Development of a Defeathering Machine from Locally Sourced Materials

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Abstract—The increase in demand for chicken among the non – vegetarians worldwide has imposed greater responsibility on chicken processing industry. The traditional manual method of de-feathering of chicken is gradually going into extinction with the development of different capacities of de – feathering machines for both commercial and household use. This paper is focused on fabrication of a drum style small scale de – feathering machine. The drum style chicken de -feathering machine was fabricated with locally available materials. Design calculations were done correctly to ensure appropriate shaft diameter as this could affect the efficiency of the machine. The rubber plucker which does the actual plucking of the feathers is attached to the rotating plate against the stationary plucking drum carrying pop out rubber pluckers. The machine was tested with 10 chicken of 1.5 kg, the chicken was first soaked inside hot water at about 90 ^{0}C and put into the drum for about 50 – 60 seconds. The machine removed the feathers without damage to the chicken and also discharged the feathers continuously during the operation through the output chute. In conclusion, the machine performed effectively with an overall efficiency of 82 %, leaving behind products that could meet market standard.

Index Terms— Drum – Style Defeathering Machine, Fabrication, Hygienic, Locally Sourced Materials, Market Standard, Performance Evaluation, Small – Scale.

1 INTRODUCTION

Chicken meat is popularly consumed among non-vegetarians world-wide due to low fat and calorific content. Chicken is defined as domestic fowls reared for flesh or eggs. 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 likely be increasing correspondingly to meet the affective protein requirements of the world. In third world countries, and developing countries, chicken processing has faced challenges that are of safety and health concern [1], [2].

The level of human exposure to occupational risk and other health hazard resulting from intense manual operation is significant in scalding and de-feathering operations. This calls for effective mechanization of the process which will support quality, safe, ergonomic and economic operation. Various machines have also been developed for de-feathering process which can handle either large or few number of chickens [3]. However, their demand and acceptance are different from one country to another. Some years ago for instance, Nigerian Government placed an embargo on the importation of some poultry processed meat. This step placed a boost on the operation of local poultry industries and allied [4]. There are large numbers of large scale processing plants currently located around the world but small sized of household capacity are scarcely found [1].

Development of a poultry de-feathering machine is such an economical practice of a mechanized poultry processing plants to replace the removal of poultry feathers by hand for meat preparation, so as to increase the numbers of poultry products processed per day. On the other hand de-feathering or plucking simply means the process of removing feathers from scalded fowls [5]. Therefore, development of a poultry de-feathering machine is planning and building of a mechanical structure that will remove feathers of poultry birds. To avoid accidents and infections from poultry carcass which may occur during some of the processing operations, there is need for user friendly, reliably and efficient poultry processing devices [6].

Chicken defeathering machine is a machine whose function is to pull out the feathers of the chicken skin. The de-feathering process is one of the most processing before bird reaches the end product for cooking. It involves removing feather from the slaughtered bird. A de-feathering machine for removing the feather of poultry birds removes the feather under the force supplied to the rubber finger by the rotating electric motor. In order to optimize energy and overcome difficulties involved in manual de-feathering process of chicken, several factors such as scalding temperature, duration of immersion, age of the chicken and feather retention force determine the quality of the final product [7].

'De-feathering' is always used interchangeably with 'plucking' depicting the same meaning of removal of feathers from poultry birds. Therefore, development of a poultry de-feathering machine is planning and building of a mechanical structure that will remove feathers of poultry bird [7]. Increasing the number of birds processed per day, human labour is greatly reduced; problem of boredom through manual removal of feathers is eliminated, avoiding the situation of touching hot water while removing the feathers that might have been soaked in hot water and making the price of processed poultry products cheap are some of its advantages among many others. Again, tearing of carcass skin during the plucking process in the slaughterhouse has become one of the major economic problems during processing [8].

