Journal of Engineering and Engineering Technology

School of Engineering and Engineering Technology,
The Federal University of Technology, Akure, Nigeria

Journal of Engineering and Engineering Technology

Development of a Poultry De-Feathering Machine with an Adjustable Basin

Abioye T.E.

Mechanical Engineering Department, Federal University of Technology, Akure, Ondo State, Nigeria

A B S T R A C T

Keywords:
De-feathering
machine;
adjustable basin;
efficiency;
poultry;
Development.

Removing poultry feathers by hand is time consuming, tasking and becoming obsolete. Development of a poultry de-feathering machine is a mechanical process of removing poultry feathers so as to overcome the existing challenges. This work aims at producing a poultry de-feathering machine with an adjustable basin for accommodating poultries of varying sizes. Locally available materials were used for the development of the machine. Design calculations were effectively done so as to ensure correct shaft diameter as this could affect the efficiency of the machine. The machine consists of rubber pluckers which do the actual plucking of the feathers. The rubber pluckers are attached to a base plate which rotates against a stationary basin carrying protruding rubber pluckers. The base plate was powered by 1 Hp electric motor and was set to rotate at 180 rpm using a speed reduction mechanism. Test was carried out on the machine using three chickens successively. First, the chickens were soaked inside a hot water (temperature of about 80 °C) for approximately 60 s. Thereafter, the soaked chickens were sequentially put inside the adjustable basin and the machine was switched on. The machine removed the chicken feathers without any major damage to the chickens in an average time of 21 s. The machine efficiency for each of the three runs was calculated and average efficiency was found to be approximately 96%. The machine performed efficiently and effectively, leaving behind products that meet market standard.

1. Introduction

Poultry is defined as domestic birds raised for eggs or flesh for examples chicken, duck, goose, turkey, etc. The demand for the consumption of poultry products, most especially poultry (white) meat, has been on the increase due to the fact that white meat consumption is considered healthier compared with the red meat *(*Abdalla *et al.,* 2014*;* Hung et al., 2011*)*. Poultry meat is consumed worldwide even among the vegetarians because of its low fat and calorific content. The increasing demand for the poultry meat is the major factor driving many into poultry farming and processing industry. For example, a research on innovations and trends in meat consumption using Delphi method was conducted in Spain by Chamorro *et al.* (2012), it was established that the demand for meat did not change significantly in amount but varies noticeably in the composition with chicken replacing beef as the

meat of most importance in the shopping basket. In Nigeria, chicken meat, gizzard and turkey meat are widely consumed and investigation has shown that they form a major source of protein to the *population* (Iwegbue *et al.,* 2008).

The processing of poultry into meat for shopping involves a number of stages. However, more emphasis is on the slaughtering and de-feathering so as to maintain the high standard of hygiene and fast product delivery (Roger and Don, 1995). In the past, poultry are de-feathered manually (i.e. removing the feathers by hand after soaking in hot water). This method creates bottlenecks in the poultry meat production line because of the long time it takes to de-feather manually. It has been established that it takes a minimum of 10 minutes to de-feather a bird manually (Adetola *et al.,* 2012). Also, it is relatively unhygienic because dipping hand in the dirty hot water exposes the workers to skin infections and burn. Hence, there is need for effective mechanization of the poultry-to-

meat processing. This method is believed to be safe, hygienic and quick. The process economy is better because an average sized bird (~3.6 kg) can be processed, using poultry de-feathering machine, in 30 s (Adetola *et al.,* 2014).

In the past, the development of the poultry de-feathering machines has not been well researched because only few authors have worked on the machine. **Adesanya and Olukunle (2015)** developed a poultry de-feathering machine for small scale farmers. The machine is 95% efficient and capable of processing a bird in 30 s. Also, a poultry de-feathering machine of about 96% efficiency has been developed by Tanimola *et al.* (2014). The major shortcoming in the existing machines is that the size of the bird processed per time is limited since the basins of the machines are fixed.

In this study, a poultry de-feathering machine with an adjustable basin was developed. The machine has the capability of processing birds of different sizes. Also, a maximum of three averagely sized birds can be de-feathered per unit time. The performance of the machine was evaluated and reported.

