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Development of a Dual Mechanized Chicken De-Feathering and Yam Pounding Machine

I. D. Erhunmwun[1], F. Erhabor[2], O. Ayala[3], O. Uwagboe[4], C. O. Eferetin[5], D. Oshie[6]
Department of Production Engineering, Faculty of Engineering, University of Benin, Benin City

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ABSTRACT

The demand for poultry meat world-wide and pounded yam most especially in Africa has imposed great responsibility on poultry and yam processing industries, and especially in de-feathering operation and pounding of yam which are usually achieved manually in Nigeria and other part of Africa. Therefore, the need to have a machine to carry out defeathering of poultry and pounding of yam becomes sacrosanct. This study was focused on design, construction and performance evaluation of a dual mechanized chicken de-feathering and yam pounding machine using locally available materials. The design was based on market weight of chicken. The selected materials used to fabricate the machine were sheet metals, stainless steel, belt and shaft. The length of yam beater is 200mm x 30mm x 5mm. The diameter of driving pulley is 70mm. The diameter of driven pulley is 210mm. The length and breadth of the frame is 580mm x 580mm. The performance evaluation result showed that chicken variety had effect on the de-feathering efficiency, throughput capacity and energy consumption of the machine. Scalding time and scalding temperature did not significantly affect through put capacity and energy consumption but scalding temperature had significant effect on de-feathering efficiency. The average efficiency is about 81.5 % and the total efficiency is about 83.5%.

1. Introduction

The earliest patent found for a feather-plucking machine was issued in 1891 to a Virginia man. This foot treadle-powered device had two rollers that turned in opposite directions. The upper of the two rollers was spring-loaded to press firmly against the lower while allowing it to rise when feathers passed between the rollers.

In the tropical West Africa region, including Nigeria, not much had been done in this research area. However, Adetola designed and developed a household poultry de-feathering machine for boilers. He observed that tearing of the carcass during plucking process is the major problem associated with bird dressing; He however added that this problem was taken into account during the design process of the developed machine [1].

An evaluation was carried out on feather plucking machine using two breeds of birds namely Isa brown and Cockerel at machine speed of 225, 312, 369 and 426 rpm. With a scalding time of 30, 60 and 90 seconds respectively. The result of the work showed that the developed machine performed better when the speed was increased with cockerel having the better plucking result [2].

Also, Adeyinka and Olawale carried out performance evaluation of chicken de-feathering machine for small scale farmers. They observed that it took the machine about 25 seconds to de-feather poultry birds with a machine speed of 300 rpm. However, they failed to indicate the specie, type and age of birds that were evaluated [3].

In a related development, Adetola considered birds raised in South Western Nigeria with a view to establishing the optimal scalding temperatures of both the exotic and local breeds. The result of their finding showed that for local breeds, the scalding temperature of 800C – 850C is adequate, while those of the exotic breed falls between 650C to 700C [1].

Again, Ugwu and his crew carried out optimization and performance evaluation of a developed feather plucking machine. He showed that at 400 rpm the machine was able to pluck completely at an average time of 22.8 seconds. He added that the speed of the machine and the species of poultry birds affects the efficiency of the machines [4].

In South-Western Nigeria, [5] designed and developed a bird de – feathering machine capable of de – feathering 360 mature birds in an hour, irrespective of the type of bird involved. He added that the machine recorded about 96 percent when tested with under controlled condition.

Nguyen [6] investigated the optimal operational parameters for a chicken slaughtering system in Vietnam. He recommended an optimal scalding temperature of about 67 degree Celsius and an optimum scalding time of 80 seconds (Ashiedu, F. I. et al, 2018).

In 1975, Herbert and Kenwood mixing machines were introduced into the market for use. This however, gave rise to the conception and development of the yam pounding machine. The Herbert and Kenwood mixers were not originally designed for yam but gradually faded away due to its inefficiency in operation such as longer time in meshing operation and overheating of the machine which had to be stopped intermittently for cooling and the non-homogeneity in bond formation after meshing.

Among the researchers that have worked on Yam Pounders [7-10] Ayodeji and Abioye, (2011); Olaoye and Oyewole, (2012); just to mention few names.

At present there exists different makes of yam pounding machine. One type cooks and pounds while another pounds only. The problem associated with them is that they are expensive to operate and acquire.