Defeathering operation or process is one of the most processing that a chicken must undergo before chicken reaches the end product for cooking. It involves removing feather from the slaughtered chicken [9]. A number of

important activities are involved in the production of ready - to - cook (RTC) poultry a large percentage of which are labour intensive and these contribute to the high cost of processed poultry meat in the market. Identified production processes for eviscerated birds are (i) Pre - slaughter: catching and transport; (ii) Immobilizing, killing, and bleeding, (iii) Feather removal: scalding and picking, (iv) Removal of head, oil glands, and feet, (v) Evisceration, (vi) Chilling, (vii) Cut-up, deboning, and further processing, (viii) Aging, (ix) Packaging, (x) Storage and (xi) Distribution [10].

Among the processes, feather removal is the most time consuming and risky next to eviscerating process especially when carried out manually. It takes an average time of 5 minutes for a person to de-feathering a bird [10], [11]. Manual de-feathering operation is done traditionally in this part of the world by the use of hand after it has been soaked in hot water of about temperature 80 – 85 ^{0}C takes 40 – 50 seconds [11]. This process result in low output, time consuming, tedious and could lead to injury. The traditional way to pluck a chicken involves plunging it into boiling water before you begin plucking. Plucking can take anywhere from five minutes to a half hour, depending on how good you are at plucking. Proper attention is needed when plucking young chicken, as their skin may tear [3], [12]. If pulling out feathers becomes difficult, consider soaking the chicken in hot water again. This process takes a lot of time putting for instance a situation where numbers of chickens are to be de-feathered and considering the side effect of putting ones hand in hot water which is very dangerous and may affect the skin [13].

2 MECHANIZED DEFEATHERING OPERATION

Basically chicken plucker machine is using the same principles in a way manual or traditional revocation i.e. chicken that was killed and soaked in hot water and then plucked one by one. The difference is that if the traditional process, quill removed manually by hand or manual equipment while on this machine quill lifted through the lifting of a system using multiple fingers, and then after the de-feathering process, water is supplied from the pump to clean the chicken which makes it to be free from the peel – off feathers. The basic concept also resembles the traditional way. The concept is a chicken held by the left hand or using a tool holder while the right hand moves plucking chickens. On this machine chicken feather held by some of the finger is placed in the static part and dynamic part. When the dynamic part is driven and static part remains silent, then the quill held by finger would be interested to release it [14].

The use of de-feathering machine in processing chicken has contributed to the successful processing of dressed and hygienic chicken for consumption. This is an improved and simplest method of de-feathering operation; this is done after slaughtering the bird which is accompanied by bleeding period. The dead bird is removed and lowered into a tank of heated water to a certain temperature and then plucked by switching on the machine [15]. Different de-feathering machine designs are available e.g. the table-top plucker machine, drum – style de-feathering machine. Table-top plucker machine is very risky to drum-style de-feathering and washing machine because, in table-top plucker machine, you will have to up hold the chicken and gradually dropping the chicken to the spinning fingers and manually move it around the machine but for drum-style plucker and washing, you just need to lowered your chicken in the drum and allow the machine to do the whole job for you. This machine is used for conditions of a chicken that has been boiled in hot water of about temperature 80 – 85 ^{0}C first. This machine is designed easy to use and easily removable [14].

This machine is important because the demand for chicken meat continues to increase every year. These conditions impact on increasing demand for businesses based chicken from a chicken farm, slaughter chickens, broilers seller, chicken restaurants and chicken-based company. On the other hand, people also began to care about the hygiene and quality of the chicken so chicken processing should be supported with adequate facilities and equipment both in terms of efficiency, quantity, quality and technology. Chicken processing in large quantities will also make it difficult to control the level of hygiene and quality of chicken meat, if processing is done manually. Therefore the use of appropriate technology is needed, especially in the chicken slaughter and plucking chickens [16]. The various types of defeathering machine available are the Drum style de-feathering machine and the horizontal defeathering machine.

