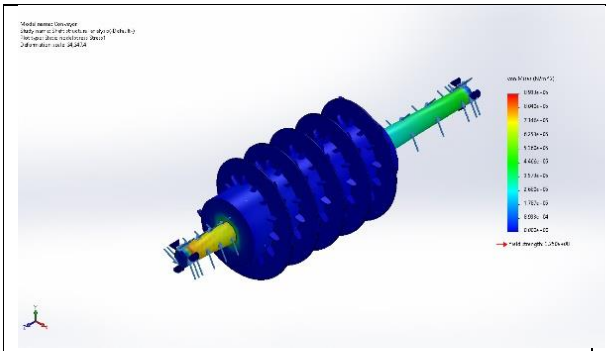
3.2 Finite Element Modelling for Optimizing and Evaluation of the equipment

Mathematical definition of optimisation is obtaining conditions, which give the maximum or minimum magnitude of a function Rao (1996). Three values are required to define the design optimisation problem: design parameters (variables), design constraints and goal (objective) function Akhoroz (1999). In engineering terms, the definition of optimisation is the act of obtaining the best results under given circumstances. There are many deciding factors in engineering design processes, such as minimising costs and weight of a product whilst maximising profit and yield. If these factors are defined as a function of specific variables, that could become an optimum design problem. However, different optimisation methods have been developed for different optimisation problems. Structural optimisation is defined through three categories: (a) mass optimisation (design optimisation), (b) shape optimisation and (c) topological optimisation Haubler *et al.* (2001).

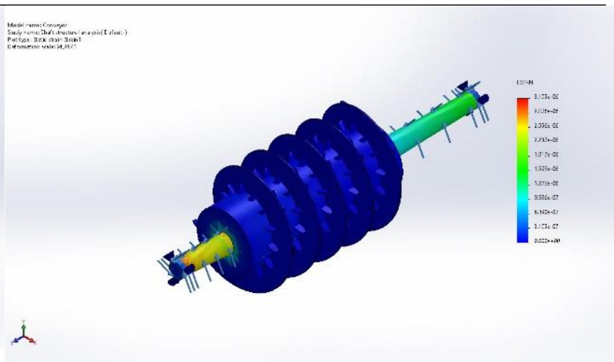
3.3 Structural Optimization of the Equipment

3.3.1 Structural Analysis of the Shaft

Structural optimization of the major parts of the fermented cassava mashing and sieving equipment was carried out using SOLIDWORKS simulation, ANSYS 2021. The images below show structural analysis and optimization of the shaft - mashing and conveying element of the equipment. A Torque of 17.42 Nm was applied on the shaft for its structural analysis. The structural analysis was conducted to determine the minimum and maximum values of Stress, Strain, displacement and factor of Safety of the designed Shaft. The deflections that resulted was scaled to help visualize how deformation occurred on the structure (figures 9 and 10). Each colour on the structure can be traced to a corresponding value on the rectangular tab by the side of the structure. Thus, a minimum and maximum stress of 0.000e+00N/m^2 and 8.933e+05N/m^2 occurred on the shaft. Whereas a minimum and maximum strain of 0.000e+00 and 3.195e-06 resulted respectively; with a minimum and maximum displacement of 0.000e+00mm and 4.333e-03mm correspondingly. Accordingly, minimum and maximum factor of safety were 3.638e+02 and 1.000e+16.