Odior and Orsarh [7] designed a pounding machine that beats using the process of cutting to pieces as well as crushing and turning to produce the natural taste. The shortcoming of the machine was that the shaft was made from mild steel; mild steel is not friendly to health when consumed, the persistent usage of the machine through the rotation of the shaft will lead to wear of the mild steel which will allow the fallen fillings mix with the yam in process, this when consumed overtime leads to build up of material inside the body and at the end results to cancer. Also there was no air vent and the heat produced by the electric motor has no exit vane, so it had to be stop intermittently like by the early generation pounding machine.

After a period of two years, Osueke in 2010 improved on the design made by Odior by incorporating a steaming chamber inside the pounding machine. Some of the setbacks in the machine was overheating problem continued, high cost of production and manufacturing, high cost of Purchase, only a particular species of yam was known to pound well with this machine that is the water yam and the bulky nature of the machine.

Against this background, this work seeks to design and fabricate a yam pounding machine component for small scale processors. To evaluate the performance of the machine component, select materials which are relatively cheap and whose service area is applicable to the design. With this, the overall cost of the machine is reduced.

The aim of this project is to develop a dual mechanized household poultry de-feathering machine and a household yam pounding machine that will perform efficiently, effectively, give a good appearance and quality to birds being de-feathered and yam's been pounded.

2. Materials and Method

The design was targeted towards achieving the following: producing good and quality dual component machine for defeathered chicken and pounder yam with high probable efficiency, availability of raw materials and cost of the machine.

Selection of materials depends on many features such as the intensity and type of stress to which the components are subjected to, whether it is flexible or rigid or it is to experience high temperature or corrosive action and how it leads itself to processes of manufacture, i.e. forging, machine etc. Therefore, the designer selection will be influenced the following factors: strength, weight, appearance, manufacture, cost of production.

2.1. Machine fabrication

The fabrication sequence of the machine is as follows: fabrication of both the stainless steel Plucker basin and Yam Basin, Construction of frame, Erection of bearings/sheave on shaft, installation of electric motor, fixing of Rubber finger Pluckers in the defeathering basin, fixing the beater the yam basin, finishing and painting.

The frame of the machine is of over-all dimension 580 X 580 X 580mm for both the plucking component and the pounding component. The frame was being constructed in such a way that it would provide support for the electric motor, shaft, pulley, belt, and bearings. The electric motor of capacity **1.5kW, 1440rpm** by capacity was installed to provide adequate setting. A sheave of **70mm** nominal diameter was fixed on the shaft of the motor which would transmit power to the shaft through the belt. The motor was being attached to the frame by using Hex head bolt and nut. The shaft of diameter **20mm** and length **595mm** was erected vertically at the centre of the main frame supported by two bearings and brazed at the top and bottom of the frame. Attached to the shaft is a driven sheave of diameter **210mm** which reduces the actual speed of the electric motor because it is greater than the sheave of the motor.

The plucker basin is cylindrically shaped which has both top diameter and bottom diameter of 508mm, and a height of 450mm. The basin was developed from Stainless Steel. The top and the bottom of the basin are concentric with the rubber plucker plate. Holes of diameter 23mm was drilled on the plate which was used to hold the rubber Pluckers. Also, holes of diameter 23mm were being drilled on galvanized steel plate of diameter 320mm, thickness 1.4mm.

As well, the pounding basin is a cylinder which has a top and bottom diameter of 280mm, and a height of 184mm alongside a steel thickness of 10mm. The basin was developed from Stainless Steel. The top and the bottom of the basin are concentric with the beater as the like the defeathering basin. A hole of diameter 25mm was drilled through the bottom of the basin for the entry of the shaft. The beater was of length 190mm and width 20mm.