3 VARIOUS CARCASS SCALDING TEMPERATURES

The appearance of the dressed bird when sold is largely determined by the temperature of the water in which it was scalded before feather removal. Under normal ice storage condition, birds scalded between 51 ^{0}C – 54 ^{0}C for 45 seconds will last for just 7 – 10 days without any discoloration, and they retain their skin colour. However, at this condition it is always difficult to pluck with any type of plucker due to the inadequate scalding temperature. Barbut [1] and Pitchovsci [8] used scalding temperature of 50 – 53 ^{0}C for 60 – 180 seconds duration for young broiler and young turkey because it does not damage much of the outer layer of the skin, while it still allows for relatively easy removal of the feathers. Carcass scalding at 60 ^{0}C – 62 ^{0}C for (15 – 30 seconds duration) does not require as long a time in the picker's mechanism, as the equipment will perform faster and will also do a more thorough cleaning. But the appearance of the bird will last only 4 – 5 days under refrigeration. The researchers also used 54 – 58 ^{0}C for 60 – 120 seconds for mature birds which can cause the removal of part of the outer skin layer that leaves the skin sticky.

At this scalding temperature 71 ^{0}C and above for (10 seconds duration), no hand picking of the remnant pin feathers is necessary. Birds processed at this temperature are white and may start to discolour in as little as 3 days. Thus, the type of scald to be selected is very important in selecting processing equipment, particularly for automated one rather than manual. Barbut [1], Pitchovsci [8] and Buhr et al., [17] reported that poultry scalded at temperature range of 59 – 61 ^{0}C for 45 – 90 seconds duration, has skin discolouration which

does not occurred in water flow.

Different de-feathering machines and rubber plucker have been designed and constructed even with different materials for different species of poultry. This is for the fact that the amount of energy required to remove the feathers vary from one species to another. For the purpose of this paper, the de-feathering machine was being developed for both local and exotic chicken products. Also, to avoid complexity in design and construction, the machine has the capacity of de-feathering a chicken per time. This paper aims at the development of a small scale drum-style de-feathering machine with a water reservoir from locally sourced materials whose plucked feather will be discharge continuously during the operation powered by electric motor.

4 METHODOLOGY

4.1 Materials Selection

The choices of the material and component used here are based on the consideration of the following factors, cost analysis of the material, durability of the materials, availability of the materials, properties of the material such as; physical properties, thermal properties, relative properties, chemical properties and mechanical properties.

Table 1: Materials Used and Selection Criteria

S/N.	MATERIALS USED	SELECTION CRITERIA
1.	Stainless plate	It has a very high resistance to corrosion
2.	Angle bar	It is very rugged and easily to fabricate
3.	Pipe	It is rugged and easily to fabricate
4.	Electric motor	To transmitting the torque, with aid of V-belt
5.	Water pump	To wash the chicken and to discharge the plucked feather
6.	Plucker rubber	To plucked the feather
7.	Bolt and nut	It is used to couple the drum and frame together
8.	Paint	To enhance the resistance to corrosion

4.2 Construction Technique

The following operation sequences were undertaken in the fabrication of de-feathering machine, measurement and marking out, cutting of material, welding, grinding, and drilling operation. And the following tools were used: Hack saw, Scriber, Try-square, Measuring tape, Welding machine, Grinding machine and Drilling machine.

Operation Sequence include:

Measurement and Marking Out: The measurement were used according to the design specification and the marking out was done accordingly.

Cutting of Materials: Sheet metal (stainless plate) of 1mm thickness, sheet metal (mild steel) 1mm thickness and angle iron were marked out according to the dimension. The cutting operation was carried out manually using shearing machine to cut angle bar, pipe and shaft while hand cutting machine is used to cut sheet metal manually.

Welding Operation: All materials being cut out were joined by the use of arc welding machine.

Grinding Operation: Contours on the welded joints of the work piece were smoothened using grinding machine. It is the operation in which all welded area and rough surfaces are slightly grinded for smooth and aesthetes surface finishing. The welded joint were slightly grinded, because too much of grinding will weaken the strength of the bond.

Drilling Operation: The drum, rotating plate and the base of the machine were drilled accordingly, using drilling machine with (21mm) drill bit.

