



## Development and Performance Evaluation of a Rubber and Canvas Strip Fingers Defeathering Machine

\*BELLO, RS; SALIU, MO; NEBO, EU; AYODELE, AA

*Department of Agricultural & Bioenvironmental Engineering Technology, Federal College of Agriculture Ishiagu, Nigeria;*

*\*Corresponding Author Email: [segemi2002@fcaishiagu.edu.ng](mailto:segemi2002@fcaishiagu.edu.ng); Tel.: +234-8068-576-763*

*Other Authors Email: [saliuola@gmail.com](mailto:saliuola@gmail.com); [ugochukwugeneral@yahoo.com](mailto:ugochukwugeneral@yahoo.com); [ugochukwugeneral@yahoo.com](mailto:ugochukwugeneral@yahoo.com); [ugochukwugeneral@yahoo.com](mailto:ugochukwugeneral@yahoo.com); [dotswamamtz2011@gmail.com](mailto:dotswamamtz2011@gmail.com); [dotswamamtz2011@gmail.com](mailto:dotswamamtz2011@gmail.com)*

**ABSTRACT:** Human labour requirement in poultry products processing has continued to increase and more demanding, especially defeathering which is faced with challenges such as lacerations and hygiene in handling. To solve these challenges, mechanical defeathering proffered a solution, which further posed a problem of equipment cost and efficiency of operation. This paper investigated a developed a low-cost axial-loading (horizontal) defeathering with dual fingers for small and medium-scale poultry processors. This study reported the development of a defeathering machine which comprises of an axial defeathering drum with strip fingers, which flaps on the carcass to pluck off feathers in motion. The machine is electrically powered with a defeathering power requirement of 0.304 kW and at a power rating of 0.269 kW. The performance evaluation carried out with a broiler, cockerel and layer birds at a soaking temperature of 80 degree Celsius for an average time of 1 minutes showed that the efficiency and the effectiveness of the machine varies with respect to the quality of cleaned carcass produced. It was also observed that it takes the machine about 60 seconds to completely defeather a broiler of 2.4 kg weight, 70 seconds to defeather an old layer breed of bird of about 1.2 kg weight and 105 seconds to defeather a 1.3 kg weight of local chicken. However, test carried out on local birds showed that the machine was less effective defeathering local chicken at low temperature, because of the toughness of the skin. Comparatively, canvass (leather) fingers have the highest defeathering efficiency while rubber strip fingers produced the least defeathering efficiency. Therefore, canvas (leather) strip finger performed better than rubber strip fingers.

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The demand for the consumption of poultry products, most especially poultry (white) meat, has been on the increase due to its low fat and calorific content. The relatively increased preference for chicken over some other type of meat has generated keen interests in poultry farming and processing industry. Likewise, with the growing world population, livestock consumption rate may have to increase correspondingly to meet the effective protein requirement of the world (Adetola *et al.*, 2012). Therefore, there is need for user-friendly, reliably and efficient poultry processing devices in order to meet the ever increasing demand of poultry meat. However,

the costs of a numbers of important activities such as slaughtering, defeathering, eviscerating, chilling, deboning, packaging and storage, involved in ready to Cook-RTC meat remotely contributed to the high cost of poultry meat in the market (Adetola *et al.*, 2012) especially when carried out manually. Due to the increasing number of birds processed per day, human labour requirement in plucking out feathers continued to increase and demanding. In addition, poultry processing activities such as defeathering faced challenges that are of safety and health concern because of lacerations and hygiene in handling. Being a core stage in poultry processing, manual

*\*Corresponding Author Email: [segemi2002@fcaishiagu.edu.ng](mailto:segemi2002@fcaishiagu.edu.ng)*

defeathering attracts low production rate (in terms of the number of birds produced per hour), high time consumption and labour intensive. The level of human exposure resulting from this intense manual operation is significant in scalding and can equally expose the workers to occupational risk and other health hazards musculoskeletal disorder, cuts, skin rashes, dermatitis and avian influenza virus due to prolong activity (Adetola *et al.*, 2012). Hence, the introduction of mechanical system becomes imperative in order to greatly reduce the problem of boredom, finger scalding due to touching hot water while removing the feathers and several other benefits including tearing of carcass skin during the plucking process, which has become one of the major economic problems during processing (Adetola *et al.*, 2012). This project was aimed at further contributing to reducing the cost of machine and improving efficiency through ergonomic design and performance evaluation of an axial-loading horizontal defeathering machine.

