

Design and Development of a De-Feathering Machine

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ABSTRACT: Consumption of poultry birds as a source of protein is on the increase due to the spate of the fast growing eatery, restaurants and festive periods in Nigeria. De-feathering of the birds is one process which is time consuming and cumbersome. It involves a process of removing the feather from birds and this is commonly done manually which results in waste of time, low output and injury. In order to make de-feathering process easy, a de-feathering machine was designed and developed. The machine consists of the frame, shaft, rotating drum and rubber spines, made of locally sourced materials thereby making it cost effective.

Tests were carried out using birds of different weights and efficiency of 98% was achieved. The machine has a capacity of 360birds/hr.

Keywords: Machine, Feather, Birds Power, Electric motor, Process, De-feathering, Injury

1.0 INTRODUCTION

One of the steps in bird processing before it reaches the end product for cooking is de-feathering of the bird. De-feathering involves removing feathers from the slaughtered birds. Traditionally, in this part of the world it is done manually by the use of hand after it has been soaked in hot water for few minutes. This process results in low output, time consuming, tedious and could lead to injury. In order to avoid all of these challenges, there is need to design and develop a machine from locally sourced material. David (1999) stated that it takes an average time of 5minutes for a person to de-feather a bird while the machine processing of a bird which is lowered in a hot water of about temperature 80°C – 85°C takes 40 – 50 seconds. Buckland (2005) reported that the objective of a centralized poultry processing paltry of any scale of operation is to produce hygienic, wholesome, attractive and saleable of consistent appearance and quality of high standard. Ogunidipe (2002) reported that de-feathering machine saves time, easy to operate and better picking is achieved.

Mechanical de-feathering employs various de-feather mechanism such as rubber finger, rotating plate, drum and angle bar mechanism. This is done after slaughtering the birds which is accompanied by bleeding period. The carcass is removed and lowered into a tank of heated water to a certain temperature and plucked. The use of de-feathering machine in processing poultry has contributed tremendously to the successful processing of dressed and hygienic chicken for consumption. The de-feathering machine overcomes the tediousness, time consumption, messy, nasty and discouragement in that of hand de-feathering. Also, there is mass production of processed chicken in de-feathering machine than hand de-feathering. There are three ways in which feathers can be removed

completely from the chicken. The first is for broilers only and is by hand. The feathers are simply pulled from the carcass and placed in a feather bin. This method takes a lot of time. It is tedious and results in low output. The second method is by holding the carcass against rubber fingers protruding from a continuously rotating horizontal drum. The drum rotates away from the operator and the feathers follow until they are thrown towards the back of the machine. The bird is held with a leg in each hand and laid firmly on its left breast on the rotating rubber fingers. It is agitated backwards and forwards to pluck the left breast and thigh. The bird is turned over to pluck the right breast and thigh. Both legs are taken in the left hand and the tail feathers gripped in the right hand before pulling them out with a twisting movement. The third method uses a bowl de-feather. Scaled birds, to a weight specified by the manufacturer, are placed in the bowl de-feather chute which passes into the body of the machine, the machine is stopped and a door to the bottom of the machine is opened. The plucked carcasses emerge ready for further processing. Time taken in the bowl de-feather will depend on the nature of the bird, its age, condition etc (David, 1999).

In Nigeria, fast food business is fast growing so also is the population of people eating chicken during festivals (Christmas) and other ceremonies. There arise need to design and develop a de-feathering machine that will be low cost, rugged, simple, with locally sourced materials.

2.0 MATERIALS AND METHODS

2.1 Design Consideration

The following factors were considered in the process of the design and development of the machine.

- i. Damage to the birds should be minimal.
- ii. The removed feather should be separated from the bird.
- iii. Little or no damage to the bird.
- iv. The cost should be minimal is materials will be sourced locally

2.1.1 Frame

The frame is made of angle iron for it to be rigid and it takes rectangular shape of length 810mm and breadth 380m.

Area of frame = Length x Breath (L x B)

(i)

2.1.2 Rotating Drum

The rotating drum was made from mild steel formed into a circular shape of diameter 440mm.

Area of plate used = πDL

(ii) $3.142 \times 0.44 \times 0.81 = 0.356 \text{ m}^2$

2.1.3 Power Requirement

According to David (1999) power requirement of **1.5kW (2HP)** electric motor is required to drive the rotating drum.