4.3 Description of Part of the Defeathering Machine

The parts of the machine includes the Outer drum, Static finger, Dynamic finger, Upside down finger, the Finger plate, Bearing, Main Frame, Output Chute, Electric motor, Main shaft, Driven Pulley, Driven pulley, V-Belt, Foot adjuster and Water reservoir

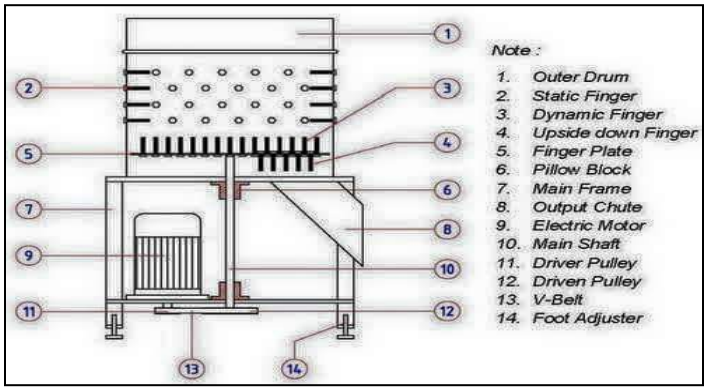

Fig.1. showing the drum style de-feathering machine with parts

4.4 Principle of Operation of the De-feathering Machine

Chicken de-feathering machine is a machine designed by using an electric motor. Electric motor drives the dynamic finger studded on the rotating plate at a certain speed. Transmission power from the electric motor to the rotating

plate is using v-belt transmission. Driver pulley mounted on the electric motor and the driven pulley mounted on the main shaft. Main shaft rotating on a vertical axis direction and moving the rotating plate directly. This principle distinguishes between vertical and horizontal retraction system.

Chicken will be processed placed on a finger plate. In the rotating plate has been installed dynamic finger made of rubber with a screw shape that serves to bind the chicken feathers. When the rotating plate rotates at a certain speed, the chicken will come round and is likely to be thrown into the drum wall due to centrifugal force. Chicken feathers tied in dynamic finger will be regardless of chicken when the chicken thrown into the drum wall. In the drum wall studded with finger rubber that will bind chicken feathers when chicken thrown into the drum wall. Chicken will fall back to dynamic finger due to gravitational forces. Chicken feathers tied in static finger will fall into finger plate.

5 DESIGN CALCULATIONS

Certain calculations were made on certain parameters so as to make correct choice in selecting them. Design calculations were carried out on the following: sheave, belt, and shaft and rubber plucker basin.

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 1400 rpm. In order to calculate the speed that would be transmitted to the shaft, the following analyses were been carried out:

$$N_1D_1 = N_2D_2 \text{ [18]} \quad (1)$$

where N_1 = speed of the motor, 1400 rpm,
D_1 = diameter of the motor sheave, 24 mm,

N_2 = speed of the shaft/shaft sheave,
D_2 = diameter of the shaft sheave, 140 mm

$$N_2 = \frac{N_1D_1}{D_2}$$

$$N_2 = \frac{1400 \times 24}{140}$$

$$N_2 = \frac{33{,}600}{140} = 240\ rpm$$

Therefore, the speed that the motor will transmit to the shaft/shaft sheave through the belt is 240 rpm.

Shaft Design: 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 [18]. 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.

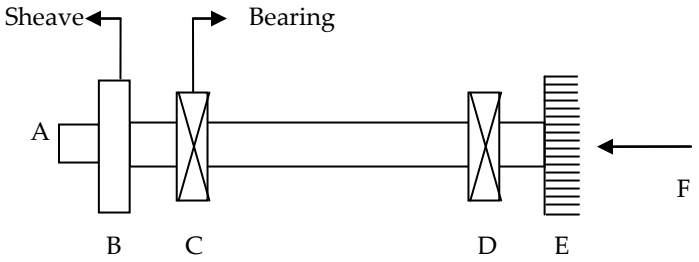

Fig. 2. Forces acting on the shaft

Drum: The drum was made up of stainless of 1mm thick, the diameter of the drum is 470 mm and length 500 mm. the area of the drum is calculated as follows:

The diameter of the de-feathering drum is 470 mm = 0.47 m

The length of the de-feathering drum is 500 mm = 0.50 m

$$Area\ of\ the\ defeathering\ drum = \pi dl \quad (2)$$

$$= 3.142 \times 0.47 \times 0.50$$

$$= 0.74\ m^2$$

Frame: The frame is made of angle iron for it to be rigid and it takes rectangular shape of length 580 mm and breadth 570 mm

$$\text{Area of frame} = \text{Length} \times \text{Breath} \quad (3)$$

$$\text{length} = 580\text{mm} = 0.58\ \text{m}$$

$$\text{breath} = 570\text{mm} = 0.57\ \text{m}$$

$$= 0.58 \times 0.57 = 0.331\ m^2$$

Rotating Plate: The rotating plate was made from a stainless steel of 1 mm thick; it takes a circular shape of diameter 430 mm. To calculate the area of the rotating plate, the following analysis was been carried out:

$$Area = \pi d^2 = 3.142 \times (0.43)^2 \quad (4)$$

$$= 3.142 \times (0.1849)$$

$$= 0.58\ m^2$$

6 RESULT AND DISCUSSION

The machine was developed and constructed. Test was carried out by taking the weight of the bird before the de-feathering process and time taken to complete the process was noted. After the process has been carried out, the machine was stopped. Visual observation of the chicken revealed the state

of de-feathering and the time taken and final weight recorded. The feather was then discharged from the machine with the help of output chute and weighted to know the weight of the removed feather from the chicken. The test was replicated three times and the summary of results obtained as recorded in

Table 2: Results obtained from de-feathered Chicken

Test	Initial Weight (kg)	Weight feather removed by machine (kg)	Time (sec)	Final weight	Efficiency $= {}^{w_f}/_{w_i} \times 100$
1	2.20	0.41	25	1.79	81
2	2.00	0.39	25	1.61	80
3	1.95	0.28	22	1.67	85

$$Average\ Efficiency\ = (81 + 80 + 85)/3$$

$$Average\ Efficiency = 82\ \%$$

It can be seen from Table 3 that the time taken to de-feather the chicken of average weight of 3.65 kg is 25 s. According to [10] when birds are de-feathered manually, a time of five minutes was required and an output of 12 birds per hour was achieved. In this design, an average output 360 birds per hour was achieved. The machine was designed to accommodate two birds per process. There was significant difference of ($P < 0.32$) between the weight of the birds and the time taken to de – feather. This means that the bigger the bird, the more the time taken to de-feather. There was no significant difference between the weight of feather removed by the machine and the time taken to de-feather while there is significant difference between the feather removed by hand and time taken. Feather retention forces of chicken carcasses from scalded exotic chicken are shown in Table 4 and 5.

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Table 3: Force required plucking out contour feather at varied temperature [19]

Temperature (^{0}C)	Force for exotic (N)
70	4.13
75	3.63
80	3.00
85	2.45
90	2.00

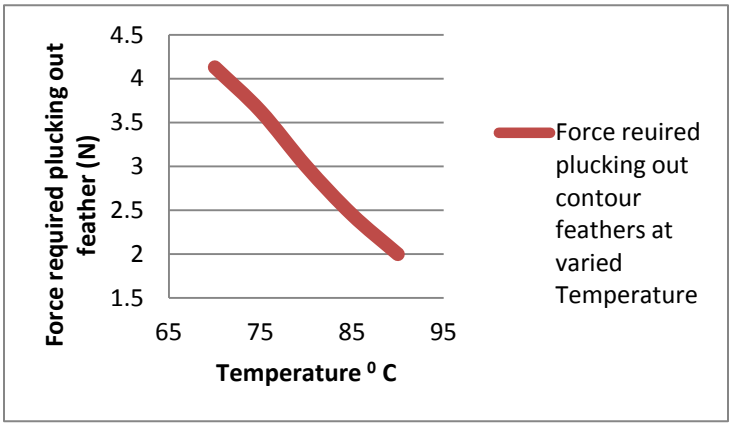

Fig. 2. Showing a graph of force required to plucking out contour feather against temperature

Table 5: Force required plucking out down feather at varied temperature [19]