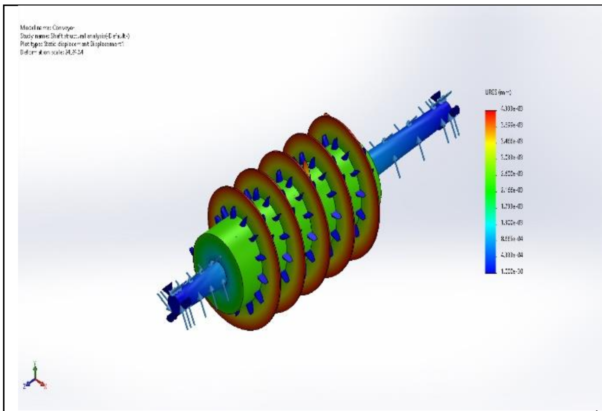


(i) Stress

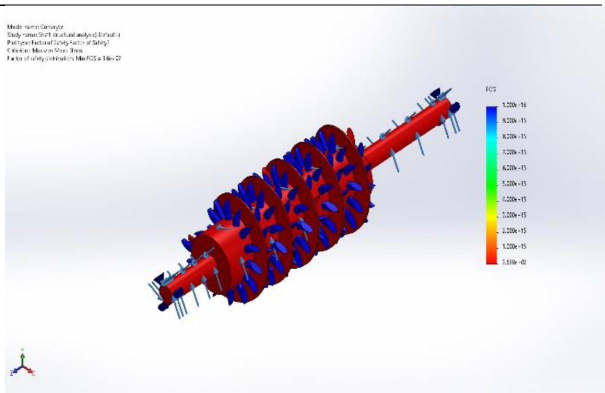


(ii) Strain

Figure 9. Showing minimum and maximum (i) stress and (ii) strain of shaft/auger



(iii) Displacement

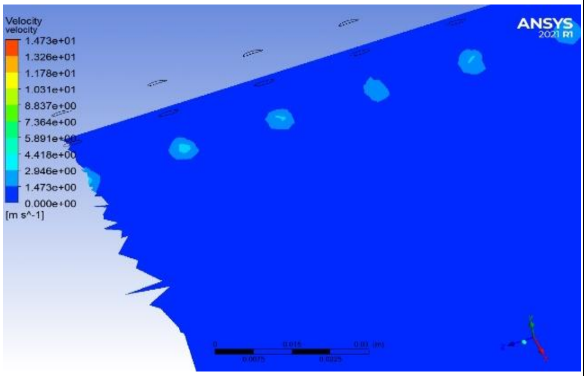


(iv) Factor of safety

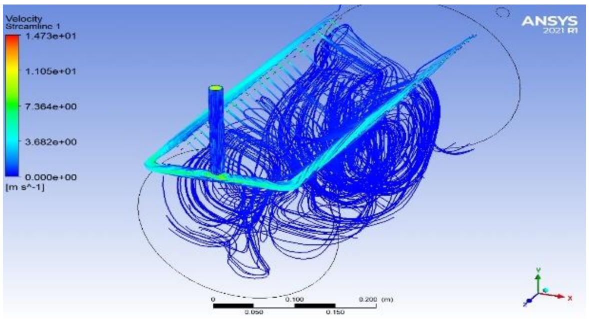
Figure 10. Showing minimum and maximum (iii) displacement and (iv) factor of safety of the shaft

3.3.2 Structural Analysis of the Piping system

After carrying out flow analysis of the water going into the feed layer under gravity, a velocity of 3m/s was estimated to be the inlet velocity at the pipe opening of 4mm diameter as shown by the image (figure 11a) below. The second image (figure 11b) shows the predicted flow pattern of water into the feed layer.



(a) Inlet velocity at pipe opening

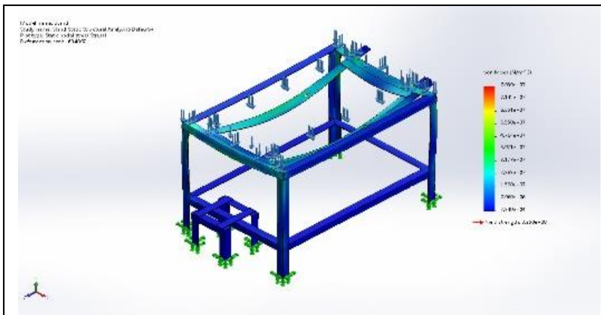


(b) Predicted flow pattern of water into the feed layer

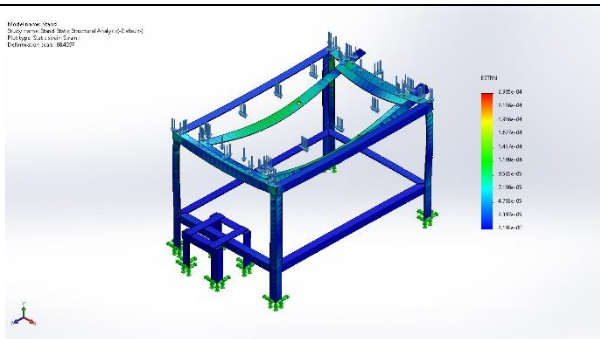
Figure 11. Showing (a) Inlet velocity at pipe opening and (b) Predicted flow pattern of water into the feed layer

3.3.3 Structural Analysis of the Machine Frame/Chassis

Figures 12 (A and B) and Figures 13 (C and D) shows the structural analysis of the machine frame /chassis. The images below show the results for stress, strain, displacement and factors of safety. The deflections that occurred are scaled to help visualize how deformation will occur on the structure. Each Colour on the structure can be traced to a corresponding value on the rectangular tab by the side of the structure. A load of 3000N which is far greater than the actual load to be supported by the stand is used for the structural analysis. The structural analysis was conducted to determine the minimum and maximum values of stress, strain, displacement and factor of safety. As shown below, the minimum and maximum values of stress and strain were 2.349e+04N/m^2 and 7.939e+07N/m^2, and 2.192e-08 and 2.395e-04 respectively. While the minimum and maximum values of displacement and factor of safety were 0.000e+00mm and 1.536e+00mm, and 4.094e+00 and 1.383e+04 respectively.

