International Journal of Research and Review
DOI: https://doi.org/10.52403/ijrr.20211285
Vol.8; Issue: 12; December 2021
Website: www.ijrrjournal.com
E-ISSN: 2349-9788; P-ISSN: 2454-2237

Research Paper

Design, Fabrication and Performance Evaluation of Chicken De-Feathering Machine

Adefuye O.A[1], Adedeji K.A[2], Fadipe L.O[3], Arowoka Z.M[4], Mohammed O.A[5]

[1-5]Department of Mechanical Engineering, Lagos State University Epe Campus, Lagos, Nigeria.

Corresponding Author: Adedeji Kasali A

ABSTRACT

Due to its low fat and calorie content, chicken meat is popular among non-vegetarians all over the world. The design, fabrication, and performance evaluation of a chicken de-feathering machine using locally available materials are described in this paper. The design calculations were done correctly to guarantee the right shaft diameter, as this might impact the machine's efficiency. The machine uses rubber fingers to do the actual removal of the feathers. The rubber fingers are attached to a rotating plate against a stationary plucking basin carrying protruding rubber fingers. From the analysis, a 1.0 H.P electric motor is required to drive the machine and this was used to drive the machine. Following the design and fabrication of the machine, three different types of chickens were used to test its performance. The chickens were immersed in hot water between 60 and 90 degrees Celsius and held between the 40s and 60s. The machine removed feathers without any major damage to the chickens. At each trial, the efficiency was calculated. In conclusion, the machine performed efficiently and effectively, leaving behind products that are readily marketable.

Keywords: [Chicken, De-feathering, Efficiency. Fingers, Scalding, Rubber.]

INTRODUCTION

Meat products from poultry processing facilities have a large market in today's globe. Because of the growing mechanization of poultry farming, the daily demand for the products is constantly fulfilled. (Adetola et al, 2014). Because of its low fat and calorie content, chicken meat is popular among non-vegetarians all over the world. A domestic fowl raised for meat or eggs is known as a chicken. Over with the heightened yearning for chicken. Other types of meat have sparked intense interest in the poultry farming and processing industries. Similarly, as the world's population grows, animal consumption rates are anticipated to rise in tandem to satisfy the world's dietary protein needs. The use of a poultry de-feathering machine is an economical practice of a mechanized poultry processing plants. It replaces the removal of poultry feathers by hand for meat preparation. It increases the numbers of poultry meat products processed per day. Plucking simply means the process of removing feathers from scalded fowls manually. So the de-feathering Machine is basically a means of getting ‘plucking’

