ARID ZONE JOURNAL OF ENGINEERING, TECHNOLOGY & ENVIRONMENT
AZOJETE, September 2019. Vol. 15(3) 702-713
Published by the Faculty of Engineering, University of Maiduguri, Maiduguri, Nigeria.
Print ISSN: 1596-2490, Electronic ISSN: 2545-5818
www.azojete.com.ng

ORIGINAL RESEARCH ARTICLE

DESIGN, CONSTRUCTION AND PERFORMANCE EVALUATION OF CHICKEN DE-FEATHERING MACHINE

M. Abubakar, A. Zakariyah and A. Usman
(Department of Agricultural and Bioresources Engineering, Ahmadu Bello University, Zaria, Nigeria)
** Corresponding author's email address: basaleft@gmail.com, zakariyahabdulbasit@gmail.com*

ARTICLE INFORMATION

Submitted 22 November, 2018
Revised 7 March, 2019
Accepted 10 March, 2019

Keywords:
de-feathering
Scalding
chicken
feather release force FRF
cone

ABSTRACT
The demand for poultry meat world-wide has imposed great responsibility on poultry processing industry, and especially in de-feathering operation which is usually achieved manually in Nigeria. Being a core stage of poultry processing, de-feathering when carried out manually attracts low production rate (the number of birds produced per hour), high time consumption and labour intensity. This study was focused on design, construction and performance evaluation of chicken de-feathering machine using locally available materials. The design was based on market weight of chicken. The selected materials used to fabricate the machine were trimmed tyre rubber, sheet metals, angle iron and shaft. The rubber cross section was 20 mm×20mm and were arranged both on the shaft length (50mm, 70mm, 90mm, 110mm, 130mm and150mm in length) and at the wall of the bottom cone (80mm length). The height of the machine was 1400mm and 500mm×500mm square area. 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 throughput capacity and energy consumption but scalding temperature had significant effect on de-feathering efficiency. Maximum mean throughput capacity of 1034 chickens per hour was obtained at 96 % de-feathering efficiency.

1.0 Introduction

Poultry is a domesticated species of birds reared for production of eggs, meat, feathers. Poultry is reared in great numbers with chicken being the most numerous. According to Federal Department of Livestock and Pest Control Service, no recent nationwide survey on commercial poultry exist, but expected annual production capacity was estimated as 96,981,001kg dressed broilers and 40,738,698kg dressed culled layers. Poultry meat is popularly consumed among non-vegetarians world-wide 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 up with ever increasing demand of poultry meat. There are numbers of important activities involved in the production of poultry meat (Ready to Cook-RTC meat) which contribute to the high cost of poultry meat in the market. slaughtering, de-feathering processes involving scalding and feather plucking, eviscerating, chilling, deboning, packaging and storage are the most important activities in poultry processing industry. Scalding is process of soaking slaughtered chickens in hot water to softened the follicle around feathers prior to de-feathering operation. De-feathering process is identified as highly technical and time consuming among the various numbers of poultry processing activities when carried out manually (Adetola et al., 2012).