However, one major challenge faced by these processors was the high cost of imported chicken pluckers. Adetola *et al.*, (2012) reported that household defeathering machine designed to handle less than 5 birds was sold for between (\$532.5 and \$3000. Currently, those machines market value based on exchange rate (#240,000.00 and above) is far above the reach of small-scale processors. It is therefore important to address the effective mechanization of the process considering the ergonomic and economic potentials of this process (Adetola *et al.*, 2012), which is beyond the reach of a small-scale farmer. Several machines have been developed for defeathering process which can handle either large or few number of birds (Adetola *et al.*, 2012; Barbut, 1998; Dickens and Shackelford, 1998; Lucas and Adetola, 2013; Jekayinfa, 2005; Nguyen *et al.*, 2011; Adejumo *et al.*, 2013; Irshad and Arun, 2013; Adetola *et al.*, 2014; Tanimola *et al.*, 2014; Adesanya and Olukunle, 2015; Ugwu *et al.*, 2015; Pitchovsci *et al.*, 1997). In the past, the development of the poultry defeathering machines are not common in Nigeria because the demand and acceptance placed on such machine differ from one continent to the other, especially in Africa. This research work is therefore dwelt on the development

of a low-cost axial (horizontal) loading feather-plucking machine for small and medium scale processors using sustainable engineering materials differing from the conventional rotary table plucker commercially available.

## MATERIALS AND METHODS

**Design considerations and material selection:** The choices of the material and component used here are based on the consideration of the following factors: (1) Cost analysis of the material, (2) Durability, reliability and availability of the materials for production when the need arises, (3) Properties of the material such as; physical properties, thermal properties, relative properties, chemical properties and mechanical properties (4) The economics in the ergonomic considerations such as safety of the machine operator and (5) The ease of operation and alteration of the system and the various machine components.

**Materials selected:** The major engineering materials selected for use in this project include wood, rubber, plastic and fiber materials. Metal was replaced by these materials to significantly reduce cost of materials without reduction in performance.

**Selection of defeathering fingers:** The conventional plucker material for the finger is rubber with smooth surface. Rubber fingers with round configurations and smooth surfaces have conventionally been used as defeathering fingers in most defeathering machines because of the fleshy nature of chicken. However, other studies have shown that plucker fingers made up of polypropylene plastic with serrated fingers pick on the poultry feathers, exerts a shear force on the bird causing the feathers to be plucked (Chukwudi and Ogunnedo, 2017). In material consideration, canvas leather strip and rubber strip (Figure 1) was selected for their slightly abrasive surfaces similar to the polypropylene plastic and closely related material available. Trimmed strips of tractor tyre was also considered as alternative material because of its hardness, rebound resilience, tear and tensile strength. The finger is 5 mm by 40 mm in cross section and 130 mm long.