Therefore the speed of the rotating drum can be calculated

$$\frac{N_1 D_1}{N_2 D_2} =$$

$$N_2 = \frac{N_1 D_1}{D_2} = \frac{1410 \times 105}{200}$$

$$N_2 = 720 \text{ rpm}$$

2.1.4 Angular Velocity

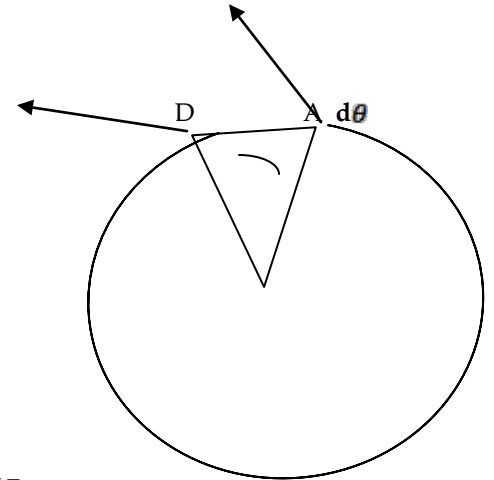
$$V = \frac{\pi DN}{60}$$

(iv)

$$\frac{3.142 \times 0.44 \times 720}{60} = 16.58 \text{ m/s}$$

2.1.5 Centrifugal Force

The drum rotate in a circular path with a radius R and constant speed ω



Change in velocity = $V d\theta$

(v)

Acceleration

$$V \frac{d\theta}{dt}$$

$$\therefore F = \omega v$$

(vii)

Where $\omega = \text{Angular Velocity}$

But $V = \omega r$

(iii) $f = \omega^2 r$

(viii)

$$f = v^2 / r$$

(ix)

The acceleration is directed toward the centre of rotation

Therefore, the centrifugal force required is

$$f_c = mf = m\omega^2 r$$

(x)

Where, m = average mass of the birds.

$$f_c = mf = mv^2 \frac{7.50 \times (16.58)^2}{0.22} = 9.37 \text{ kN} = 9.40 \text{ kN}$$

(xi)

2.1.6 Design for Shaft

From the force developed by the machine, the diameter shaft required is

$$F_c = \frac{\pi d^2}{4}$$

(xii)

$$9.4 \times 10^3 \times 4 = 3.142 \times d^2 \times 40$$

$$d^2 = \frac{9.4 \times 10^3 \times 4}{3.142 \times 40}$$

$$d = 17.3 \text{ mm}$$

For actual design, a factor of safety of 1.5 was used to multiply the diameter in the design and as such 30mm shaft was chosen

2.1.7 Shear Stress and Bending moment

For a beam of circular section the maximum shear stress as given

$$i_{max} = \frac{4}{3} i_{ave}$$

(xiii)

$$i_{ave} = \frac{\text{Force}}{\text{Area}} = \frac{\text{Force}}{\frac{\pi d^2}{4}} = \frac{9.4 \times 10^3 \times 4}{3.14 \times (30)^2} = 13.3 \text{ N/mm}^2$$

(xiv)

2.1.8 Length of Belt

The length of open belt is given by

$$l_o = \frac{\pi}{2} (D_1 + D_2) + 2c + \frac{(D_2 - D_1)^2}{4c}$$

(xv)

l_o = Length of belt

D_1 = Diameter of driver pulley = 105mm

D_2 = Diameter of driver pulley = 200mm

C = Centre distance

$$= \frac{3.142}{2} (105 + 200) + \frac{(200 - 105)^2}{4 \times 400} + 2 \times 400$$

$$l_o = 479.155 + 5.6 + 800 = 1284.76 \text{ mm}$$

2.1.9 Angle of Arc of Centre (θ)

$$\theta = 2 \sin^{-1} \left(\frac{D_2 - D_1}{2c} \right)$$

(xvi)

$$= 2 \sin^{-1} \left(\frac{200 - 105}{2 \times 400} \right)$$

$$= 2 \sin^{-1} \left(\frac{95}{800} \right)$$

$$= \sin^{-1} 0.1188$$

$$= 6.8^\circ = 180 - 6.8 = 173.2^\circ$$

2.1.10 Belt Speed

$$v = \frac{\pi D_1 N_1}{10^3 \times 60} \left(\frac{100 - s_1}{100} \right)$$

(xvii)

$$\frac{3.142 \times 105 \times 1400}{10^3 \times 60} \left(\frac{100 - 3}{100} \right) = 7.6796 \times 0.97 = 7.466 \text{ m/s}$$