In Nigeria, poultry processing is done manually, off-farm through local markets. De-feathering process is identified as highly technical and time consuming next to eviscerating process among the various numbers of poultry processing activities especially when carried out manually (Dicken and Shackelford, 1998). Being a core stage of poultry processing, de-feathering when carried out manually attracts low production rate (the number of birds produced per hour), high time consumption and labour intensity. It can equally expose the workers to musculoskeletal disorder, cuts, skin rashes, dermatitis and avian influenza virus. Level of human exposure to occupational risk and other health hazard resulting from intense manual operation is significant in scalding and de-feathering operations (Adetola et al., 2012). Jekayinfa (2007) assessed energy requirement of an automated de-feathering machine comprises an electric motor which drives a shaft supported by a bearing assembly and a belt system which drives the plucking head. The machine consists of a series of rotating plates held at an angle by a thrust plate at each end of the plate bearing. As the discs rotate, the chickens come together, drag in the feathers, grip them and pull them from the bird. Adetola et al. (2012) investigated the mechanized scalding and de-feathering processes of both local and exotic birds, where effective and efficient de-feathering was achieved on local chicken at a scalding temperature between 80oC – 85oC for 5min immersion duration, while that of exotic chicken took place between 65oC – 70oC for 3 min immersion duration. Feather retention force (FRF) of each categories of bird also varies significantly (Adetola et al., 2012). In order to measure up with increasing demand for poultry meat, there is need for de-feathering machine in our local markets. Also, to avoid accidents and infections from poultry carcasses which may occur during some of the processing operations, there is need for user-friendly, reliably and efficient poultry processing devices (Ralph, 1980; Scolt, 2000). Though de-feathering machines exist in most developed countries, currently, they are not common among the local chicken processors. This is due the cost implication of the machines. Adetola et al. (2012) reported that household de-feathering machine designed to handle less than 5 birds sold for between #83200 ($532.5) and #480000 ($3000), and that is quite expensive for an average Nigerian. It is paramount to address the de-feathering problem associated with poultry processing industries. This calls for effective mechanization of the process which will support quality, safe, ergonomic and economic operation (Adetola et al., 2012). The general objective of the study is to design, construct and evaluate the performance of a chicken de-feathering machine.

2. Materials and Methods

2.1 Materials

The materials used in the fabrication and performance evaluation of the chicken de-feathering machine include 1.5mm sheet metal, Angle Iron 50 mm × 50 mm, Shaft of 25mm diameter and 1050 mm length, Transmission Belt of 1143 mm, a Pulley size of 250mm, three bands shaft de-feathering finger 20 mm × 20 mm cross section of 150 mm to 50 mm long, Ball bearing 6305,

Corresponding author's e-mail address: basaleft@gmail.com, zakariyahabdulbasit@gmail.com

Hitches and Bolts and nuts. Instrumentations used were stopwatch, thermometer and digital weighing balance.

2.2 Methods

The chicken de-feathering machine was designed and fabricated at the Department of Agricultural and Bio-resources Engineering, Ahmadu Bello University, Zaria, Nigeria. The procedures for the design, fabrication and performance evaluation including cost implication of the chicken de-feathering machine are as followed.

2.2.1 Establishment of Design Parameters

2.2.1.1 Survey method and physical properties of chicken

Questionnaires were administered at some selected abattoirs in Zaria (Sabon Gari abattoir Centre and Samaru market abattoir) and Kaduna (railway station market). The questionnaire was designed to determine the volume of chicken, scalding temperature, average scalding time, plucking time and cost of processing the chicken. Feathers of various categories of poultry specifically layers, broilers, local chicken and guinea fowl were experimented by soaking respective feather in the hot water at specific temperature range of 65°C - 70°C. This temperature was in accordance with scalding temperature obtained from conducted survey and scalding temperature used as operational parameter in chicken processing (Adetola, et al., 2012). Angle of repose of the wet feather of layers and broilers was determined. Body parameters viz. neck length, back length, kneel length, wing length, breast width, thigh length and shank length, of eight (8) weeks old broilers at National Animal Production Research Institute, NAPRI Zaria, were obtained.

2.2.1.2 The feather plucking force

The feather retention force of non-scalded local chicken was selected as 41.53N. Because, higher force is required to de-feather local chicken under the same condition with exotic chickens. This is in accordance with the investigation into mechanized de-feathering process and optimal scalding temperature of exotic and local birds in southwestern Nigeria (Adetola et al., 2012). Also Dickens and Shackelford (1987), the percentage reduction in feather retention force FRF ranges from 18% to 81% after 2.5 min, 56oC scalding.