Done better and faster. Some advantages of the de-feathering machine are; human labour is greatly reduced; problem of boredom through manual removal of feathers is eliminated; avoiding scalding of the hand by hot water used in plucking is eliminated, uniformity of de-feathering is guaranteed (provided machine is in good order), Minimize the spread of COVID, Ebola infections etc. Efficiency of de-feathering is increased. More over the machine is not very expensive and it’s easy to operate and maintained. Making the price of processed poultry products cheap. Again, during the plucking process at the slaughterhouse, ripping of carcass skin has become one of the primary economic concerns. The sole potential drawback is that it will eliminate jobs for some people; but, it will provide new ones for others, such as engineers developing and constructing the machine. The technologists who repair the machine, the increase in the capability of our poultry meat processing out fits will lead to more employment opportunities than the ones it eliminated. Poultry meat production has grown from a home company to an industrial and commercial enterprise, as seen by the growing demand for its goods across the world today. (Awotunde et al, 2018). To guarantee that the supply of chicken meat matches the expectations of customers, poultry de-feathering machine are required. Adejumo et al, (2013) developed poultry feather plucking machine which was evaluated using two breed (Isa Brown layer and Cockerel). The present feather plucking equipment was created and built by Federal College of Agriculture's engineering department. The frame assembly, plucking, and power transmission units are the three primary components of the machine. The frame is triangular in shape and bears the total weight of the machine. The plucking unit consists of a drum that can hold three birds each batch. The drum's wall is studded with rubber fingers, and a spinning plate contained by the drum is likewise studded with fingers. The development of poultry feather plucking machine which was evaluated using two breed (Isa Brown layer and Cockerel)at the machine speed of 225, 312, 369 and 426rpm, and scalding time of 30, 60 and 90 seconds. Plucking efficiency calculated on mass basis. The results reveal that the machine's plucking efficiency is highest on cockerel. As the machine speed and scalding temperature increased, the plucking efficiency dropped. Awotunde et al, (2015) developed a De-Feathering Machine from Locally Sourced Materials. The paper focuses on the fabrication of a small-scale de-feathering machine in the drum style. The drum style chicken de-feathering machine was made from locally sourced materials. The rubber fingers that pluck the feathers are linked to a spinning plate that is set against a fixed plucking drum with pop out rubber fingers. The machine was tested with 10 chicken of 1.5 kg each, the chicken was first soaked inside hot water at about 90 °C and put into the drum for about 50-60 seconds. The machine plucked the feathers without harming the bird and released them constantly down the output chute during the process. In conclusion, the machine performed effectively with an overall efficiency of 82 %, leaving behind products that could meet market standard. Omoniyi Ezekiel et al, (2019) designed and developed a Bird Feather Removal Machine. This machine incorporates the boiler into the de-feathering machine. As a result, the study recommends that the modified de-feathering machine be used as a viable replacement for the old technique (manual plucking), which is sluggish and laborious. With the addition of a boiling chamber for first-stage scalding and a hot spray channel directly in the plucking chamber, this suggested method improves on the de-feathering machine. After the fabrication and construction of the machine, various tests were conducted, and the initial weight and final weight were recorded for each 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. The average feather removal time was estimated as 32.5 Seconds. This value indicated that the removal rate for this design is 107birds/h. However, because the birds are spinning at a fast speed, it is impossible to accurately see when all feathers have been removed, this value is entirely dependent on the operator's opinion or satisfaction. The type of bird also affects the removal rate as this value applies to chicken. From study, manually feather removal rate was estimated at 12birds/h. This therefore highlights the advantage of this design as an average output rate of 360birds/h was achieved. The equipment was built to process two birds at a time. Physical observation shows that at low scalding temperatures, entirely removing the feathers becomes difficult, necessitating a greater motor speed to minimize scalding time. Similarly, for higher scalding temperatures, there is a risk of the skin being cooked. As the feather seemed to tear away parchment of skin tissue from the bird, which makes feather removal tough. The ideal temperature for achieving satisfactory results, on the other hand, is determined by the type of bird being processed. For the locally breed chicken, substantial plucking force difference was noticed between 750C and 800C while for temperatures greater than 800C, the required plucking force remained fairly constant. For Exotic birds, the optimum recorded temperature ranged between 650C to 750C. After testing, the machine's design has been improved. To begin, spinning parts were modified to reduce noise and vibrations in sections such as the belt, and dampers were put on the motor to accomplish this. Alignment of shaft was done, and the bearings were all replaced. (Jekayinfa et al, 2007) Energetic Analysis of Poultry Processing Operations was studied. The energy audit of the chosen poultry processing industries indicated that either national grid or captive produced power was used as the main source of energy input for poultry processing operations. It was also observed that the total energy requirement per 1000 birds in the three selected plants is respectively 50.36MJ, 28.04MJ and 17.83MJ. In all the plants, scalding of de-feathering accounted for 44% of the total energy consumption followed by eviscerating, slaughtering, washing & chilling and packing in that order. The study's findings were beneficial in budgeting, projecting energy consumption, and planning facility expansion. The usage of a spreadsheet application on Microsoft Excel was used to estimate energy requirements in the 5 key unit activities of chicken processing. Any plant operator wanting to compute the energy consumption pattern of their processing activities at any accounting period will find the computing technique simple to follow. Adeyinka A. Adesanya et al, (2015) designed, developed, and evaluated the performance of a Chicken De-Feathering Machine for Small Scale Farmers. In the bid to achieving these objectives, the de-feathering chamber was made from a food-grade plastic drum, the frame was made out of wood, and the plucking fingers were made out of tapered rubber. After the design and fabrication, the machine was carefully evaluated to ascertain its performance. It was observed that at constant speed (300 rpm) and at time interval of 5 seconds, the mass of feather removed was found to be 38.35 g, 31.72 g, 25.15 g, 19.25 g, 12.50 g and 0 g respectively. The total mass of feather removed was 126.97 g. During the de-feathering process, it was found that the flesh of the chicken was not damaged. Consequently, the machine capacity was found to be 1 bird per 25 seconds while the machine efficiency was 95%.