2.1.11 Coefficient of Friction

$$\mu = 0.54 - \left(\frac{0.7}{v + 25} \right)$$

(xviii)

$$= 0.54 - \left(\frac{0.7}{7.47 + 25} \right) = 0.54 - 0.022$$

$$\mu = 0.54$$

2.1.12 Belt Size

$$= \frac{10^3 P}{v(\theta v - P v^2) K_1} \left[\frac{e^{\mu \theta}}{e^{\mu \theta} - 1} \right] K_2$$

(xix)

$$\frac{10^3 \times 1.5 \times 1.2}{7.47 \times (2.405 - 102 (7.47)^2) 0.35} \left(\frac{4.81}{3.81} \right)$$

$$= 152.7 \text{ mm}$$

The thickness is 5mm and belt mid $l_k = \frac{152.7}{5} = 30.54 \text{ mm}$

2.1.13 Belt Tension

$$\frac{F_1}{F_2} = e^{\mu \theta}$$

(xx)

Where f_1 = tightened side

F_2 = slacken side

But
$$P = \frac{(f_1 - f_2) v x k_j}{1000 x K_s}$$

(xxi)

Where V = Speed of the electric m/s

K_j = Constant

P = power of the electric motor

$$105 \times 10^3 \times 1.2 = F_1 - F_2 \times 7.42 \times 0.9$$

$$F_1 - F_2 = \frac{105 \times 10^3 \times 1.2}{7.42 \times 0.9}$$

$$F_1 - F_2 = 269.54 \text{ kN}$$

$$F_1 = 269.54 + F_2$$

Substituting into equation xxi

$$F_1 - F_2 = \frac{269.54 + F_2}{F_2} = 4.81$$

$$269.54 = 4.81 F_2 - F_2 \quad 269.54 = 3.81 F_2$$

$$F_2 = 70.71 \text{ kN}$$

But $F_1 - F_2 = 269.54 \text{ kN}$

$$\therefore F_1 = 269.54 + 70.71$$

$$= 304.25 \text{ kN}$$

2.1.14 Width of Pulley

$$a_s = 1.19d + 10 \text{ mm for single belt}$$

(xxi)

$$a_s = 1.19 \times 30 + 10 \text{ mm} = 46.3 \text{ mm}$$

Thickness

$$L = 0.25 \sqrt{D + 1.5} = 0.25 \sqrt{200 + 1.5} = 5.04 \text{ mm}$$

Crown Height

$$h = \frac{a_s}{200} = \frac{46.3}{200} = 0.23 \text{ mm}$$

From table maximum pressure for transmission shaft with self aligning bearing maximum for a load of 1.5kw electric motor and a speed of 16.58m/s

$$P \text{ N/m} \times 10^6 = 1.03 \text{ N/m}^2 \times 10^2$$

(xxii)

$$C/d = 0.001$$

$$\text{Ratio} = 1/d = 3.0$$

Dynamic Viscosity = 35

Bearing modulus (maximum) $Nn/p \times 10^{-6}$

(xxiii)

Diameter of bearing = 30mm

$$\frac{i}{d} = 30$$

So that $A = 3.0d^2$

(xx) Required projected Area = $\frac{W}{P}$

$$P = \frac{9.316}{3 \times 72.5 \times 10^{-3}} \times \frac{740}{60} = .528 \times 10^6 = 0.528 \text{ MN}$$

Required projected Area

$$\frac{1500}{0.528 \times 10^{-6}} = 2840 \times 10^{-6} \text{ m} = 2840 \text{ mm}^2$$

$$\frac{i}{d} = 30$$

$$A = 3.0d^2$$

$$2840 = 3 \times d^2$$

$$d^2 = \frac{2840}{3} = 946.67 \text{ mm}^2$$

$$d = 30.77 \text{ mm}$$

$$\frac{i}{d} = 30$$

$$l = 3 \times 30.77 = 92.31 \text{ mm}$$

2.1.15 Actual Pressure

$$\frac{1500}{31 \times 92 \text{ mm}} \times 10^{-6} = 0.525 \text{ MN/m}^2$$

Permissible pressure

$$P = \frac{1.3\eta\pi}{10^2} \left(\frac{d}{c}\right)^2 \left(\frac{l}{d+l}\right)$$

$$P = \frac{1.3 \times 9.316 \times 740}{10^2} \left(\frac{1}{0.001}\right)^2 \left(\frac{92.31}{92.31+30.77}\right)$$

$$= \frac{1.3 \times 9.316 \times 740}{10^2 \times 60} \times (1,000,000) (0.75)$$