Design calculation

In the course of this design, the following design consideration were observed. These are; power requirement, availability of raw materials, de-feathering speed, plucking force, weight of chicken, de-feathering capacity, quality of the material, cost of material and safety

2.2.2.1 Selection of de-feathering rubber fingers

Rubber was used as the de-feathering finger because chicken is fleshy. Based on available material, trimmed tractor tyre was used as de-feathering finger because of its hardness, rebound resilience, tear and tensile strength. The rubber finger is 20 mm by 20 mm in cross section.

2.2.2.2 Determination of power required to pluck feather from the follicles

The torque required to detach feather from follicles was calculated using the Equation (1) due to Kurmi and Gupta (2006) and stated as follows:

$$T = F \times r \quad (1)$$

where: T = torque (kNm),

r = mean radius of de-feathering chamber (0.175m)

F = total force on the shaft (N)

Total force required by the shaft = FRF + W_r + W_s

where: FRF = feather retention force (plucking force) (N)

W_r = weight of rubber around the shaft (N)

W_s = weight of shaft (N)

2.2.2.3 Feather retention force (FRF)

According to Dickens and Shackelfold (1987), FRF can be estimated as follows

$$\%reduction = \frac{unscalded\,force - scalded\,force}{unscalded\,force} \times 10 \quad (2)$$

where: unscalded force = 41.53N (Adetola et al, 2012)

% reduction = 80% (Dickens and Shackelfold, 1987)

Thus, the feather retention force FRF is selected to be 10N. For ten chickens, FRF is 100N.

2.2.2.4 Power requirement

According to Kurmi and Gupta (2006), the power required for de-feathering is expressed as;

$$Power\ P = \frac{2\pi NT}{60} \quad (3)$$

where: N = shaft speed (320 rpm),

P = power requirement (W)

The speed of 320 rpm was selected in accordance with an Investigation of Optimized Operational Parameters for a Chicken Slaughtering System in Vietnam (Nguyen et al., 2011).

T = torque (34.77 Nm)

Power P = 1165 W (1.56 hp)

2.2.2.5 Pulley size determination

The drive speed is the criteria for which the pulley sizes were based. Single groove pulley was used on the de-feathering shaft and this pulley was driven by electric motor. Kurmi and Gupta (2006) expressed the ratio of pulley size as follows;

$$N_1D_1 = N_2D_2 \quad (4)$$

where: N_1 = speed of the motor (1400rpm)

N_2 = speed of de-feathering (320rpm)

D_1 = diameter of motor pulley (50mm)

D_2 = diameter of de-feathering pulley.

Shaft pulley of 250 mm pulley diameter was suitable.

2.2.2.6 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 belt thickness and properties are based upon the power to be transmitted. Kurmi and Gupta (2006) stated the length of the belt as follows

Corresponding author's e-mail address: basaleft@gmail.com, zakariyahabdulbasit@gmail.com

$$L = 2C + 1.57(D + d) + \frac{(D-d)^2}{4C} \quad (5)$$

where: L = effective belt length (mm)

C = centre distance from driven to drive pulley (330 mm)

d = diameter of de-feathering pulley (250 mm)

D = outside diameter of motor pulley (50 mm)

Estimated length from motor to shaft of 1161mm and the belt length of 46 inches were selected.

2.2.2.7 Determination of minimum shaft diameter for de-feathering

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.

Kurmi and Gupta (2006) stated the equation for determining the minimum size of solid shaft having little or no axial loading as

$$d^3 = \frac{16}{\pi \times \tau_{max}} \sqrt{[(k_m M)^2 + (k_t T)^2]} \quad (6)$$

where: d = diameter of shaft (mm)

π = 3.142

τs = design stress of mild steel (56 × 106 N/m^2) (Kurmi and Gupta, 2006)

K_m & K_t = combine shock and fatigue factor applied to bending and torsional moment respectively (K_b = 2.0 & K_t = 1.5)

T = Torsional moment (34.77 Nm)

M_b = Maximum bending moment (48.7 Nm)

The minimum shaft diameter was calculated as 21.6 mm. Based on the available shaft size, 25mm shaft size was selected.