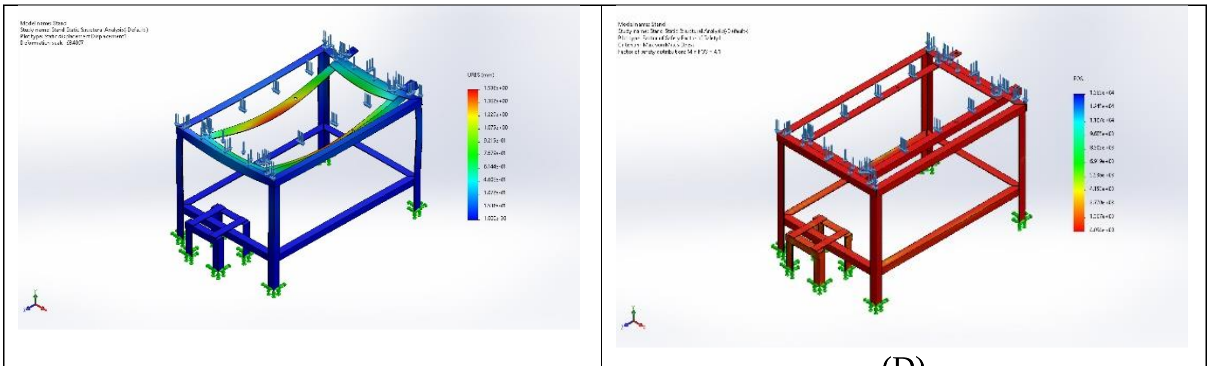


(A)



(B)

Figure 12. Showing Machine frame/chassis showing (A) and (B) Min and Max values of stress and strain respectively



(C) (D)

Figure 13. Showing machine frame/chassis (C) and (D) Min and Max values of Displacement and Factor of safety respectively

3.4 Speed of Shaft and Conveyor Capacity

Optimization and simulation were carried out on the modelled machine using ANSYS 2021 to visualized and predict its performance. The simulation was done using variable speeds of motor at 200, 400, 600, 800, 1000, 1200, 1400 and 1600, 1800 and 2000, that is three treatments with three replications. Table 1. Shows the values of corresponding speeds of shaft, axial speeds of feeder and conveyor capacities were determined. The data was subjected to analysis using IBM SPSS statistics 20. ANOVA showed significant difference between treatments. While both regression and correlation analysis showed R^2 of 1.000, revealing the effect of variable motor speed on the shaft and axial speed of feeder and conveyor capacity.

Table 1. Speed of shaft and conveyor capacity

Treatments/ Replications	Speed of motor rpm	Speed of shaft Rpm	Axial Speed of feeder m/s^2	Conveyor Capacity kg/hr
	200	75	0.11875	6156.00
1	200	74	0.11717	6073.92
	200	77	0.12192	6320.16
	400	150	0.2375	12312.00
2	400	148	0.2343	12147.84
	400	152	0.2407	12476.16
	600	225	0.35625	18468.00
3	600	224	0.35467	18385.92
	600	225	0.35625	18468.00
	800	300	0.47500	24624.00
4	800	301	0.47658	24706.08
	800	299	0.47342	24541.92
	1000	375	0.59375	30780.00
5	1000	375	0.59375	30780.00
	1000	372	0.58900	30533.76
	1200	450	0.71250	36936.00
6	1200	449	0.71092	36853.92
	1200	451	0.71408	37018.08
	1400	525	0.83125	43092.00
7	1400	525	0.83125	43092.00
	1400	524	0.82967	43009.92
	1600	600	0.95000	49248.00
8	1600	595	0.94208	48837.60
	1600	599	0.94842	49165.92
	1800	675	1.06875	55404.00
9	1800	671	1.06242	55075.68
	1800	674	1.06717	55321.92
	2000	750	1.18750	61560.00
10	2000	751	1.18908	61642.08
	2000	753	1.19225	61806.24
Std. Dev.	**584.2**	**218.9**	**0.3466**	**17968.5**