2. Materials and Methods

2.1 Materials

Some design factors are taken into consideration in the choice of material for the design of this de-feathering machine so as to enhance its efficiency, reliability, workability, stability and sustainability. These include availability, strength and rigidity, cost, weight and corrosion resistance of the materials. Table 1 shows the machine components and the selected materials.

2.2 Machine Design

Fig. 1 shows the conceptual drawing of the poultry de-feathering machine with an adjustable basin. The machine comprises some major components as listed in the Table 1. The machine was fabricated using available local materials. The fabrication was done based on some initial calculations (i.e. designs).

2.2.1 Determination of the electric motor required

In order to ensure effective de-feathering 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 de-feathering machine (Adesanya and Olukunle, 2015; Tanimola et al., 2014). 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 2.

2.2.2 Determination of the shaft speed and torque at the driving pulley

Since the base plate is directly attached to the shaft, the shaft will definitely rotate at 180 rpm. As a result, the speed of the motor (900 rpm) was reduced and transmitted to the shaft using pulley system. Equation 1 was used to determine the relative sizes of the two pulleys required. The symbols 'D' and 'N' represent the diameter and speed of the shaft (driven) pulley whereas 'd' and 'n' denote the diameter and speed of the electric motor (driving) pulley, respectively.

$$\frac{D}{d} = \frac{n}{N} \tag{1}$$

A velocity ratio of 5:1 was obtained indicating that the driving pulley diameter is by a factor of 5 bigger than the driven pulley. Subsequently, the torque (T) at the driving pulley was determined from equation 2.

$$T = \frac{60P}{2\pi N} \tag{2}$$

P in the equation 2 is the power rating of the electric motor selected in W (746 W). The symbol 'N' is the speed of the motor (900 rpm).

2.2.3 Determination of belt parameters

The parameters of the belt used including the length and angle of contact with the pulleys were determined. The belt tensions and power transmitted were also calculated. The length (L) of the belt was determined using equation 3 (Khurmi and Gupta, 2005) where 'C' is the centre distance between the two pulleys (400 mm).

$$L = \frac{\pi}{2}(D+d) + 2C + \left(\frac{D-d}{4C}\right) \tag{3}$$

The angle of contact is calculated as described in equations 4 and 5.

$$\theta = (180 - 2\alpha)\frac{\pi}{180} \, rad \tag{4}$$

$$\alpha = \sin^{-1}\left(\frac{R-r}{C}\right) \tag{5}$$

The 'R' and 'r' represents the radius of the driven and driving pulleys respectively.

Thereafter, the linear velocity (V) of the belt and the belt tension

(Tc) due to centrifugal force were obtained from equations 6 and 7 respectively (Khurmi and Gupta, 2005). The symbols 'A', 'w' and 'g' represent the belt cross-sectional area, belt's weight and acceleration due to gravity respectively.

$$V = \frac{\pi DN}{60 \times 1000} \qquad (6)$$

$$T_c = \frac{A \times 12 \times w \times v^2}{g} \qquad (7)$$

The tensions in the weak (T1) and tight (T2) sides of the belt are determined by solving equations 8 and 9 simultaneously.

$$T_1 - T_2 = \frac{2T}{D_s} \qquad (8)$$

$$\frac{T_1 - T_c}{T_2 - T_c} = \ell^{\mu\theta} \qquad (9)$$

The symbols Ds and µ in the equations 8 and 9 are constants. The values are given as 0.071 m and 0.5 respectively.

2.2.4 The shaft power

Since the driven pulley is connected directly to the shaft, the power of the shaft is equivalent to the maximum power transmitted by the belt system from the motor. The power transmitted by the belt to the shaft was determined using equation 10 (Khurmi and Gupta, 2005).

$$P = (T_1 - T_2)V \qquad (10)$$

2.2.5 Determination of the shaft diameter

As shown in Fig.1, the shaft transmits power from the belt to the rotating plate in the basin. It is supported at the two ends by ball bearings. With this arrangement, the shaft is subjected to both torsional and bending loads while operating. According to Paul and Eugene (1968), the auger shaft diameter was determined using equation 11.

$$d^3 = \frac{16}{\pi S_s} \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \qquad (11)$$

Where Mt is the torsional moment, Mb is the maximum bending moment and d is the shaft diameter. Kb, Kt and Ss are the combined shock and fatigue applied to bending, combined shock and fatigue applied to torsional moment and allowable stress respectively.