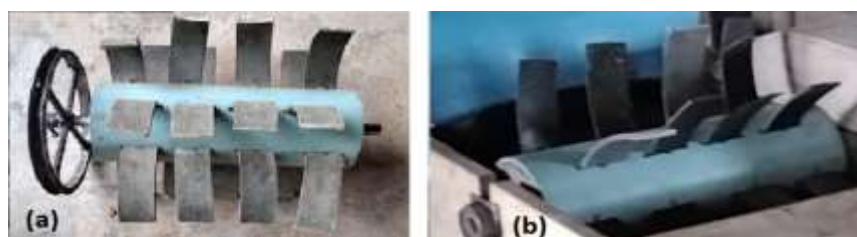


Fig 1: Defeathering drum showing the strip fingers a) Canvas b) Rubber fingers

**Instrumentation:** Instrumentations used include key hole saw, stopwatch, digital weighing balance, thermometer (mercury in glass, range 0°C-400°C), 5kg gas stove, Cooking accessories (e.g. pot, tray, bowl etc.), 2 plastic buckets for evisceration and scalding, weighing scale (25kg).

**Determination of the electric motor required:** In order to ensure effective defeathering process without significant damage to the body of the chickens, the base plate was set to rotate at a speed of 180 rpm. The speed was selected based on the existing range (146-300 rpm) obtained from the review of past work on the design of defeathering machine (Tanimola *et al.*, 2014; Adesanya and Olukunle, 2015). As a result, an electric motor of 1 Hp was selected to power the machine. The details of the motor is given in the Table 1.

**Table 1:** Details of the electric motor selected description

Description	Data
Power characteristic available	AC
Motor type	Single Phase
Power rating	1 hp (0.745 kW)
Speed	900 rpm
Frequency	50 Hz
Voltage	220 V
Motor enclosure	Total Enclosure

**Machine description:** The defeathering machine comprises of three major parts: the power source and transmission, the defeathering mechanism, the feather outlet and the safety shields. The power source is an induction coil mounted on a seating underneath the defeathering chamber. The motor is adequately protected from water by the plastic lined feather recovery chute. The electric motor is connected to the driven pulley attached to defeathering drum by an A-type V-belt. The defeathering mechanism comprises of a 20mm diameter high-pressure plastic pipe with slits to contain 24 leather canvas strips 5 mm x 40 mm x 130 mm in dimension. The pipe is closed at both ends by two wooden side covers with a central hole to contain the 12.5mm diameter, 400mm hollow shaft. The shaft is made of hollow shaft because of the minimal axial load due to the weights of the pipe and the plucker fingers. The shaft is dynamically supported at both ends by two pressure lubricated 6305 ball bearings with 12.5mm internal bore. The 270 mm diameter driven pulley is attached to one end of the shaft (Figure 1). The feather chute constructed of hardwood and lined with plastic sheet to prevent it from regular water soaking is rectangular, and installed directly below the defeathering mechanism, which open to the defeathering chamber. The plucked feather is washed by water irrigation system for effective feather removal from the chamber, which is collected in the chute in clean operation. Two safety shields installed on the driven pulley and the plucker

drum shields the driven pulley from direct contact with moving body while the plucker drum shield prevents the scattering of the plucked feathers in clean operation.

## MATERIALS AND METHODS

**Machine design considerations and equations:** Machine design considerations include; power requirement, availability of raw materials, defeathering speed, plucking force, weight of chicken, defeathering capacity, quality of the material, cost of material and safety. Figure 2, shows the engineering drawings of the machine drawn in first angle projection. The components of the machine include the rest board, feather shield, plucker drum, feather outlet, shaft; rubber strips (fingers), pulley and belt system and induction motor.

**Total power requirement:** Total power requirement in defeathering operation is a function of power required to drive the drum, and the power required to pluck the feather which is a function of the feather retention force (FRF) (Krupala and Sams, 2000, Buhr *et al.*, 1997). It is of major economic importance to the poultry industry because this necessary step in poultry processing causes damage if not performed properly. The total power,  $P_t$  requirement of the machine is the sum of power required to drive the plucker drum  $P_r$  and the power required to de-feather  $P_d$  the chicken. It is expressed below according to Adeyinka and Olawale (2016):

$$P_t = P_{drum} + P_{pluck} \quad 1$$

**Power  $P_{drum}$  required to drive the plucker drum:** The power delivered to turn the plucker drum is required in order to determine the amount of power needed to defeather the bird. Since the plucker fingers are attached to the drum, it is assumed that power delivered to the plucker drum equals power needed to defeather the bird.