MATERIALS & METHODS

Design consideration

Some of the criteria considered in the design of the machine include use of local materials, adequate capacity, affordability, reduction in time and energy spent in de-feathering chicken manually, detachable components, using bolts and nuts to attach for easy repair and maintenance.

De-feathering Chamber Design

The plucking chamber will be opened at both ends. The diameter of the chamber is 400mm. seventy holes will be strategically drilled on the walls of the chamber and on the rotating plate. The diameter of each hole will be 18mm.

The sizes of the chicken consider is stated as follows;

Height = 440mm
Width = 304.8mm
Mass = 5kg
Weight = 49.05N
Volume of plucking chamber

The volume of the plucking chamber is determined using the formula for calculating the volume of a cylinder

$$\boldsymbol{V = \pi r^2 h} \qquad (1)$$

Where, V = Volume of the cylinder;
Considering the size of the chicken selected;
R = Radius of the cylinder = 200mm
h = height of the cylinder = 457.2mm

$$\boldsymbol{V = 3.142 \times 200^2 \times 457.5}$$

$$\boldsymbol{V = 57491145.56 mm^3}$$

Volume of the plucking chamber = $\boldsymbol{57491.14\ m^3}$

Velocity Ratio of belt drive

Considering the standard dimension of pulley according to Khrumi et al (2009) the following dimensions of pulley was selected for easy computation;

Diameter of the motor (driver) pulley = d1 = 70 mm = 0.07m
Diameter of the driven pulley = d2 = 230 mm = 0.23m
While the speed of the motor selected was 1425rpm.

Using velocity ratio of belt drive formula (Khrumi et al, 2009)

$$\boldsymbol{\frac{N2}{N1} = \frac{d1}{d1}} \quad \mathbf{(2)}$$

Where
N_1 = speed of the driver = 1425rpm
D_1 = diameter of the driver = 70mm
D_2 = diameter of the driven =230mm

Therefore

$$\mathbf{N2} = \boldsymbol{\frac{N1d1}{d2} = \frac{1425\ x\ 0.07}{0.23} = 433 rpm}$$

Force Required for Feather Removal

The force required for feather removal Fc is determined from the equation according to Khrumi et al, (2009)

$$\mathbf{Fc = M\ \omega^2 r}$$

Where
M = Mass of the rotating plate = 0.7kg;
ω = Angular velocity of the pulley = 46.9 rpm
r = Radius of the pulley = 0.115m;
The force required to remove the feather,
Fc = 177N.

Torque = force x radius = f x r (3)
Where; r = 185 mm and F =177N
T = 177N x 185mm
T = 32375Nmm = 32.375Nm

Power needed to drive the plate

The power needed to drive the plate is expressed as (Khrumi et al, 2009)

$$\mathbf{P = 2\pi TN/60} \quad (4)$$

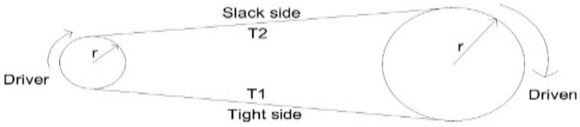
Where
P = Power transmitted to shaft in Watts
T = torque in Nm
N = Speed of the shaft in rpm
Substituting the values of T and N above
Therefore

$$\mathbf{P = \frac{2\pi TN}{60}}$$

$$\mathbf{P = \frac{2\ x\ 3.142\ x\ 32.375\ x\ 300rpm}{60}}$$

P = 1017.2W = 1.0176 KW
The power needed in horse power
I H.P = 745.7W
1W = 0.001341H.P
Therefore
1017.2W = 1.3 H.P
Hence, this machine is designed to use two-horse power (1.3hp) electric motor