2.2.2.8 Hopper design

The hopper was made into frustum of cone, basically to occupy ten (10) chickens sequentially. The chickens were fed to the machine through the hopper, and had downward flow aided by gravity. The average volume 2 kg – 3 kg chicken was determined as approximately 1900 cm3. The hopper was;

H = height of the cone (500 mm)

D = large radius of the cone (500 mm)

d = small radius of the cone (360 mm)

2.2.2.9 Bottom cone dimensions

The bottom cone aids the de-feathering and temporary storage of dressed chicken immediately after de-feathering. The bottom cone was constructed to occupy two chambers; the de-feathering chamber and the dressed carcass chamber. The de-feathering chamber was made of arrangement of de-feathering rubbers around a vertical revolving shaft and at the wall of the cone. The de-feathering rubber fingers were 18 in number which formed 6 bands around the shaft, each band having 3 rubber fingers of equal length. The space between the rubber fingers along the longitudinal axis of the cone's wall was selected based on back length (BL) of eight-week broiler at National Animal Production Research Institute, NAPRI. The space between the revolving fingers and the wall of the cone was limited to 90mm which was selected in accordance with the breast width (BW) of the eight weeks broiler at NAPRI. The space enables the easy and downward movement of the chickens, and sufficient rubbing through the successive contact of the fingers. Therefore, the dimension of the de-feathering chamber was selected as;

H = height of the cone (500 mm)

D = large diameter of the cone (500 mm)

d= small diameter of the cone (300 mm)

2.2.2.10 Cross section for dressed chicken carcass

The design was made for at least average of five chickens, therefore,

Volume of chickens = 5 × 1900

= 10000mm^3

$$\text{volume of chicken} = \frac{\pi H}{3}\left(R^2 + r^2 + Rr\right) \quad (7)$$ (www.analyzemath.com)

where: H = height of the cone (200 mm)

R = large radius of the cone (150 mm)

r = small radius of the cone (mm)

π = 3.142

Solving the quadratic equation, r = 100 mm, diameter of 200 mm.

2.3 Construction Procedure of the Machine

Construction of chicken de-feathering machine was carried out at Agricultural and Bio-resources Engineering Department workshop, ABU, Zaria, Nigeria. Plate 1 and plate 2 show the fabricated and the orthographic views of the de–feathering machine. The various components of the machine are hopper, bottom cone, feather outlet, shaft, rubber fingers, pulley and belt system and electrical motor.

Corresponding author's e-mail address: basaleft@gmail.com, zakariyahabdulbasit@gmail.com