$$P_{drum} = W_{drum} \times r_{drum} \times \omega_{drum} \quad 2$$

Where W= weight of the rotating drum, r = radius of the rotating drum,  $\omega$  = angular velocity of the rotating drum. But

$$\omega_{drum} = \frac{2\pi N}{60} \quad 3$$

**Power  $P_{pluck}$  required to pluck feather from the follicles:** Power required to de-feather the bird is determined the equation below according to Adeyinka and Olawale (2016);

$$P_{pluck} = \frac{2\pi NT}{60} = T \cdot \omega_{drum} \quad 4$$

$$T = \frac{\pi d^3 \tau}{16} \quad 5$$

Where N = Driven shaft speed, P = Power requirement (W),  $\omega_{drum}$  = Angular velocity of the de-feathering chamber, rad/s, T = torque of the de-feathering chamber expressed as

Where d = Mean diameter of the de-feathering chamber, m. To determine the total power requirement, the force dynamics are required.

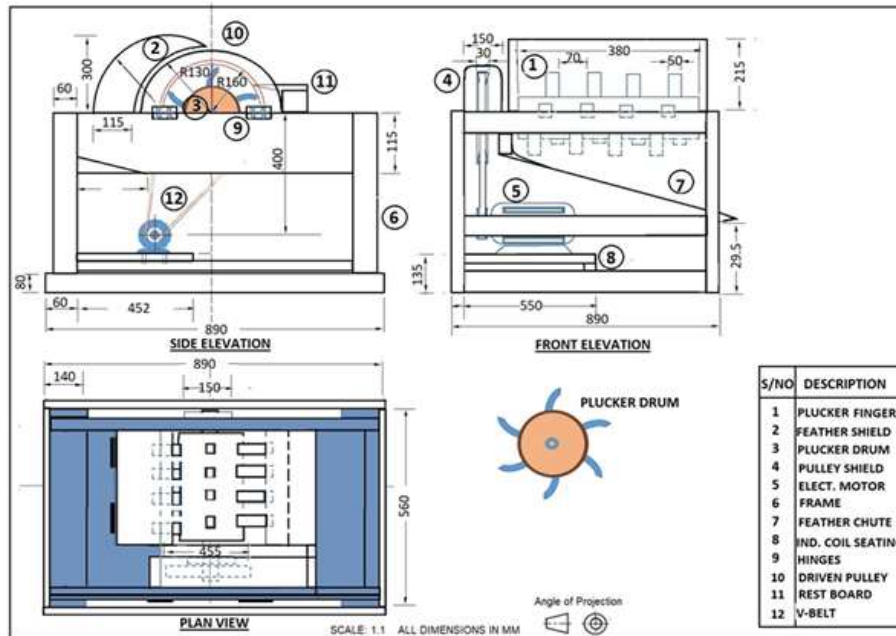


Figure 2. Orthographic drawing of machine

Force required for plucking feather from bird: The force required to remove feather from bird is given by;

$$F_c = M\omega^2 r \quad 6$$

Where M is the mass of the rotating pulley, kg,  $\omega$  = Angular velocity of the pulley, rpm, r = Radius of the pulley, m; Assume N to be 1285 RPM

Feather retention force (FRF): The feather retention force (FRF) is estimated by the following expression according to Dickens and Shackelford, (1988).

$$\% Red = \frac{UF - SF}{UF} \quad 7$$

Where: Red = reduction; UF = unscaled force; SF = scaled force. The unscaled is the force required to pluck feather from follicle when bird is yet to be scald; while scald force is the required to pluck feather out of bird immersed in hot water at certain time duration and temperature.