Calculating the tensions of the belt



Belt drive mechanism above, from the figure above
T1 = Tensions in Newton on the tight side
T2 = Tension in Newton on the slack side
R1 = Radius of driver
R2 = Radius of driven

Calculating length of the belt

From Khurmi et al (2013), the formula for calculating length of belt drive is obtained as

$$L = \frac{\pi\,(r2 + r1) + 2x + (r2 - r1)2}{x} \qquad (5)$$

Where

r1 = radius of smaller pulley = 0.07m
r2 = radius of bigger pulley= 0.230m
x = distance between the centre of the pulley = 0.315m

Substituting the values of r1, r2, x in equation (4)

$$L = \frac{\pi\,(0.230 + 0.07) + 2\,(0.315) + (0.230 - 0.07)2}{0.315}$$

$$L = 1.65\mathrm{m}$$

Calculating Angle of contact between belt and the smaller pulley

According to Khurmi et al (2013), the angle of contact is expressed in radian as:

$$\emptyset = (180 - 2\alpha)\frac{\pi}{180} \qquad (6)$$

Where

$$\mathrm{Sin}\ \alpha = \frac{r1+r2}{x} \qquad (7)$$

$$\mathrm{Sin}\ \alpha = \frac{0.230+0.07}{0.315}$$

Sin = 0.9523
= sin-1 (0.9523) = 72.240
Substitute 72.240 for in equation (5)

$$\emptyset = (180 - 2 \times 72.24)\frac{\pi}{180}$$

$$\emptyset = 0.62rad$$

Calculating mass of the belt per meter length of a rubber belt

From Khurmi et al (2013), the density of rubber belt was 1140kg/m2

Also, the breath and thickness of the belt selected were 13mm and 8mm respectively.

We know that

$$\mathrm{Density} = \frac{\mathrm{Mass}}{\mathrm{Volume}}$$

$$\mathrm{Mass} = \mathrm{Area\ x\ length\ x\ density} \qquad (8)$$

Mass = 0.11856kg

Calculating Velocity ratio of belt

From Khurmi et al (2013), the velocity ratio of a belt drive is expressed as

$$V1 = \frac{d1N1}{60}\ \mathrm{m/s} \qquad (9)$$

Substituting the values of d1 and N1 in equation 2

$$\mathbf{V1} = \frac{\boldsymbol{\pi}\ \mathbf{x\ 0.07\ x\ 1425rpm}}{\mathbf{60}}$$

$$\mathbf{V1 = 5.22m/s}$$

The following expression are obtained from (Khrumi et al, 2009)

1. The ratio of driving tension for flat belt drive

$$2.3\log\frac{T1}{T2} = \mu\,\emptyset \qquad (10)$$

Where μ = Coefficient of friction between the belt and pulley

Coefficient of friction between rubber and dry steel is usually taken to be 0.3 (Khrumi et al, 2009).

∅ =Angel of contact in radians

2. Centrifugal Tension

$Tc = M.V^2$ (11)

Where

M = mass of belt per unit length in kg
V = linear velocity of belt in m/s

3. Maximum tension

T = σ.b.t (12)

Where

σ = maximum safe speed
b = width of belt
t = thickness of belt

4. Tension on tight side

T1 = T – Tc (13)

Where

T = Maximum tension
Tc = centrifugal tension

Substituting the value of M and V in equation (10)

$Tc = M.V^2 = 0.11856 \text{ x } (5.22)^2 = 3.230N$

Also, maximum tension

T = 2.5MPa x 13mm x 8mm = 260N

Substituting value of T and Tc in equation (12)