2.2.6 Design of the de-feathering basin

The average volume of a fully grown chicken was determined using Archimedes' principle. However, the volume of the basin was designed to accommodate different sizes of the chicken by incorporating an adjustable device. The basin is designed to be cylindrical in shape so as to enhance the rotation of the chicken by the base plate. The fabrication is done, considering the average volume of a fully grown chicken, using equation 12. Adjusters were provided so as to vary the size of the basin depending on the requirement.

$$V = \pi R^2 H \qquad (12)$$

H is the height of the basin was constant for all variations in volume whereas the radius (R) can be adjusted depending on the size of chicken to be de-feathered per time. In the inside surface of the basin are pluckers attached at equidistance (~ 60 mm) to one another. The pluckers are also fixed to the rotating base plate using similar procedure. The pluckers are made of elastomers. This material was used so as to ensure an easy and safe removal of the feathers without causing severe damage on the body of the chicken. Also, elastomer retains its visco-elastic property up to a temperature of 200oC.

2.3 Determination of the efficiency of the machine

The efficiency of the machine was determined using the weighing method. The entire mass of the test chicken was weighed before scalding and it is denoted as M_1. The de-feathered chicken was also weighed after the de-feathering process and the mass is known as M_2. M_R which is the mass of the feathered removed by the machine was calculated using equation 13.

$$M_R = M_1 - M_2 \qquad \textbf{(13)}$$

After the de-feathering process, some few feathers remained on the body of the chicken were removed manually and the chicken was weighed. The mass is denoted as M_3. The mass of the feather remained on the body of the chicken after de-feathering (M_r) was determined from equation 14.

$$M_r = M_2 - M_3 \qquad (14)$$

Table 1: The poultry de-feathering machine components and the selected materials

S/N	Machine components	Material selected
1	Body Frame	Galvanised steel
2	Shaft	Galvanised steel
3	Pulley	Cast iron
4	Belt	A 52 rubber belt
5	De-feathering basin (adjustable)	Galvanised steel
6	De-feathering disc	Galvanised steel
7	Plucker	Elastomer
8	Electric motor	1 horse power (0.746kW)

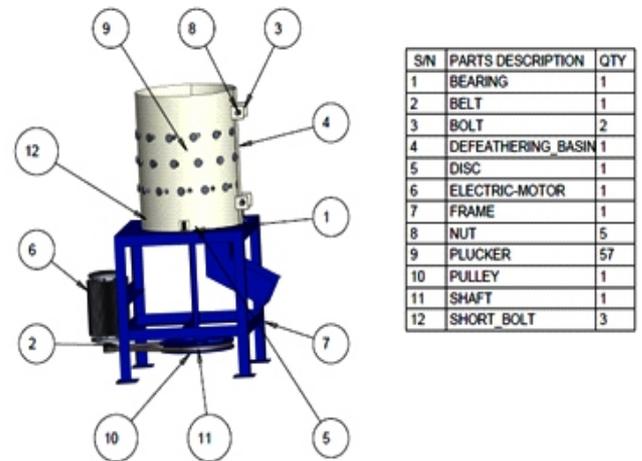| S/N	PARTS DESCRIPTION	QTY
1	BEARING	1
2	BELT	1
3	BOLT	2
4	DEFEATHERING_BASIN	1
5	DISC	1
6	ELECTRIC-MOTOR	1
7	FRAME	1
8	NUT	5
9	PLUCKER	57
10	PULLEY	1
11	SHAFT	1
12	SHORT_BOLT	3

Fig1: A conceptual drawing of the poultry de-feathering machine with an adjustable basin