Torque required to detach feather from follicles: The torque required to detach feather from follicles was

calculated using the Equation (8) due to Adeyinka and Olawale (2016) and stated as follows:

$$T = F \times r \quad 8$$

Where T = torque (kNm), r = mean radius of defeathering chamber (0.175m), F = total force on the shaft (N)

Electric motor power rating: The power rating of the electric motor needed to provide the necessary torque for the de-feathering action is expressed as:

$$P_{motor} = \frac{P_{drum}}{\eta_{motor}} \quad 9$$

Pulley size determination: The drive speed is the criteria for which the pulley sizes were based. Single groove pulley was used on the defeathering shaft and this pulley was driven by electric motor. Adeyinka and Olawale (2016) expressed the ratio of pulley size as follows;

$$N_1 D_1 = N_2 D_2 \quad 10$$

Where  $N_1$  = speed of the motor, rpm,  $N_2$  = speed, of defeathering, rpm,  $D_1$  = diameter of motor pulley, mm,  $D_2$  = diameter of defeathering pulley, mm

*Determination of belt size:* The Selection of belt sizes depends on the length thickness and properties of the materials from which the belt is made. The effective pitch length of v-belt, L mm is calculated from equation 11

$$L = 2C + \frac{\pi(D + d)}{2} + \frac{(D - d)^2}{4C} \quad 11$$

Where: L = effective belt length (mm), C = centre distance from driven to drive pulley (mm), d = diameter of defeathering pulley (mm), D = outside diameter of motor pulley (mm). The belt thickness and properties are based on power to be transmitted (Adeyinka and Olawale, 2016).

*Determination of minimum drum shaft diameter:* The determination of the correct shaft diameter and length is such that it can transmit required power under the stated operating and loading conditions. It also involves material selections so that the stated conditions are economically and efficiently met. By applying the maximum shear equation modified by introducing shock, fatigue and column factors, the minimum shaft diameter having little or no axial loading is expressed by equation (12):

*Shaft diameter:* By applying the maximum shear equation modified by introducing shock, fatigue and column factors, the shaft diameter for a solid shaft having little or no axial loading

$$d^3 = \frac{16}{\pi S_s} \sqrt{k_b M_b + k_t M_t} \quad 12$$

Where:  $M_b$  = bending moment (Nm),  $k_b$  = combine shock and fatigue factor applied to bending moment ( $k_b = 2.0$ ), **Error! Bookmark not defined.**  $M_t$  = torsional moment in (Nm),  $k_t$  = combine shock and fatigue factor applied to torsional moment. ( $k_t = 1.5$ ),  $S_s$  = allowable shear stress. ASME code specifies that for commercial steel shafting without keyway  $S_s = 560 \text{ kg/cm}^2$  (Error! Bookmark not defined.) and shaft with keyway  $S_s = 420 \text{ kg/cm}^2$ .

*Shear stress developed in drum:* This is the stress developed in the drum because of the power transmitted for the defeathering of the poultry bird. For the design to be valid, the value for the stress developed in the drum should not exceed the

maximum allowable shear stress for the drum material.

$$\tau_{drum} = FS \times \tau_{w,all} \quad 13$$

Where *FS* is the factor of safety and  $\tau_{w, all}$  is the allowable shear stress expressed by equation (14).

$$\tau_{w,all} = \frac{16}{\pi d^3} \tau_{drum} \quad 14$$

*Shear failure analysis of the defeathering chamber:* The shear stress of the de-feathering chamber is determined by the equation below according to Adeyinka and Olawale (2016);

$$\tau = \frac{16M_t}{\pi d^3} \quad 15$$

*Bearing selection:* In selecting a bearing that will support the line shaft, the basic dynamic radial load service factor for radial ball bearings and the reliability of the bearing (Chukwudi and Ogunedo, 2017) as well as suitability of the area within the intended machine were considered. Since the machine will undergo a uniform and steady loading, an expected service life corresponding to 90% reliability is expressed as

$$L = L_{90} \times 6.84 \left[ \log_e \left( \frac{1}{R_{90}} \right) \right]^{1/1.17} \quad 16$$