4.0 CONCLUSION

Development using finite element modelling and optimization of fermented cassava mashing and sieving equipment was done using SOLIDWORKS 2021 3D Computer Aided Design (CAD) software, and imported to ANSYS 2021, a finite element analysis software. Simulation of the machine was carried out. The machine had a capacity, 140-160 kg/hr, average sieving speed, 415 rpm, torque, 17.42Nm, minimum and maximum stress of 0.000e+00N/m^2 and 8.933e+05N/m^2 respectively, minimum and maximum strain of 0.000e+00 and 3.195e-06 respectively, with minimum and maximum factor of safety, 3.638e+02 and 1.000e+16 respectively. While the average speed of shaft and axial speed of feeder were found to increase with the speed of motor. There is urgent need to work towards mechanizing the processing of cassava into akpu and fufu paste to make its production effective, efficient and timely, leading to products availability, accessibility, affordability and storability – a step towards HiTech Agriculture and food security and sustainability in the face of Pandemic.

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REFERENCES

Adetola, A. O. and Akindahunsi, D. L. (2020). A Review on Performance of Rice De-stoning Machines. Journal of Engineering Research and Reports. 13(1): 1-11.

Adisa, A. F., Eberendu, N. O., Aderinlewo, A. A. and Kuye, S. I. (2016). Performance evaluation of a developed rice-processing machine. Journal of Agricultural Engineering 2016; volume XLVII:506, pp 171-176.

Ajis, T. and Lanya, B. (2018). Design, Fabrication and Testing of Hammer Thresher. Asian Journal of Applied Science and Engineering, Volume 7, No 1. Pp. 21-28. ISSN 2305-915X(p); 2307-9584(e).

Akhoroz, E. (1999). Design Optimization with Ansys FEM Code. *M.Sc. Thesis*, Istanbul Technical University, Ýstanbul, Turkey.

Amare, D., Yayu, N. and Endeblihatu, A. (2015). Development and Evaluation of Pedal Thresher for Threshing of Rice. *American Journal of Mechanics and Applications.* Vol. 3, No. 4, 2015, pp. 27-32. doi: 10.11648/j.ajma.20150304.11.

Ani, O. I., Onoh, G. N., Akpor, O. J. and Ukpai, C. A. (2020). Design, Development and Performance Evaluation of a Mobile Rice Threshing Machine. International Journal of Emerging Trends in Engineering and Development Issue 10, Vol.2. pp. 7-17. ISSN 2249-6149.

Asante-Pok, A. (2013). Analysis of incentives and disincentives for cassava in Nigeria. Technical notes series, MAFAP, FAO, Rome.

Bariya, N. D. Patel, H. Patel, R. Patel, H. Patel (2019). Study and Modification of Rice Threshing Machine. IJRAR March 2019, Vol. 6, issue 1. pp. 217-220.

Caringal, B. K. M., Zyrom S. D. R., Kyle, V. R. M. and Nestor, C. C. (2016). Design and Development of Rice Milling and Grinding Machine. EPH - International Journal of Science and Engineering, 2(8). Pp. 6-14.

El-Sharkawy, A. M. (2006). International Research on Cassava Photosynthesis, Productivity, Eco-physiology and Responses to Environmental Stresses in the Tropics. Photosynthetica, 44 (4): 481-512..

Gbasouzor, A. I. (2015). Development of a Motorized Akpu Milling Machine Design to Improve Poverty Eradication in Nigeria. Proceedings of the World Congress on Engineering and Computer Science 2015 Vol II. WCECS 2015, October 21-23, 2015, San Francisco, USA.

Haubler, P., Emmrich, D., Müller, O., Ilzhöfer, B., Nowicki,L. and Albers, A. (2001). Automated Topology Optimization of Flexible Components in Hybrid Finite Element Multibody Systems Using ADAMS/Flex. and MSc. construct. *16th European ADAMS User's Conference,* Institute of Machine Design, University of Karlsruhe, Germany.

Hughes TJR (2000). The Finite Element Method: linear, static and dynamic finite element analysis. Dover publisher.

IITA (2005). The uses of Cassava. Published by the Integrated Cassava Project of the International Institute of Tropical Agriculture, Ibadan, Nigeria, pp. 87, 98, 95.

Jagota, V., SETHI, A. S. and KUMAR, K. (2013). Finite Element Method: An Overview. Walailak J Sci & Tech.; 10(1): 1-8.

Jayasuriya, H.P.W. and Salokhe, V.M. (2001). Review Paper. A review of soil-tine models for a range of soil conditions. *Journal of Agricultural Engineering Research*, **79:** 1-13.

Kolawole, O. P. and Agbetoye, L. A. S. (2007). Engineering Research to Improve Cassava Processing Technology. International Journal of Food Engineering, Vol. 3 issue 6 Article 9: 1- 15.