Temperature (^{0}C)	Force for exotic (N)
70	1.02
75	0.96
80	0.91
85	0.86
90	0.81

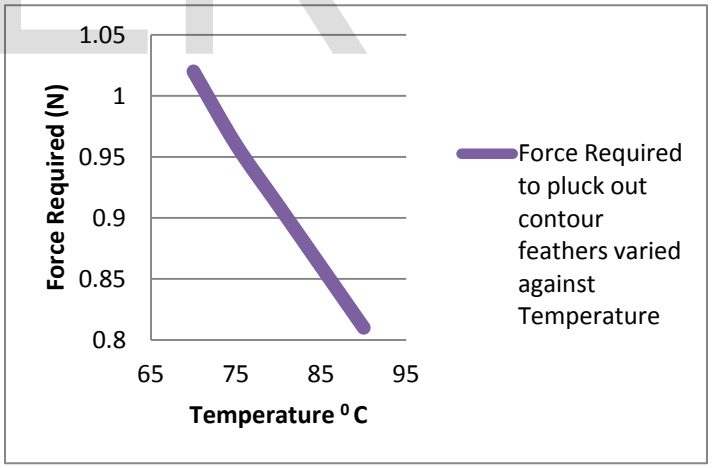

Fig. 3. A graph of force required to plucking out down feather against temperature

7 CONCLUSION

The existing drum style de-feathering is a very common machine used in this part of the world used by various categories of people. The de-feathering machine is mostly used by local or small scale poultry farmers in running their business. Road side poultry sellers during festivals, small scale processing industries etc. find it very useful in their business plan but the problem associated with this machine includes

the absence of water supply (reservoir) which makes it the work tedious and very stressful. The improvement is in terms of using the water supplied to clear the feather from the carcass and help to discharge the plucked feather continuously during the operation. The following are recommendation to cater for efficient use:

- The machine should be placed leveled on the ground
- The machine should be used as instructed.
- Machine should be cleaned after use
- The weight of the chicken to be de-feathered must be below or same as the stated weight.

More work can be done on the machine incorporating a heating chamber where the chicken goes straight into the boiled water and a passage linking the defeathering chamber and there must be continuous supply water available.

REFERENCES

[1] Barbut S. Primary processing of poultry (Boca Raton London New York Washington, D.C: CRC Press), 2002.

[2] OSHA (Occupational Safety and Health Administration), Prevention of muscle skeletal injuries in Poultry Processing. OSHA 3213-12R 2013.

[3] Herrick K. Anyone can build a Tub-Style Mechanical Chicken Plucker. Complete instructions for the Kimball Whizbang, vol 1., 2003.

[4] Adetola, S. O., Onawumi, A. S., and Lucas, E. B. Investigation into mechanized de-feathering process and optimal scalding temperature of exotic and local birds in Southwestern Nigeria. *Transnational Journal of Science and Technology* vol. 2, No.3, pp 87-96, 2012.

[5] S. O. Adetola, G.A. Daramola and S.O. Ogundiran. Development of a Household Poultry De-Feathering Machine with Better Efficiency. *IOSR Journal of Mechanical and Civil Engineering* Vol. 11, Issue 3 Ver. VIII Pp 51-59, 2014.

[6] Jekayinfa S. O. Energetic analysis of poultry processing operations. *Leonado Journal of Science* A10, Pp 77-92, 2007.

[7] A. A. Klose, E. P. Meechi and M.F. Pool, Feather release by scalding another factors, Finland, Academic Press, 1962.

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[8] Pitchovsci J., Ohana N., Amzaleg L., Krispel S., Bercovich D., and Pinchasovt Y. Identification of a starting point of breast skin tear during chicken plucking. *Isreal. Poultry Science,* Pp 76,405 – 409, 1997.

[9] Dickens J. A. and A. D. Shackelford. Feather releasing force related to stunning, scalding time and scalding temperature, *Poultry Science*. Vol 67: Pp 1069-1074, 2004.

[10] David R.A. You can build your mechanical plucker. http//www.FAO.Org, 1999.

[11] Buckland, C. "Small scale poultry processing,". Online available at www.fao.org/docrep/003/t0561e/T0561E03.htm, *2005.*

[12] M. R. Scolt. "Disinfection of poultry carcasses during scalding and immersion chilling," http://www.knaseconic.com 2000.

[13] Tanimola, O. A, Diabana, P. D. and Bankole, Y.O. Design and Development of a De-Feathering Machine. *International Journal of Scientific & Engineering Research*, Volume 5, Issue 6, June – 2014.