Plate 1. Chicken De – feathering Machine

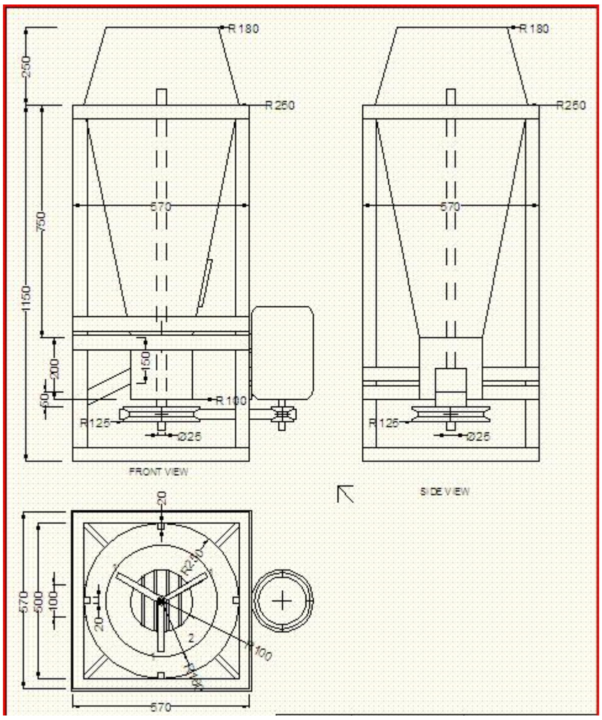

Plate 2. Orthographic views of De–feathering Machine

2.4 Experimental setup

The fabricated chicken de-feathering machine was evaluated at Chiromawa poultry processing market, a registered market along Zaria road, Kano State. Eighty chickens each for both local and exotic chicken were used in the evaluation. Two level of chicken varieties (local and exotic chicken), two level of scalding time (3 minutes and 5 minutes) and two levels of scalding temperature (50°C and 60°C) were considered in a Complete Randomized Design (CRD). Scalding equipment was adopted for the experiment. The chickens were voluntarily obtained from respective volunteers at the market, weighed, slaughtered, scalded and de-feathered by the machine. The results were subjected to analysis of variance ANOVA test using Statistical Analysis Software (SAS) application.

2.5 Operational and Working Principles

The chicken is feed into the machine through the hopper, after which the chicken move to de-feathering chamber where set of de-feathering rubber fingers were arranged to aid easy and effective de-feathering process. The de-feathering process is achieved when chicken revolved through the spaces between the adjacent wall fingers. In the same pass, the de-feathered chickens were finally deposited at dressed carcass chamber and eventually removed through the carcass outlet. The de-feathering machine works on the principle of impact, rubbing and collision. The revolving shaft exerts impact force on the chicken and subsequently creates rubbing action. This is in accordance with automated method of de-feathering reported by Jekayinfa (2007) and investigation on optimum scalding temperature and de-feathering process by Adetola et al. (2012). The degree of rubbing action depends on the area of contact of the rubber and roughness of the surface of the rubber. Also, collision between the studded rubber at the wall of the cone and the chicken, indeed contribute significantly to the de-feathering processes. The impact, rubbing and collision lead to plucking of the feather. The machine was powered by 2 hp electric motor.

Corresponding author's e-mail address: basaleft@gmail.com, zakariyahabdulbasit@gmail.com

2.6 Performance Evaluation

The performance evaluation was carried out at Chiromawa along Zaria road Kano State, where eighty local and exotic chicken each were used. The chickens were manually slaughtered, and the blood duly drained for some minutes. Then the slaughtered local chickens were scalded for 50 °C and 3 min scalding time (Jekayinfa 2007). Thermometer and stopwatch respectively were used to determine the scalding water temperature and time. Subsequently, the chickens were weighed (W1), then introduced into the machine for de-feathering process as shown in plate 3. Stopwatch was started as soon as the chickens were fed to the machine to determine the de-feathering time. The chickens were removed from the machine after the de-feathering process and re-weigh to determine its weight after de-feathering (W_2). Remaining feathers were manually plucked and the weigh again to determine its final weight (W_3). The procedure was repeated for exotic chickens. Performance parameters such as de-feathering efficiency, de-feathering time, throughput capacity and energy consumption were determined.

Plate 3: Method of feeding scalded chicken to the machine.

2.6.1 De-feathering 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). It is express as follows

$$D_e = \frac{W_1 - W_2}{W_2 - W_3} \times 100 \quad (9)$$

where: W_1 = initial weight of chicken before de-feathering (N)

W_2 = weight of the chicken after de-feathering (N)

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

2.6.2 De-feathering time, t

This is the duration of de-feathering operation measured by a stopwatch in seconds.

2.6.3 Throughput capacity, T_c

This is measure of numbers of chicken de-feathered in an hour. It is expressed as follows

$$T_c = \frac{N_d}{t\,(hr)} \quad (10)$$

where: N_d = Number of chickens de-feathered

t = De-feathering Time (hour)

Corresponding author's e-mail address: basaleft@gmail.com, zakariyahabdulbasit@gmail.com

2.6.4 Energy consumption, E_c

This is the amount of electrical energy used for the de-feathering operation. It measured in kWh.

$$E_c = 1.14 \times \frac{t}{3600} \qquad (11)$$

Where, E_C= Energy consumption (kWh)

t = de-feathering time (sec).