Table 2: Details of the Electric Motor Selected

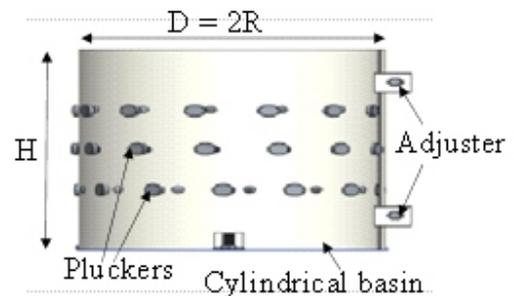| Description	Data
Power characteristic available	AC
Motor type	Single Phase
Power rating	1 hp
Speed	900 rpm
Duty requirement	Continuous
Frequency	50 Hz
Voltage	220 V
Motor enclosure	Total Enclosure

Fig. 2: A diagram showing the adjustable de-feathering basin

3.   Results and Discussion

3.1   *Physical quality of the machine*

Fig. 3 shows a diagram of the fabricated de-feathering machine with an adjustable basin. The machine is of good dimensional stability and well protected against environmental degradation by adequately coated with paint. It has adequate mechanical strength and rigidity to carry out the de-feathering operation. The de-feathering operation is easy, quiet and can be easily maintained. The machine functions satisfactorily according to the design and is without any visible significant defect.
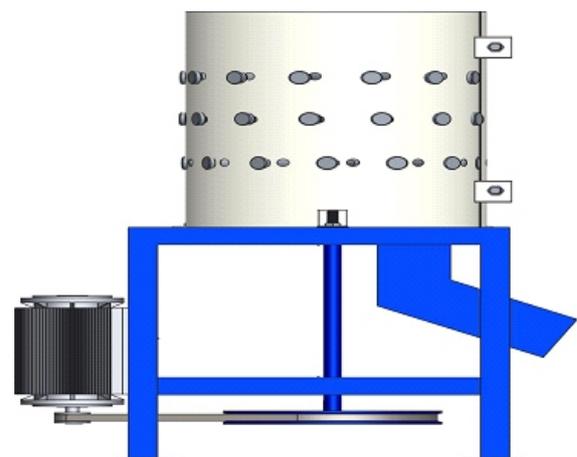

Fig. 3.1: A diagram showing the assembled adjustable de-feathering machine

3.2   *Performance of the Fabricated De-Feathering Machine*

First, the chickens of different sizes were scalded inside hot water (~ 80°C) for less than one minute. Thereafter, the scalded chickens were put inside the adjusted basin and de-feathering was done. **De-feathering was done until further spinning or rotation of the chicken resulted in no significant removal of the feathers**. The test was repeated for three times with different sizes. Table 3 presents the initial and final weight of the chicken after de-feathering operation, the mass of the feather removed and the de-feathering efficiency of the machine.

As seen in Table 3, it is evident that the fabricated machine effectively de-feathered chickens of different sizes ranging between 1.24 -1.89 kg. The chickens which were of different sizes were effectively de-feathered as about 90% of the chicken feathers were removed in an average time of 21 s. This is more efficient, quicker and less tedious when compared with the manual operation which takes an average of 10 minutes to de-feather a fully grown chicken.

3.3   Cost estimation of the machine

The Bill of Engineering Measurement and Evaluation (BEME) for the developed de-feathering machine is estimated and presented in Table 4. The total cost of fabrication is approximately N 55,000:00. This indicates that the cost of the machine is relatively cheap and affordable by small, medium poultry farmers.

4.0   Conclusion

A de-feathering machine with an adjustable basin has been successfully developed and its performance was evaluated. The following conclusions were drawn:

i.   The machine effectively de-feathered chickens of different sizes ranging from 1.24 -1.89 kg without significant damage to the chickens.

ii.   An average de-feathering time of 21 s was achieved for all the chickens tested at an efficiency of about 90%.

iii.   The developed de-feathering machine is rigid, dimensionally stable, durable and can easily be afforded by the small and medium poultry farmers.