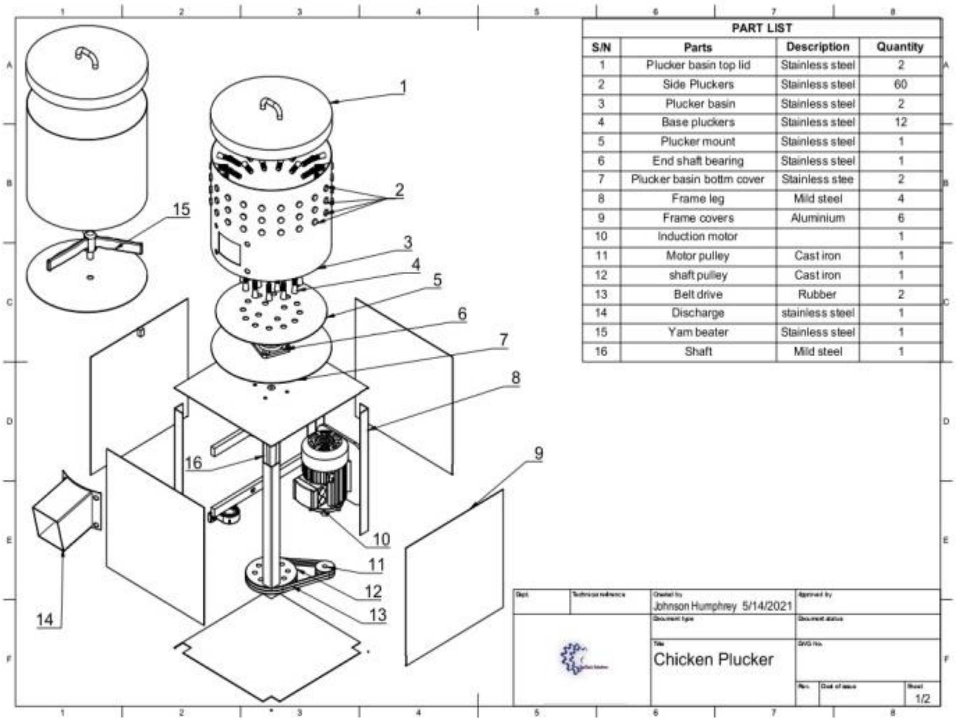

Fig. 1: Showing the de-feathering and pounding machine with parts

2.2. Principle of Operation of the Machine

When working on the defeathering component, Scalded birds are conveyed manually without delay to the de-feathering basin. The machine consists of an electric motor transmitting torque to the sheave by a belt. Torque is transmitted to shaft supported by two bearing assembly. The shaft drives the plucker plate rotating against a stationary basin consisting protruding rubber pluckers as well as the plucker plate. Rubber pluckers get a grip on the feathers as the plate is rotating against the basin, thus removing the feathers from the birds. The feathers are ejected from the basin through an opening at the bottom of the plucker basin.

When working on the pounding component, boiled yam piece are conveyed manually without delay to the pounding basin. The machine consists of an electric motor transmitting torque to the sheave by a belt. Torque is transmitted to shaft supported by two bearing assembly. The shaft drives the beater rotating against a stationary basin. The Yam Beater get a grip on the yam piece as it rotate against the basin, thus pounding the yam piece.

2.3. Design Calculations

Certain calculations were made on certain parameters so as to make correct choices in selecting them. Design calculations were carried out on the following: Sheave (Pulley), Belt, Shaft, Yam Beater, and Plucker Basin.

2.3.1. Sheave System:

The sheave system comprises of two sheaves. The bigger, being the driven, is mounted on the shaft and the smaller sheave, the driver, is mounted on the electric motor. Since the diameter of the sheave on the motor is smaller, then there is reduction in speed (rpm) on transmission to the larger sheave attached to the shaft. The speed of the motor is 1440 rpm. In order to calculate the speed that would be transmitted to the shaft, the following analyses were been carried out:

The analytical equations were gotten from Khurmi R.S, and Gupta J. K, [12]

$$\mathbf{N_1D_1 = N_2D_2} \quad (1)$$

Where: N_1= Speed of the motor, 1440 rpm; D_1= Diameter of the motor sheave, 70 mm; N_2= Speed of the shaft/shaft sheave; D_2= Diameter of the shaft sheave, 210 mm; N_2= 100,800/210 = 480rpm.

Therefore, the speed that the motor will transmit to the shaft/shaft sheave through the belt is 480 rpm

2.3.2. Belt Design and Selection:

A belt and pulley system was used to transmit the power and torque from electric motor section to both the plucking chamber and the yam pounding section.

b = 12mm, t = 8mm, w/l = 1.06;D_1 = diameter of driving pulley, 70mm; D_2 = Diameter of driven pulley, 210mm; P_{belt} = 1250kg/m^3, P = 746 Watts; Rotational Speed of driver pulley, N_1 = 1440rpm; S_s = 3.0MPa, μ = 0.25; Groove angle of pulley = 30° = 2β

Length of belt, $$\mathbf{L} = \frac{\pi(D_1 + D_2)}{2} + 2C + \left(\frac{(D_1 + D_2)^2}{4C}\right) \quad (2)$$