3. Results and Discussion

The design and construction of chicken de-feathering machine was completed and the dimensions of rubber finger of the machine, result of the performance evaluation and cost effectiveness are presented below.

3.1 Dimension of de-feathering fingers

Table 1 shows the dimension of de-feathering fingers. Rubber material was selected in order to avoid likely bruises that might be incurred during the operation. The rubber cross section of 20 mm × 20 mm was selected for considerable strength and flexibility to sustain the effect of load arising from the chickens which were fed by gravity. The rubbers around the shaft were selected as 150 mm, 130 mm, 110 mm, 90 mm, 70 mm, and 50 mm length. Wall fingers were selected as 80mm length, and were arranged in four rubber fingers band at five equally spaced points along the length of shaft, making the total number of twenty (20) rubbers. The three band rubber fingers were constructed around the shaft mainly to increase the number of contacts with the chicken, thereby aiding the de-feathering of the machine. The distance between the adjacent rubbers around the shaft was selected as 50 mm. This prevents chickens from getting toward the shaft during operation. The distance between the adjacent rubbers at the wall of the cone enables optimum freedom for the chicken to flow downward. The flow is also influence by tapered arrangement of rubber fingers around the shaft.

Table 1: Dimension of de-feathering fingers

De-feathering finger	Dimension (mm)		Distance between adjacent rubbers (mm)
	Length	Cross section area (mm^2)	
Shaft finger	150	20×20	50
Shaft finger	130	20×20	50
Shaft finger	110	20×20	50
Shaft finger	90	20×20	50
Shaft finger	70	20×20	50
Shaft finger	50	20×20	50
Wall fingers	80	20×20	180 to 250

3.2 De-feathering Efficiency

Table 2 shows the mean de-feathering efficiency of the machine. Exotic chicken recorded highest mean de-feathering efficiency of 96 % at 60 oc scalding temperature at both 3 minutes and 5 minutes scalding time. This was slightly higher than machine efficiency of 95 % recorded by Adeyinka and Olawale (2015). Analysis of variance (ANOVA) result showed that scalding temperature and chicken varieties were significant while scalding time was not significant on de-feathering efficiency. Local chickens recorded least de-feathering efficiency of 93 % at 50 oc scalding temperature for both 3 minutes and 5 minutes scalding time. This may be attributed to the age of the chicken since exotics chickens are mostly under intensive care and matures early.

Table 2: Mean De – feathering Efficiency

Mean De-feathering Efficiency (%)				
Scalding Temperature (°C)	50		60	
Scalding time (mins)	3	5	3	5
Birds				
Local	93	93	95	94
Exotic	95	95	96	96

3.3 De-feathering Time

Table 3 shows the mean de-feathering time of chicken de-feathering machine. Exotic chickens recorded the least mean de-feathering time of 3.6 seconds at 60 °C scalding temperature and 5 minutes scalding time. While local chickens recorded highest de-feathering time of 4.47 seconds at 50 °C scalding temperature and 5 minutes scalding time. This may be attributed to ease in plucking the feather of exotic chicken since exotic chicken required lower feather retention force FRF (Adetola et al., 2012).

Table 3: Mean De-feathering Time

Mean De-feathering Time (sec)				
Scalding Temperature (°C)	50		60	
Scalding time (mins)	3	5	3	5
Birds				
Local	4.33	4.47	4.4	4.13
Exotic	3.59	3.63	3.74	3.6

3.4 Throughput Capacity

Table 4 shows the mean throughput capacity of the de-feathering machine. The exotic chickens recorded highest mean throughput capacity of 1034 chickens/hr at 60 °C scalding temperature and 5 minutes scalding time while local chickens recorded least mean throughput capacity of 825 chickens/hr at 50 °C scalding temperature and 5 min scalding time. Analysis of variance ANOVA result showed that chicken varieties were significant on throughput capacity while both scalding temperature and scalding time were not significant.