Kolawole, O. P., Agbetoye S. L., Ogunlowo, A. S. (2010). Cassava Mash Process Handling. 2nd Conference on Chemical Engineering and Advanced Materials (CEAM) VIRTUAL FORUM, Praise Worthy Prize S.r.l., November 15th - 26th, 2010.

KPMG (2019). Rice Industry Review. https://home.kpmg/ng/en/home/insights/2019/10/rice-industry-review.html. Retrieved September 15, 2020.

Kudabo, E.A; Onipede, E.A and Adegbenro, O. A (2012). Design, Fabrication and Performance Evaluation of an Improved Cassava Mash Sifter. Journal of Agriculture and Veterinary Sciences. Volume 4, pp. 53-64.

Madenci, E. and Guven, I. (2007). Finite element method and application in engineering using ANSYS. Springer publisher.

Maynard, E. (2013). Ten Steps to an Effective Bin Design. American Institute of Chemical Engineers (AIChE). www.aiche/cep. Retrieved September 18, 2020.

Mehmet Topakci, Huseyin Kursat Celik, Murad Canakci, Davut Karayel and Allan Rennie (2010). Structural Optimisation of a Subsoiler. Pak. J. Sci. Ind. Res. 2010 53 (5) 281-287.

Nakasone, Y (2006). *Engineering analysis with Ansys software*. Oxford Burlington, MA: Butterworth-Heinemann. ISBN 978-0-7506-6875-0.

Nam H. Kim, Bhavani V. Sankar and Ashok V. Kumar (2018). Introduction to Finite Element Analysis. John Wiley & Sons, Inc. New York.

Ohwofadjeke, P. O. (2020). Development of Low Cost Rice De-Stoning Machine. International Journal of Engineering and Applied Sciences (IJEAS). Volume-7, Issue-1, pp. 5-12. ISSN: 2394-3661.

Okunola, A. A., Bamgboye, A. I., Olayanju, A., Osueke, C. O. and Alhasan, E. A. (2018). Development of A Rice Cleaner Cum Grader For cottage Industry Processors in Nigeria. International Journal of Mechanical Engineering and Technology, 9(11), pp. 2339–2351.

Olugboji, O. A. (2004). Development of a Rice Threshing Machine. AU J.T. 8(2): 75-80.

Olugboji, O. A. and Jiya, J. Y. (2014). Design and Fabrication of Rice De-Stoning Machine. Food Science and Technology 2(1): 1-5. DOI: 10.13189/fst.2014.020101.

Ovat, F. A. & Odey, S. O. (2019). Development and Performance Evaluation of Coconut Dehusking Machine. The International Journal of Engineering and Science (IJES), 8(10), pp. 15-23.

Owolarafe, O. K., B. O. Adetifa, A. C. Oyekanmi, T. G. Lemikan and T. M. Samuel (2018). Assessment of Fufu Production Technologies in Ogun State, Nigeria. Arid Zone Journal of Engineering, Technology and Environment, Vol. 14(4): 547-558, Electronic ISSN: 2545-5818.

Oyewole, O. A. and Isah, P. (2012). Locally fermented foods in Nigeria and their significance to national economy: a review. Journal of Recent Advances in Agriculture, 1(4): 92-102.

PWC (2020). Harnessing the economic potential of cassava production in Nigeria. Accessed online on December 27, 2020. https://www.howwemadeitinafrica.com/.

Rao, S.S. (1996). Engineering Optimization-Theory and Practice, 3rdedition, John Wiley and Sons Inc., New York, USA.

Ruekkasaem, L. and Sasananan, M. (2018). Optimal Parameter Design of Rice Milling Machine Using Design of Experiment. Materials Science Forum, *Vol. 911, pp 107-111*.

Sharma, P.C. and Aggarwal, D. K. (2006). *Machine Design.* S.K. Kataria and Sons, Nai Sarak, Delhi, pages 19-58, 483-839.

Uthman, F. (2011). Design and fabrication of cassava lump breaking and sieving machine. Oasis Journal of Research and Development, 1(2),42 –50.

Zhifeng, D, Zhongkai C, Hua Z and Jin Z, (2018). Design and Experiment of Rasp Bar and Nail Tooth Combined Axial Flow Corn Threshing Cylinder:Transactions of the CSAE 34(2018)28 -34.

Zhongkai C, Zhifeng D, Zhoujin, (2017). Design and Research on 5TYS280 corn threshing and cleaning test bench, Journal of Agricultural Mechanization Research. 39(2017)113–117.