Where: L = Life of bearing corresponding to a reliability of 90%;  $L_{90}$  = total life of bearing in revolutions.  $R_{90}$  = Reliability of bearing,

*Ball bearing friction:* Soil internal friction for ball bearings is expressed as:

$$C = W \left[ \frac{L}{10^6} \right]^{1/k} \quad 17$$

Where: C = Soil internal coefficient of friction  
W = The rated dynamic load of the bearing given by the manufacturer for a specified lifetime, L = The rated dynamic load of the bearing given by the manufacturer for a specified lifetime and a probability of survival, usually; K = An empirical factor depending on the bearing corresponding to 3 for ball bearings, or 3.33 for roller bearings.

*Fabrication of machine:* The chicken defeathering machine was fabricated at the wood and metal workshops of the Department of Agricultural and Bioenvironmental Engineering Technology, Federal College of Agriculture, Ishiagu Nigeria. Figure 3 shows the developed defeathering machine under test.

The machine frame constructed of hardwood (Gmelina) was fastened together with iron nails. The plucking drum constructed from plastic pipe, while the finger strips, made from canvas belt was fixed into the slits made on the pipe was held in place with 2.5mm nails. The feather shield and the pulley guide were constructed of wooden frame and plastic covering.

The feather chute was constructed of wood and lined with plastic to ensure non-sticking of feather to the wood during operation. A water irrigation system was incorporated to supply trickles of water from a dripping system into the fingers and the chamber to wash off feathers removed during operation.



Figure 3. The developed machine under test

**Machine test procedure:** The machine was tested with three species of chicken (broiler chicken, layer and a cockerel) using rubber and canvas fingers to determine the machine defeathering efficiency, time  $t$ , taken to defeather, throughput capacity,  $T_c$  and the energy consumption,  $E_c$ . To evaluate these parameters, the age of bird, scalding temperature, and scalding duration were established using literature standard procedures. Materials used for this test include kerosene stove, cooking pot, 0-400 °C range mercury-in-glass thermometer, stopwatch, weighing balance and the fabricated de-feathering machine. The test procedure described by Adetola *et al.*, (2012) was adopted in experimentation.

**Machine performance evaluation:** The parameters used in the performance evaluation of the machine are as follows.

**Defeathering efficiency:** This is the measure of amount of feather plucked by the machine. It is ratio of weight of plucked feather to the total weight of chicken's feather (Adejumo *et al.*, 2013). This is expressed as follows

$$d = \frac{W_1 - W_2}{W_2 - W_3} \quad 18$$

Where  $W_1$  = initial weight of chicken before defeathering (N),  $W_2$  = weight of the chicken after

defeathering (N),  $W_3$  = weight of the de-feathered chicken after manual removal of remaining feather (N)

**Defeathering time,  $t$ :** Defeathering time  $t$  is the duration in seconds, spent in defeathering operation measured by a stopwatch.

**Throughput capacity  $T_c$ :** This is measure of numbers of chicken defeathered in an hour, expressed by equation 20 as follows

$$T_c = \frac{N_d}{t(hr)} \quad 19$$

Where  $N_d$  = Number of chickens de-feathered,  $t$  = Defeathering Time (hour)

**Energy consumption  $E_c$ :** This is the amount of electrical energy used for the defeathering operation. It measured in kWh.

$$E_c = 1.14 \times \left( \frac{t}{3600} \right) \quad 20$$

Where:  $E_c$  = Energy consumption (kWh),  
 $t$  = defeathering time (sec).

## RESULTS AND DISCUSSIONS

**Machine development:** Table 2 shows the summary of the various developed parameters evaluated. The machine is 890 x 560 x 726 mm in dimension.