T1 = (260 – 3.230) N = 256.769N

Substituting the value of N and $\emptyset$ in equation (9)

$$2.3\log\frac{T1}{T2} = \mu\ \emptyset$$

$$\mathrm{Log}\frac{T1}{T2} = \frac{\mu\ \emptyset}{2.3}$$

$$\mathrm{Log}\ \left(\frac{T1}{T2}\right) = \frac{0.3\ x\ 2.04}{2.3}$$

$$\mathrm{Log}\ \left(\frac{T1}{T2}\right) = 0.2661$$

$$\frac{T1}{T2} = e\text{^}0.2661$$

$$\frac{T1}{T2} = 1.3049$$

$$T_2 = \frac{T1}{1.3049}$$

$$T_2 = \frac{255.921}{1.3049}$$

T_2 = 196.12N

Design of Shaft

Since Stainless Rod is used for the shaft, maximum shear stress theory is used for the design of shaft diameter and it is stated below according to RS. KHUMI

$$d^3 = \frac{16}{\pi\tau}\sqrt{}(k_bM_b)^2 + (k_tM_t)^2$$

Where

Kb = combined shock and fatigue factor applied to bending moment;

Kt = combined shock and fatigue factor applied to torsional moment;

Mb = Bending moment (Nm);

Mt = Torsional moment (Nm)

τ = Allowable shear stress

When the shaft is loaded with torsion and bending loads only

$$T = \sqrt{M^2 + T^2} = \frac{\pi}{16} * \tau * d^3$$

$$M_e = \frac{1}{2(M+\sqrt{M^2+T^2})} = \frac{\pi}{32} * \sigma_b * d^3$$

Where,

T_e = equivalent twisting moment,

M = maximum moment (Nm),

T = torque transmitted (Nm),

σ_b = bending stress (N/m2),

d = diameter of the shaft (m),

τ = shear stress (N/m2), = equivalent bending moment.

Now to calculate the diameter of the shaft, the following steps were taken:

Step 1: find τ

Step 2: Torque, T transmitted

Step 3: find maximum B.M i.e. draw the free body diagram

Step 4: find diameter, d using the equation of T_e and M_e

Assuming d = 25mm and d=30mm

To choose the correct diameter out of the two, suggestion that the diameter of the shaft may be obtained by using both theories and the lower of the two values is adopted. Hence, the correct diameter of the shaft that is to be used in the construction of the de-feathering machine is 25mm and length is 595mm.

Hopper capacity

The plucking chamber capacity is determined from the equation according to [O. Eric et al, 1982]

$$P_c = \rho V$$

Where

ρ = Density of chicken sample = 1113 kg/m3;

V = Volume of plucking chamber =

Plucking chamber capacity, Pc = 16.58 kg

Shear Failure Analysis of the De-feathering Chamber

The shear stress of the de-feathering chamber is determined by the equation below according to RS. KHURMI

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

$$M_t = WR$$

If the mass of the plucking chamber = 80kg, then

W=mg

W = Weight of the chamber = 784N

R = Mean diameter of the Chamber = 0.43 m

M_t = 337.12 Nm;

τ = 1791 N/m2

Figure 3. Fabricated Chicken De-Feathering Machine

RESULT & DISCUSSION

Table 1:

s/n	Chicken	Initial mass before de-feathering (kg) M_i	Final mass after de-feathering (kg) M_f	Mass of feather (A-B)	De-feathering time (seconds)	Scalding temp (°C)	Scalding time (seconds)	Performance efficiency Efficiency = $\frac{Mf}{Mi} * 100$	Energy (KJ)
1	Broiler	1.80	1.45	0.35	22	60	50	80.1	16.5
2	Layer	2.00	1.64	0.36	28	78	35	82.0	21.0
3	Cockerel	3.00	2.50	0.50	50	90	80	83.3	37.5