Sommer Field number

$$K = \frac{\eta\pi}{P} \left(\frac{d}{c}\right)^2$$

$$= \frac{9.316 \times 12.33}{0.525 \times 10^2} \left(\frac{1}{0.001}\right)^2 = 218.79$$

Coefficient of friction

$$\mu = 2\pi^2 \left(\frac{\eta\pi}{P}\right) \left(\frac{d}{c}\right) + k \tag{xxv}$$

$$\mu = 2\pi^2 \left(\frac{9.316 \times 10^{-2} \times 12.33}{0.525 \times 10^2}\right) \left(\frac{1}{0.001}\right) + 0.002$$

$$\mu = 6.32 \times 10^{-3}$$

2.1.20 Heat Generated

$$H_g = \mu p l d U$$

(xxvi)

$$H_g = 6.32 \times 10^{-3} \times 5.25 \times 10^{-6} \times (30.77 \times 92.31) \times 10^{-2} \times \pi \times 30.77 \times 10^{-2} \times \frac{740}{60}$$

$$= 11.23W$$

2.2 Description of the Machine

The machine consist of a frame made from iron angle which bears the load of the machine from the electric motor which is attached to the body of the machine to drive the shaft from the top of the machine the machine also have an electric motor of 1.5kw, a drum which has rubber spikes attached to the drum and rotating plate which is designed to de-feather two birds at a time.

2.3 WORKING OPERATION

The chickens to be de-feathered are soaked in hot water for some minutes, and then introduced into the drum through an opening on the drum. The engine is then switched on, as the rotating disc laden with the spikes rotates, the chicken rubs with the spikes attached to the drum. This rubbing with the spikes, causes the feather to peel off from the chicken within a short time. The feathers are thereby separated from the chicken. The time taken to complete the operation was noted and recorded, birds of different weights were used and the results obtained recorded.