But C = Unknown

$$\mathbf{C = max}\left(\frac{3D_1}{2} + \frac{D_2}{2}\right) \quad (3)$$

$$= \max\left(\frac{3\times 70}{2} + \frac{210}{2}\right) = \mathbf{210mm.}$$

We use a centre distance of 250mm.

$$L = \frac{\pi(70+210)}{2} + 2\times 250 + \left(\frac{(70+210)^2}{4\times 250}\right) = \mathbf{1018mm}$$

A standard belt is then chosen as the nearest match is 1026 mm which is type **A43 belt.**

Tension on tight side of belt T_1:

$$\mathbf{T_1 = btS_s} \quad (4)$$

$T_1 = 0.012 \times 0.008 \times 3.0 \times 10^6$ = **288N.**

Angle of Wrap:

$\boldsymbol{\theta_1 = 180 - 2\alpha}$,

$$\boldsymbol{\theta_2 = 180 + 2\alpha} \quad (5)$$

$$\textbf{Sin } \boldsymbol{\alpha} = \left[\frac{d_2 - d_1}{2C}\right] \quad (6)$$

α = Sin-1(0.28) 16.260°

θ_1 = 180 – 2(16.260) = **147.48°** and

θ_2 = 180 + 2(16.260) = **212.52°.**

Tension on slack Side of belt T_2:

To evaluate the tension on the slack side, we use the relationship:

$$2.3\log\left(\frac{T_1}{T_2}\right) = \mu\theta_1\text{cosec}\beta \quad (7)$$

$$2.3\log\left(\frac{T_1}{T_2}\right) = 0.25\text{x } 147.4 \text{ x } \frac{\pi}{180}\text{cosec } (15)$$

T_2 = 23.94N

T_1 = 288N, T_2 = 23.94N.

Power transmitted through the belt:

$$\mathbf{P = (T_1 - T_2)\ V =} (T_1 - T_2)\frac{\pi DN}{60} \quad (8)$$

$$= (288 - 23.94)\ \frac{\pi \times 1440 \times 70}{60}\ \mathbf{= 1392.969\ Watts.}$$

2.3.3. Bearing Design and Selection

The single row deep groove ball bearing was chosen because of its high load carrying capacity and suitability for high running speed. Considering the diameter of the shaft which is 25mm, a bearing of bore 25mm was then used for this calculation. The specific static load rating or capacity C_o.

$$Co = \frac{1}{5} \times ko \times i \times z\cos\alpha Dw^2 \quad (9)$$

Where: C_o = Specific Static Load rating or Capacity = 10kN; K_o = Factor depending on the type of bearing. = 12.3; D_w = Diameter of the ball; α = Nominal angle of contact = 0; i = Number of rows of ball in any one bearing = 1; z = Number of balls per row in the groove = 6

$$Ko = \frac{Q\max}{\text{Dw}^2} \quad (10)$$

Qmax = Maximum bearing load.

And the above data (Budynas et al, 2008) the ball diameter can be calculated

$$Dw = \sqrt{\left(\frac{Co \times 5}{Ko \times i \times z\cos\alpha}\right)} \quad = \sqrt{\left(\frac{10 \times 10^3 \times 5}{12.3 \times 1 \times 6\cos 0}\right)} = \mathbf{26.02896mm} \qquad (11)$$

Then the maximum bearing load Q_{max} becomes:

$Q_{max} = K_o \times D_w^2 = 12.3 \times 677.5067751 =$ **8333.333N**

A bearing of 6206, which is of an inner diameter of 25mm and outer diameter of 55mm, then was chosen. The bearing number interpreted as 200 means a light bearing of bore that is inner diameter of 05× 5 = 25mm. Also, in the selection of this bearing, the radial load of which the bearing can carry was put into consideration. However, for the ball lubrication, grease is used at low and medium speed when the temperature is not over 20ºC while oil is used at higher speed. Hence, for this design, grease is regarded as the most satisfactory lubricant.