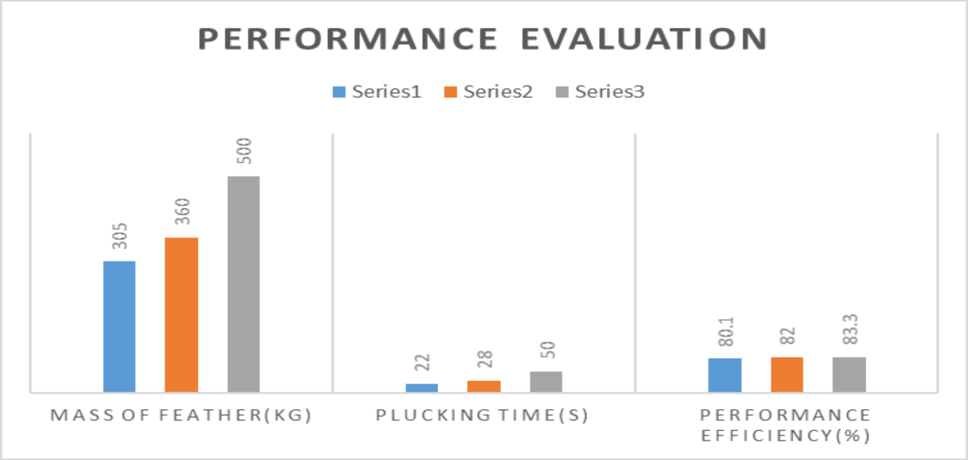


Figure 4. Bar chat representation of de-feathering time(s) against mass of feather removed (g) and performance efficiency

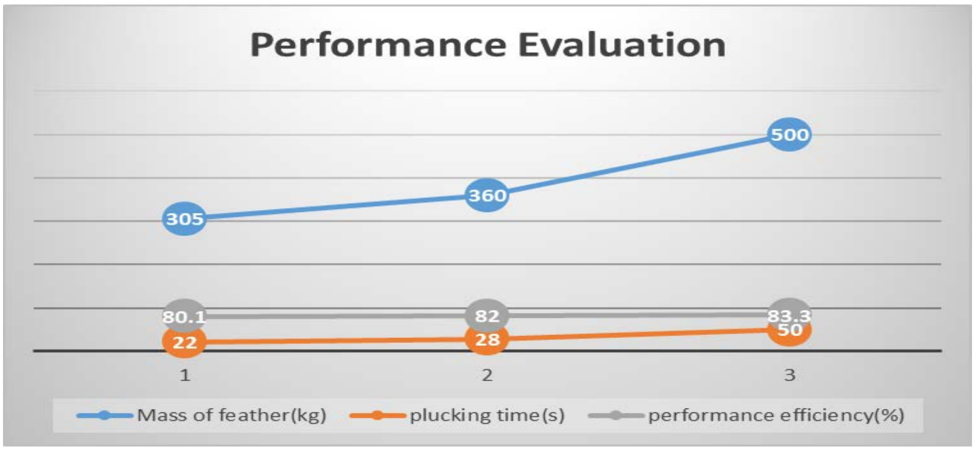


Figure 5. Line graph representation of the performance evaluation machine efficiency (%)

Performance evaluation

The machine was tested by de-feathering the chickens after slaughtering, to evaluate its performance efficiency using three kinds of chicken namely, Layers, Broilers, and cockerel.

Knife, gas, thermometer, chicken, stopwatch, weighing scale, and a jar for boiling water were all utilized in the experiment. The design calculations were done with care. This aid in computation of the height, width, mass, and weight of the chicken. Also, in order to confirm the functionality and integrity of the components that makes up the machine. The carcass fed into the machine is converted to product (fresh meat). The design analysis revealed that the machine may be driven by a 1 horsepower engine. The total length of V-belt to drive the pulley was at an angle of lap on the smaller pulley of 0.62 rad. The resultant load act on a diameter shaft of 25mm.