Acknowledgement

Table 3: A summary of the results obtained from the performance evaluation of the de-feathering machine with adjustable basin

A	B	C	D	E = C+D	F	G = (C/E)*100
Initial mass (kg)	Final mass after de-feathering (kg)	Mass of the feather removed after de-feathering (kg)	Mass of the feather remained after de-feathering (kg)	Mass of the total feather on the chicken (kg)	Time of de-feathering (s)	Efficiency of the machine
1.24	0.98	0.26	0.03	0.29	18	89.7
1.73	1.41	0.32	0.03	0.35	22	91.4
1.89	1.44	0.45	0.05	0.5	23	90.0

Table 4: BEME for the designed de-feathering machine with an adjustable basin

S/N	MATERIAL COMPONENT	SPECIFICATION	QUANTITY	UNIT COST (₦)	TOTAL COST (₦)
1	Angle Iron	2 mm thickness	2	750	1,500
2	Mild steel sheet	2 mm thickness	1 piece		1,700
3	Shaft (Mild steel)	Ø 25 mm	1 piece	1000	1,500
4	Ball bearing		2 pieces	1000	3,000
5	Belt	V-belt	1 piece	500	500
6	Big Pulley	V-pulley	1 piece	1800	2,800
7	Small pulley	V-pulley	1 piece	2000	2,000
8	Bolt and Nut	Sizes 13	8	30	240
9	Bolt and Nut	Size 17	4	50	200
10	Electrode	Gauge 12	1 packet	300	300
11	Electric motor	1 HP, 900 rpm	1	10000	25,000
12	Returning spring		1	3000	3,000
13	De-feathering Disk	Ø 38 mm	1	1000	1,000
14	Pluckers		71	15	1065
15	Transportation				2,195
16	Paints	Blue	1 Tin	500	500
17	Workmanship				8,500
	Total				**55,000**

References

Abdalla, A. A., Suliaman, S. E., Shuaib, Y. A., Abdalla, M.A., (2014): "*Bacteriological Study of Poultry Meat in Semi-Automatic Abattoir in Khartoum State-Sudan*". Journal of Agricultural and Veterinary Science. 14: 80-86

Adesanya, A. A., Olukunle, O. J., (2015): "*Development and Performance Evaluation of a Chicken De-Feathering Machine for Small Scale Farmers*" Journal of Advanced Agricultural Technologies. 2 (1): 71-74.

Adetola, S. O., Onawumi, A.S., Lucas, E.B., (2012): "*Investigating into Mechanized De-feathering Process and Optimal Temperature of Exotic and Local Birds in South western Nigeria*". Transnational Journal of Science and Technology. 2(3): 87-96.

Adetola, S.O., G.A. Daramola, Ogundiran, S. O., (2014): "*Development of Household Poultry De-feathering Machine with Better Efficiency*".Journal of Mechanical and Civil Engineering. 11: 51-59.

Chamorro, A., Miranda, F. J., Rubio, S., Valero, V., (2012): "*Innovations and Trends in Meat Consumption: An Application of the Delphi Method in Spain*". Journal of Meat Science. 92 (4): 816-822.

Hung, N. V., Minh, D.H., Son, D. T., (2011): "*An Investigation of Optimized Operational Parameters for a Chicken Slaughtering System in Vietnam*". International Transaction Journal of Engineering, Management, Applied Sciences & Technologies. 2(4): 423-436.

Iwegbue, C. M. A., Nwajei, G. E., Iyoha, E. H., (2008). "*Heavy Metal Residues of Chicken Meat and Gizzard and Turkey Meat Consumed In Southern Nigeria.*" Bulgarian Journal of Veterinary Medicine. 11 (4): 275−280.

Khurmi R. S, Gupta, H. (2005): '*Machine Design'*. Rajendra Ravindra Printers Limited, New Delhi, India.

Paul and Eugene, (1968): "*Machine Design*" McGraw-Hill Book Company London

Roger D.J. and Don R.S. (1995): "*Procedures for Killing Dressing Home Grown Fowl*". A series of the Dairy and Poultry Sciences Department, Florida Cooperative.

Tanimola, O. A, Diabana, P. D., Bankole, Y.O., (2014): "*Design and Development of a De-Feathering Machine*". International Journal of Scientific & Engineering Research. 5 (6): 208 -211.