The designed total power requirement of the machine is 0.304 kW and at a power rating of 0.269 kW, which implies that an induction coil of 0.745 kW (1 PH) motor is capable of driving the system. Other parameters were designed to specification. The machine power requirement is considerably low and economical in terms of power consumption. The water drip system efficiently delivered droplets of water

from the spray pipe to the fingers and the chamber despite the air waves set in motion by the fingers within the chamber.

The rest board sufficiently increased the depth of the defeathering chamber such that splashing of water and feather throwing was eliminated.

**Table 2.** Developed machine specifications

Machine components	Design values
Driven pulley diameter	270 mm
Motor pulley diameter	65 mm
Motor speed	1400 rpm
Drum speed	320 rpm
Power required to drive the plucker drum	21.51 W
Force required to detach feather	21.78N
Angular velocity of the rotating drum	36.40 m/s
Power required to pluck feather from the follicles	282.83 W
Torque required to detach feather from follicles	7.77 N/m
Total power requirement	304.34 W
Electric motor power rating	26.89 W
Belt length	1023 mm
Belt center distance	330 mm

### Performance tests

**Scalding time:** The result of the test carried out using a broiler, cockerel and layer birds at a soaking (Figure 4) temperature of 80-85 degrees Celsius for an average time of 1 minutes showed that the efficiency and the effectiveness of the machine varies with respect to the quality of cleaned carcass produced.

It was also observed that it takes the machine about 55-60 seconds to completely defeather a broiler of 2.4 kg weight, 70 seconds to defeather an old layer breeds of bird of about 1.2 kg weight and 105 seconds to

defeather a 1.3 kg weight of local chicken using canvas strip fingers, and 45 seconds to defeather the broiler, 55 seconds to defeather the old layer breed and 60 seconds to defeather the local chicken using rubber strip fingers respectively.

However, test carried out on local birds showed that the machine was less effective defeathering local chicken at low temperature, because of the toughness of the skin. From this result, it was evident that the scalding time, temperature and breed are dominant factors in defeathering operation.



**Fig 4.** Scalding the bird in hot water

**Table 3.** Scalding time, defeathering time and mean efficiency

Bird species	Scalding time (sec)	Defeathering time (sec)	Defeathering Efficiency (%)
Canvas strip fingers			
Local (cockerel)	90	105.00	65.22
Broiler (exotic)	60	60.20	93.75
Layer (exotic)	70	70.00	85.71
Rubber strip fingers			

BELLO, R. S; SALIU, M. O; NEBO, E. U; AYODELE, A. A.

Local (cockerel)	80	55	30
Broiler (exotic)	60	40	60
Layer (exotic)	90	45	50

**Defeathering time:** The machine is able to defeather the broiler in approximately 60 seconds, defeather the layer in 82 seconds while it was able to defeather the cockerel at 65.22 % efficiency at approximately 105 seconds. On the other hands, the rubber strip fingers defeathered the broiler in 40 seconds with 60% defeathering efficiency; this was followed by layer species of birds which was defeathered 45 seconds with 50% efficiency and the least was local (cockerel) birds which was defeathered at 55 seconds with 30 defeathering efficiency. Therefore, this implies that canvass (leather) strip finger performed better than rubber strip fingers in the defeathering of poultry birds. Adetola *et al.*, (2012) reported lowest mean defeathering time of 3.6 minutes at 60 °C scalding temperature and 5 minutes scalding time for local chickens. This may be attributed to the tough skin texture of chicken compare to the exotic breeds. The major difference between the exotic, the old layer birds and the local breed birds is that it takes less time (about 20 seconds) to defeather completely, at a scalding time of 1.5 minutes at water temperature of