The test result showed that the machine could de-feather a chicken of mass 2.0kg (layer), (broiler) 1.8kg and (cockerel) 3.0 kg at 28seconds, 22 and 50 seconds, respectively. The scalding time and the time it takes to de-feather was measured using a stop clock. To meet up with both federal and state requirement stainless steel was used for component that has direct contact with the chickens being scalded.

CONCLUSION

For this project, a chicken de-feathering machine has been designed and fabricated successfully using mainly locally available materials.

The performance shows that the chicken de-feathering machine can de-feather broiler chicken of mass 1.8kg, layer chicken of mass 2.0kg and cockerel chicken of mass 3.0kg in 22seconds, 28seconds and 50seconds respectively.

The efficiency of the machine was calculated to be 80.1, 82 and 83.3 percent for broiler, layer, and cockerel respectively.

Acknowledgement: None

Conflict of Interest: None

Source of Funding: None

REFERENCES

1. S.O. Jekayinfa, Energetic analysis of poultry processing operations. International Journal of Science academic direct. A10, 2005, 077-092.
2. J. Pitchovsci, N. Ohana, L. Amzaleg, S. Krispel, D. Bercovich, and Y. Pinchasovt, Identification of a starting point of breast skin tear during chicken plucking. Poultry Science 76, 1997, 405-409.
3. S. Barbut, Primary processing of poultry (Boca Raton London New York Washington, D.C: CRC Press, 2002).
4. M.R. Scolt, http://www.knaseconic.com. Disinfection of poultry carcasses during scalding and immersion chilling. (2000). Retrieved July 10, 2008.
5. http://www.engineeringtoolbox.com/length-belt-fans-motor-d_872.html. Engineering toolbox (n.d). Belts- length and speed of belts. Retrieved 27th June, 2012.
6. R.S. Khurmi and J.K. Gupta, Machine design, (New Delhi Eurasia Publishing House (PVT) Ltd, Ram Nagar. 14th Ed., 2006), 544711
7. 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, e-ISSN: 2278-1684, p-ISSN: 2320-334X, Volume 11, Issue 3 Ver. VIII (May- Jun. 2014).
8. Omidiji B. V., Owolabi H.A., Oyenuga A. A. and Adeleke A. A. Development of Chicken De-feathering Machine. Journal of engineering and engineering technology. 2014.
9. Awotunde, Olawale Waliyi, Adeyeye, Kehinde, Ponle, Eyitayo Ademola and Fatukasi, Samson Olusegun. Development of a Defeathering Machine from Locally Sourced Materials. ISSN 2229-5518. International Journal of Scientific & Engineering Research Volume 9, Issue 5, May-2018.
10. Adeyinka A. Adesanya, Olawale J. Olukunle. 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.
11. Adetola, Sunday Olufemi, Onawumi, Ayodele Samuel Lucas, Emanuel Babajide. Investigation into Mechanized De-Feathering Process and Optimal Scalding Temperature of Exotic and Local Birds in Southwestern Nigeria. Transnational Journal of Science and Technology. Edition vol. 2, No.3 April 2012.
12. Omoniyi Ezekiel B, Peter Oyekola, Onoriode Ovaha, Aezeden Mohamed, Nicholas Lambrache. Bird Feather Removal Machine: Design and Development. ISSN: 2277-3878. Volume-8 Issue-3. International Journal of Recent Technology and Engineering. September 2019.
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. https://www.industrialspec.com/about-us/blog/detail/what-are-elastomers-rubbers-elastomeric-material#:~:text=Elastomers%20are%20viscoelastic%3A%20sticky%2C%20very,or%20cured%20to%20be%20useful.
15. https://www.azom.com/article.aspx?ArticleID=11914
16. http://www.industrialrubbergoods.com/natural- rubber.html

How to cite this article: Adefuye O.A, Adedeji K.A, Fadipe L.O. et.al. Design, fabrication and performance evaluation of chicken de-feathering machine. *International Journal of Research and Review*. 2021; 8(12): 703-711. DOI: *https://doi.org/10.52403/ijrr.20211285*

******