2.3.4. Turning Effect

The Turning Effect is stated below according to Habart and Kenwood, 2007

Torque Computation:

F = T x D (12)

Where T = Torque, F = Force, D = Distance from centre of pivot

Torque from weight of beater with yam weight inclusive

T = 3.391 x (0.04 + 0.0125) = **0.177975Nm**

Torque from force acting on the surface of the beater

T = 40.4008 x (0.04 + 0.0125) = **2.121Nm**

Torque of RHS of beater = 0.177975 + 2.121 = **2.299Nm**

Total Torque of beater = 2 x 2.299 = **4.598Nm.**

2.3.5. Power Requirement

The Power required is obtained as stated below according to Odior A.O, et al, 2012

This is given as:

$$\text{Power (P)} = \frac{2\pi NT}{60} \qquad (13)$$

Where N = speed of revolution and T = Torque

Using a speed reduction factor of 1:31; N = 1440/3 = **480rpm.**

P = $\frac{2\times\pi\times 480\times 4.598}{60}$ = **231.121Watts.**

Hence considering the factor of safety 1.5, the minimum power requirement for the design; =231.121 ×1.5=346.681 Therefore, based on the above calculations an electric motor of 1 hp with speed 1440 rpm, phase 3 and voltage of 440 V was chosen.

2.3.6. Analysis of the Shaft Design

The structure screwed shaft can be designed for strength, rigidity and stiffness as considered for most shaft members. If these are to be considered as necessitated in our work, one or all of the followings has to be put into consideration:

a. If the shaft is subjected to a twisting moment or torque only.
b. If it is subjected to bending moment only.
c. If it is subjected to fluctuating loads.
d. If it is subjected to combined twisting and bending moments.
e. If it is subjected to axial loads in addition to combined torsion and bending loads.

In designing shaft on the basis of strength, shaft subjected to axial loads in addition to combine torsion and bending loads was taken into consideration (Khurmi R.S et al, 2006). Consideration was given to the axial load (F) which comprises the plate that was being attached to the shaft, likewise the weight of the chicken to be de-feathered.

Since mild steel is used for the shaft, maximum shear stress theory is used for the design of shaft diameter and it is stated below according to J. K. Gupter, 2008;

$$D^3 = \frac{16}{\pi S_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \qquad (14)$$

Where; K_b = combined shock and fatigue factor applied to bending moment; K_t = combined shock and fatigue factor applied to torsional moment; M_b = Bending moment (Nm); M_t = Torsional moment (Nm); S_s = Allowable shear stress

3. Results and Discussion

3.1. For the Chicken Plucking Chamber

After the fabrication and construction of the machine chamber, various tests were done, and results taken for running time. For a successful de-feathering, the bird must be scalded in the right temperature to avoid damage to the skin of the birds during de-feathering.

Table 1: Time and weight analysis

Test No	Initial weight (kg)	Final weight (kg)	Weight of feather removed (kg)	Time (sec)
1.	1.60	1.47	0.13	45
2.	1.60	1.49	0.13	40
3.	1.56	1.40	0.16	30

From Table 1 the average feather removal time was estimated as 38.3 Seconds. This value indicated that the removal rate for this design is approximately 94birds/h. However, this value absolutely depends on the operator's judgment or satisfaction since the birds are rotating at high speed, and it therefore becomes difficult to adequately observe when all feathers have been removed. The type of bird also affects the removal rate as this value applies to chicken. From (B. Bhandari, 1994) study, manually feather removal rate was estimated at 12birds/h. This therefore highlights the advantage of this design as an average output rate of 94birds/h was achieved. The machine was designed to accommodate one birds per process. From physical observation, with low scalding temperatures it becomes difficult to completely remove the feathers hence higher motor speed is required to reduce scalding time. Similarly, for higher scalding temperatures, there is a risk of the skin being cooked. This in turn makes feather removal difficult as the feather appeared to cut out parchment of skin tissue from the chicken. The optimum temperature required to achieve acceptable results however depends on the type of bird being processes. For the locally breed chicken, substantial plucking force difference was noticed between 75^{o}C and 80^{o}C while for temperatures greater than 80^{o}C, the required plucking force remained fairly constant. For Exotic birds, the optimum recorded temperature ranged between 65^{o}C to 75^{o}C. After testing, improvements were made to the current design. First, rotating parts were adjusted for the reduction of noise and vibrations in parts such as the belts. To achieve this, dampers were installed on the motor, alignment of shaft was done, and the bearings were all replaced.

3.1.1. Efficiency of the chicken Plucking Chamber

Table 2: Determination of the Efficiency of the Chicken Plucking Chamber

S/N	Initial Mass m_i	Final Mass m_f	Efficiency
1.	0.270	0.231	85.56
2.	0.300	0.260	86.67
3.	0.260	0.230	87.79

Average Efficiency = (85.56 + 86.67 + 87.79)/3 = 86.67%.

Different values of efficiency for the three trials made are significantly high. However, the last trial is exceptionally higher than each of the other two trials all because of one or two adjustments in the construction noted during the first two trials. The machine will continue to produce in replicate at higher efficiency consistently.