[14] Glenn, J. (1998) Mechanical harvesting of broilers. *Poultry Sci.* 77: 1794

[15] Adeyinka A. A., Olawale J. O. Development and Performance Evaluation of a Chicken De-Feathering Machine for Small Scale Farmers. *Journal of Advanced Agricultural Technologies* Vol. 2, No. 1, June 2015.

[16] Ogundipe, S.O, "belts-length and speed of belts, Engineering toolbox (N.D)." http://www.engineeringtoolbox.com/length belt-fans-motor-d_872 html. 2002. Accessed 27th June, 2016.

[17] Buhr R. J., Walker J. M., Bourassa D. V., Caudill A. B., Kiepper B. H., Zhuang H. Impact of broiler processing scalding and chilling profiles on carcass and breast meat yield. *Poult Sci*. Jun; 93 (6): 1534-1541, 2014.

[18] Khurmi R.S. and Gupta J.K. Machine design, (New Delhi Eurasia Publishing House (PVT) Ltd, Ram Nager. 14 edition, Pp 544-711, 2006.

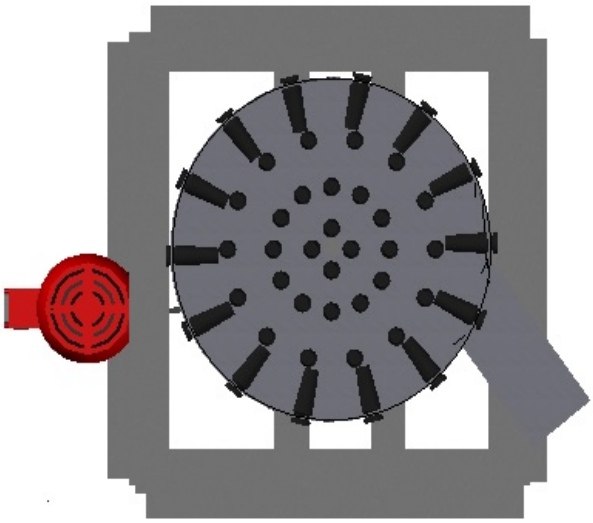
[19] E.B. Lucas, S.O. Adetola (2013) Comparative plucking force characterization of chicken produced from two breeds of chicken. International Journal of Engineering Research and Applications (IJERA), Vol. 3, Issue 4, pp. 573 – 579, Jul – Aug 2013.

APPENDIX

Appendix A: Bill of Engineering Measurement and Evaluation

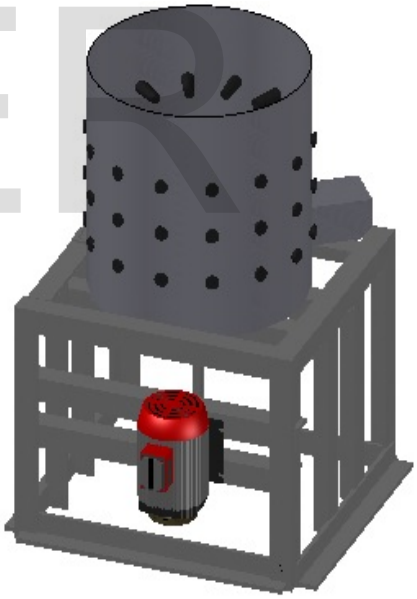
S/N	Description	Unit	Rate	Amount
1	Stainless Plate	1	25,000	25,000
2	Angle Bar	3	3,500	10,500

3	Flange Bearing	2	1000	2000
4	Shaft Sheave	1	500	500
5	Shaft	1	2,500	2,500
6	Electric Motor	1	15,000	15,000
7	Motor Sheave	1	500	500
8	V- Belt	1	500	500
9	Bolt and Nut	14	50	700
10	Plucker Rubber	90	200	18,000
11	Water Reservoir	1	500	500
	Total			#73, 050



Appendix C: Plan View of the de-feathering Machine

Appendix B: Picture of the Fabricated Defeathering Machine



Appendix D: Front Elevation of the de-feathering Machine