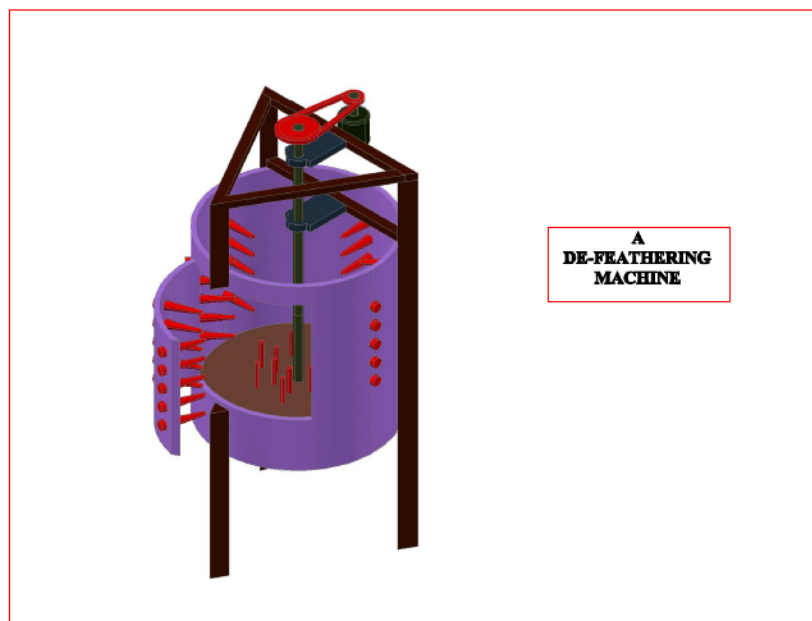


Figure 1: The de-feathering machine

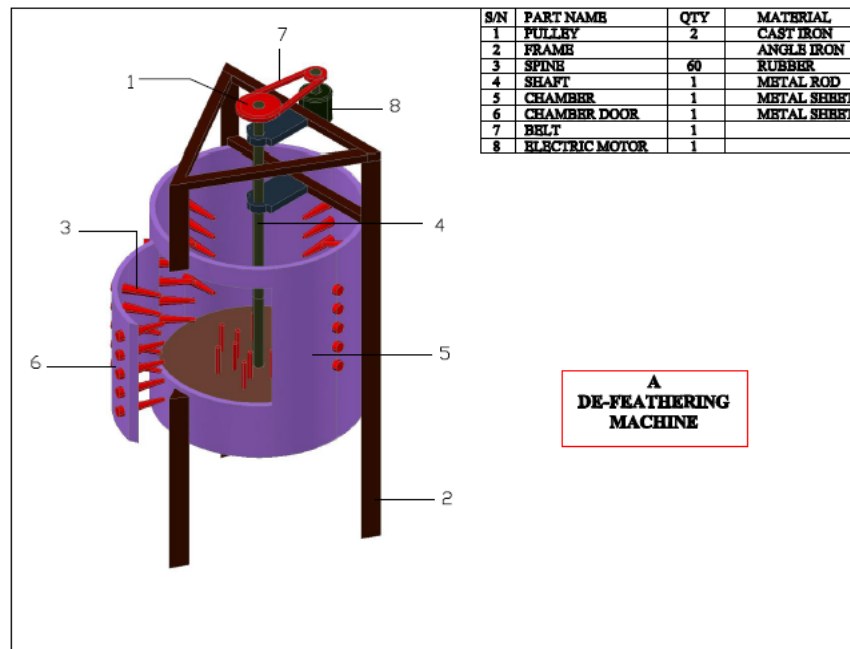


Figure 2: Parts of the machine

3.0 RESULTS AND DISCUSSION

3.1 Result

The machine was developed and constructed. Test was carried out by taken 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 removed from the machine with the help of hand and weighted to know the weight of the removed feather from the chicken. The experiment was replicated three times and the summary of results obtained as recorded in Table 1.

Table 1: Result Obtained from De-feathered Chicken

| Test | Initial Weight(kg) | Final Weight(Kg) | Weight of feather removed by the machine (kg) | Weight of feather from with hand (g) | Time (sec) |
|------|--------------------|------------------|---|--------------------------------------|------------|
| 1 | 3.65 | 3.24 | 0.40 | 0.01 | 25 |
| 2 | 3.60 | 3.20 | 0.39 | 0.01 | 25 |
| 3 | 3.50 | 3.20 | 0.28 | 0.02 | 22 |
| 4 | 3.30 | 3.10 | 0.28 | 0.02 | 20 |
| 5 | 3.45 | 3.25 | 0.18 | 0.02 | 20 |

The results obtained were subjected to ANOVA as shown in Table 2.

Table 2: ANOVA Table

| Model | | Sum of Squares | Df | Mean Square | F | Sig. |
|-------|------------|----------------|----|-------------|---------|-------------------|
| 1 | Regression | 20.833 | 1 | 20.833 | 14.313 | .032 ^a |
| | Residual | 4.367 | 3 | 1.456 | | |
| | Total | 25.200 | 4 | | | |
| 2 | Regression | 24.991 | 2 | 12.496 | 119.684 | .008 ^b |
| | Residual | .209 | 2 | .104 | | |
| | Total | 25.200 | 4 | | | |
| 3 | Regression | 25.066 | 3 | 8.355 | 62.508 | .093 ^c |
| | Residual | .134 | 1 | .134 | | |
| | Total | 25.200 | 4 | | | |

3.2 Discussion

It can be seen from Table 1 that the time taken to de-feather two birds (chicken) of average weight of 3.65kg is 25 s. while for two birds (chicken) of an average weight of 3.30kg is 20 s. According to David (1999) when birds are de-feathered manually, a time of five-minutes was required and an output of 12 birds /h. was achieved. In this design, an average output 360 birds / 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.

4.0 CONCLUSION

A de-feathering machine has been developed and tested for the use of local small scale poultry farmers. The machine will also be of tremendous use for other people in poultry business especially road side poultry sellers during festivals. The machine has an average capacity of 360 birds per hour.

REFERENCES

Buckland, C. (2005). Small scale poultry processing, <http://www.Fao.Org>
 David R.A. (1999). You can build your mechanical plucker. (whizbang) <http://www.FAO.Org>.
 Hornby, A. S, Fowler, F.G (1990). Poultry Production Year Book, Vol. 40 FAO. Rome.
 23, pp 102-103. Ogundipe, S.O. (2002).
 Nigerian Journal of Animal Production Farm Mechanization Section. Animal Production Association of Nigeria. Vol