3.2. For the Yam Pounding Chamber

The constructed yam pounding machine was tested by pounding two different types of cooked yams with the machine. Yam of weight 2kg was used and cut into small sizes.

Each yam specimen was washed, peeled, cut into small slices and cooked for a period of about 45 minutes. The cooked yam slices were then packed into the bowl or pounding chamber of the machine. The machine was then operated to pound the cooked yam slices for a stipulated time which was not the same for the different yam specimens. Test for hardness was conducted on each specimen to know if it was necessary to add water to the pounded yam, in order to achieve a desired texture. The text results are presented in Table 3.

Table 3: Test results on different yam specimens

S/N	Yam Specimen	Pounding Time (Min)	Test For Hardness Time (Min)	Total pounding time (min)	Quality
1.	White yam	4	1	5	Starchy
2.	Water yam	2	1	3	Semi – starchy.

*Test for hardness: manually stopping the machine and feeling the pounded yam texture with hands.

It was however observed that while the water yam took a period of 2minutes for pounding and 1 minute for hardness testing, the white yam took a period of 3minutes for pounding and 1 minute for hardness testing. It was also observed that the fabricated machine chamber also eliminates the tedious and laborious indigenous process of preparing pounded yam.

3.2.1. Efficiency of the Yam pounding Component

The optimum pounding efficiency of the machine was observed to be 94.90% at the feed rate of 2 kg of cooked yam and pounding time of 1.7 minutes respectively. (Adebayo AA et al, 2014) reported threshing efficiency of 93% at feed rate of 1.8kg/min using electric motor as power for the pounding machine. This higher value of 94.90% can be attributed to high horse power of the prime mover driving the beaters in the pounding chamber.

Table 4: Determination of the Efficiency of the Yam Pounding Component

S/N	Initial Mass m_i	Final mass m_f	**Efficiency**
1.	0.204	0.150	73.53
2.	0.255	0.222	87.06

Average Efficiency = (73.53 + 87.06)/2 = 80.30%

The total Efficiency of the machine becomes the mean of the average efficiency of plucking chamber and average efficiency of pounding chamber

Total Efficiency = (86.67 + 80.30)/2 **= 83.485%**

4. Conclusion and Recommendation

A dual mechanized chicken plucking and yam pounding machine with an efficiency of about 83.5 % has been conceived, designed and manufactured, to replace the crude method of manually removing birds' feather and pounding yam under the most unhygienic conditions. It is our view that the major users of this machine will find it easy and convenient since it requires no special training for the intended users. This undoubtedly will boost production, increase profit margin and ultimately increase productivity most especially now that the Federal Government of Nigeria is more interested in commercial agricultural practices than ever.

For the plucking part, the machine was able to achieve a clean de-feathering of a single bird at a time and within average of three minutes per bird. Temperature monitoring and control is very importance in scalding operation as it possess some safety challenges and a determinant for quality of scalded bird. Temperature of water for the de-feathering obtained for the chickens shows that scalding free of damage on the skin is economically achieved at lower temperature for exotic breed compared to local chicken of the same weight hence a reduce processing time and risk. Cost of production of the machine as well as cost of processing the bird is relatively reduced compared with existing de-feathering machines but with reduced production capacity. It is proved that the unit price of scalded bird can be reduced using the locally made scalding machine and thereby guarantee the safety of local processing farmer. This study therefore suggests that full support of agricultural business by government especially in areas where risk factors are high is very necessary to enhance sustenance of food and agricultural produce in the country. Such supports include the establishment of food processing and agricultural implement fabrication shops capable of manufacturing homemade equipment both at small and large scale, provision of farmer friendly loan scheme and continue the education of poultry farmers.

For the Yam Pounding part, on the other hand, pounded yam is a staple food in West Africa, it is consumed by all tribes especially in Nigeria. The indigenous process of producing pounded yam is very laborious. It requires physical pounding by two or more matured persons, depending on the quantity and the type of mortals and pistols. As a result, a mechanical yam pounding machine was developed in this work and can serve for domestic pounded yam processing. The machine presents a more hygienic process of pounded yam making; it also eliminates the laborious indigenous ways of pounding yam. The production of these machines offers an incredible opportunity for pounded yam making in large quantities in few minutes as compared to the hours that would have otherwise been wasted. The cost of labour would also be reduced if the machine is adopted in canteens and restaurants.

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