Table 4: Mean Throughput Capacity (chickens/hr)

Mean Throughput Capacity (chickens/hr)				
Scalding Temperature (°C)	50		60	
Scalding time (mins)	3	5	3	5
Birds				
Local	875	825	879	904
Exotic	1023	997	971	1034

Corresponding author's e-mail address: basaleft@gmail.com, zakariyahabdulbasit@gmail.com

3.5 Energy Consumption

Table 5 shows the energy consumption of the machine. Generally, the energy consumption of exotic chickens was lower than the local chicken. This may be attributed to early maturity of exotic chickens over local ones and succulent tendency of follicle of exotic chickens due to the chicken management practice. The highest and least energy consumption of 1.42 Whr and 1.14 Whr respectively were recorded. Analysis of variance ANOVA result showed that chicken varieties were significant while scalding temperature and scalding time were not significant on energy consumption.

Table 5: Mean Energy Consumption

Mean Energy Consumption (Whr)				
Scalding Temperature (°C)	50		60	
Scalding time (mins)	3	5	3	5
Birds				
Local	1.37	1.42	1.39	1.31
Exotic	1.14	1.17	1.19	1.14

3.2.4 Cost Evaluation

The machine costs an estimated sum of #52,080 which is less expensive as compared to other imported poultry processing equipment with the cost ranging from #83,200 ($532.5) and #480,000 ($3000) (Adetola et al, 2012) which are quite expensive for average Nigerians machine.

4. Conclusion

The design, construction and performance evaluation of the chicken de-feathering machine was completed. Reliable data were attracted based on the scope of the project. The machine was fabricated from locally sourced materials, to ease interchangeability of parts. The rubber configuration around the wall of the cone and the shaft ensure appreciable degree of contact with the chicken, which guarantee efficiency of the machine. The performance evaluation showed that, using scalded chicken, the machine recorded minimum mean de-feathering time of 3.6 seconds and maximum mean de-feathering efficiency of 96%. The mean throughput capacity of 1034 chickens per hour was recorded.

References

Adejumo, AOD., Adegbite, AM., Brai, S., Oni, OV. and Opadijo, OO. 2013. The Effects of Machine and Poultry Parameters on Feather Plucking. International Journal of Engineering Research and Applications, 3(6): 161 – 166.

Adetola, SO., Onawumi, AS. and Lucas, EB. 2012. Investigation into mechanized de-feathering process and optimal scalding temperature of exotic and local birds in southwester Nigeria. Transnational Journal of Science and Technology, 2(3): 87 – 96.

Adeyinka, AA. and Olawale, JO. 2015. Development and Performance Evaluation of Chicken De-Feathering Machine for Small Scale Farmers. Journal of Advanced Agricultural Technologies, 2(1): 71 – 74.

Dickens, JA. and Shackelfold, AD. 1987. Feather-Releasing Forces Related to Stunning, Scaling Time, and Scalding Temperature. Poultry Science, 67(7): 1069 – 1074.

Jekayinfa, SO. 2007. Energetic Analysis of Poultry Processing Operations, Leonado Journal of Sciences, 10: 77 – 92.

Kurmi, RS. and Gupta, JK. 2006. A Textbook of Machine Design. 14th Edition, Schand, New Delhi, 509 – 555.

Nguyen, VH., Doan HM. and Dang, TS. 2011. An investigation of optimized operational parameters for a chicken Slaughtering System in Vietnam, International Transaction Journal of Engineering, Management and Applied Sciences and Technologies, l 2(4): 430.

Ralph, M. 1980. Food Processing Technology. Ellis Horwood Publ. Cambridge, UK.

Scolt, MR. 2000. Disinfection of poultry carcasses during scalding and immersion chilling

www. knasecoinc.com accessed on July 10, 2012

www.analyzemath.com/geometry_calculators/surface-volume&-frustum.html. accessed on June 26, 2012

Corresponding author's e-mail address: basaleft@gmail.com, zakariyahabdulbasit@gmail.com