about 80 degrees Celsius. It was equally observed that in attempt to force-feed the bird, the carcass secure noticeable tear and wounds around the breast and the limbs making them look unattractive. **Defeathering efficiency:** Figure 5 shows the sample products obtained using the canvas and rubber fingers in machine defeathering tests. Table 3 shows the mean defeathering efficiency of the machine compared with other locally fabricated machines. The efficiency of the machine is a function of time, temperature and the rate of feather removal. The machine recorded highest mean defeathering efficiency of 93.75 % at 80 °C scalding temperature at both 1 minutes for broiler, 85.71% at 1.25 minutes scalding time, and 65.22 % at 1.5 minute scalding time for local (cockerel) chicken respectively. This was slightly lower than machine efficiency of 95 % recorded by Adeyinka and Olawale (2015). The least defeathering efficiency of 65.22 % at 80 °C scalding temperature for both 1.5 minutes scalding time was recorded for local chickens may be attributed to the nature, age and skin toughness of the chicken.



**Figure 5.** The defeathered birds (Canvas finger b) Rubber finger

**Feather removal:** Table 4 shows the machine performance in feather removal per unit time, while Table 5 shows the bird weights measured before and after defeathering. The average weight of the birds

vary from 1.3-2.5 kg. From Table 4, it is evidence that the machine was able to remove considerable quantity of the feathers from each bird species, especially the exotic birds.

Table 4. Comparative weight of feathers removed and retained after defeathering

Breeds of Chicken	Canvass strip finger		Rubber strip finger	
	Mass of feather removed (g)	Mass of feather remained (g)	Mass of feather removed (g)	Mass of feather remained (g)
Local (cockerel)	1.4	0.80	1.1	0.90
Broiler (exotic)	1.5	0.30	1.4	0.40
Layer (exotic)	1.2	0.50	1.3	0.40

Table 5. Bird weights before and after defeathering

S/no	Bird weight before defeathering (g)	Bird weight after defeathering (g)	Bird weight after manually removing remaining feather(g)
Bird weights before and after defeathering with rubber fingers			
Local (cockerel)	1050	1048.5	1048.48
Broiler (exotic)	2400	2398.5	2398.48
Layer (exotic)	1300	1298.8	1298.79
Bird weights before and after defeathering with canvas fingers			

BELLO, R. S; SALIU, M. O; NEBO, E. U; AYODELE, A. A.



Local (cockerel)	900	800	700
Broiler (exotic)	2200	2100	2000
Layer (exotic)	1600	1580	1500

**Cost valuation:** The Bill of Engineering Measurement and Evaluation (BEME) for the developed de-feathering machine is presented in Table 6. The total cost of fabricating the machine was approximately N 55,000:00, which is less expensive compared to other locally fabricated machines and subsequently,

imported poultry processing equipment ranging from NGN83,200 (\$532.5) and NGN480,000 (\$3000) (Adetola *et al*, 2012). This indicated a relatively lower cost, more affordable by small, medium poultry farmers.

**Table 6.** BEME for the developed de-feathering machine

S/no	Material	Specification	Quantity	Unit cost (NGN)	Total Cost (NGN)
	Frame (Hardwood; Gmelina)	1x12x12 board	1	1,650	8,250
		2x3x12 plank	2	400	800
	Shaft (MS rod)	25mm diameter	1	2,000	2,000
	Transmission belt (rubber)	1050 mm length	1	3,000	3,000
	Driven pulley (MS)	250mm	1	5,000	5,000
	Defeathering strips (fingers), canvas	5 mm × 40 mm cross section, 130 mm long	24	5,000	5000
	Ball bearing	6305	2	600	1,200
	Nails	½”, 1”, and 3”	1 lb wt.	800	800
	Hinges	1”	4	50	200
	Bolts and nuts	10mm	4	600	600
	High density grade plastic		3	800	2,400
	Circular hole saw	Set	1	9,000	9,000
	Labour cost			8,000	8,000
	Total				<b>46,250</b>

**Conclusions:** This research successfully developed an axial-loading feather-removing machine using rubber and canvas strip fingers differing from the conventional round rubber fingers in imported machines. The machine is easy, convenient and affordable to operate by small and medium scale processors.

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