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Development of a Household Poultry De-Feathering Machine with Better Efficiency

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Abstract: *Removing feathers by hand is the traditional means and method of removing feathers from poultry species. For certain reasons, removing feathers by hand was becoming obsolete since the inception of industrial age. Development of a poultry de-feathering machine is a process of producing a mechanical means of removing feathers from scalded birds. This paper focuses on development of a household poultry de-feathering machine. Meanwhile, in this paper locally available materials were used for the development of the devise. Design calculations were done appropriately to ensure correct shaft diameter as this could affect the efficiency of the machine. The machine consists of rubber pluckers which do the actual picking of the feathers. The rubber pluckers are attached to a rotating plate against a stationary plucking basin carrying protruding rubber pluckers.*

Test was carried out on the machine with three spent layer chickens. The chickens were soaked inside hot water at about 70°c and held for about 45-60s. The machine removed feathers without any major damage to the chickens. The efficiency at each trial was calculated and average efficiency was calculated to be approximately 95%. In conclusion, the machine performed efficiently and effectively, leaving behind products that could meet market standard.

Keywords: *Chicken, De-feathering, Efficiency, Feather, Plucker*

I. Introduction

Poultry processing plant meat products have gained a lot of markets in the world today. The daily demand for the products is always being met because of the increasing mechanization of the poultry farming. It had been shown by energetic analysis of poultry processing operations performed by [1], that most mechanized plant out of three plants that were taken into consideration required less energy consumption where there would be also corresponding increase in daily production beyond daily consumption by the poultry consumers to the extent that the system undoubtedly called for preservation by the use of refrigerator immediately after processing.

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. Poultry is defined as domestic fowls raised for eggs or flesh, examples of which are chicken; duck; choose; turkey etc. On the other hand de-feathering is a process of removing feathers from scalded birds. '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.

Furthermore, the de-feathering machine is useful if compared to the removal of feathers manually. These are some of its advantages: 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. Again, tearing of carcass skin during the plucking process in the slaughterhouse has become one of the major economic problems during processing [2]. This problem has also been taken into account during the development of the devise to give good appearance and quality to the processed poultry products. Poultry meat production has been developed from being a domestic business to an industrial and a commercial business which is justified by the increasing demand for its products in the world today. To ensure therefore, that the supply of the poultry products meet up with the demand by the consumers, it then necessitate the need for poultry de-feathering machine. Also, the energy, money and time wasted in manual de-feathering are so great which has now been reduce as a result of this development.

1.1. 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. The length of time and numbers of birds that may be processed per hour with specific equipments are also very dependent on the scald temperature. There are three major categories of scald, distinguished by temperature and types of birds [2][3].

1.1.1. Carcass Scalding at 51°C – 54°C for 45 seconds

Under normal ice storage condition, birds scalded at this temperature will last for just 7-10 days without any discolouration, 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. Also, the longer duration required for plucking limit the number of birds the equipment will be able to process within a hour and will not be able to do a thorough job [3]. [2] used scalding temperature of 50-53°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.

1.1.2. Carcass Scalding at 60°C – 62°C for (15-30 seconds duration)

This scald 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, [3]. [2] used 54-58°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.

1.1.3. Carcass Scalding at 71°C and above for (10 seconds duration)

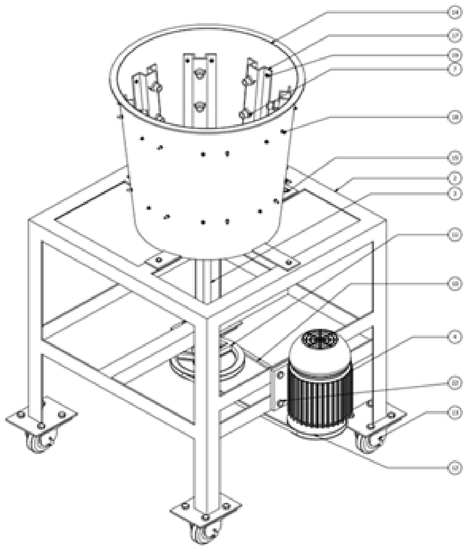
At this scalding temperature, no hand picking of the remnant pin feathers is necessary. Birds processed at this temperature are white and may start to discolour in as little as 3 days. Thus, the type of scald to be selected is very important in selecting processing equipment, particularly for automated one rather than manual [3]. [2] reported that poultry scalded at temperature range of 59-61°C for 45-90 seconds duration, has skin discolouration which does not occurred in water flow.

Different de-feathering machines and rubber pluckers 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.

The aim of this paper is to develop a household poultry de-feathering machine that will perform efficiently, effectively, give a good appearance and quality to birds being de-feathered. The objectives are to: calculate the probable efficiency of the machine, determine the time taken to de-feather the bird on the machine as opposed to manual plucking, determine the scalding temperature at which the feather will be adequately removed from the chicken without any scar.

II. Materials and Methods

The de-feathering machine was developed using locally-available materials. The materials needed were selected based on availability, mechanical properties and relative cost. The machine is able to pluck feathers from chicken of weight up to1.8-4.5kg. Constructional features of the de-feathering machine as shown in Fig.1 below while Fig. 2 below reflects the sectioning part of the de-feathering machine.



PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	2	Bearing	
2	1	Frame	
3	2	Shaft	
4	1	Electric Motor	
5	1	Holder	
6	1	Plywood	
7	44	JIS B 2301 Reducing Male and Female Socket - Class I 1/2	Socket
8	5	ANSI B18.6.3 - 3/8-16 UNC x 1.125	Hexagon Head Screw
9	8	ISO 7414 - M12	Hexagon nuts for structural bolting with large width across flats, style1 - product B - property class 10
10	1	V-Belt	
11	1	Shaft Sheave	
12	1	Motor Sheave	
13	4	Tyres	
14	1	Basin	
15	4	ISO 4017 - M8 x 16	Hexagon head screws
16	16	ISO 4017 - M12 x 25	Hexagon head screws
17	8	Plucker Holder_MIR	
18	32	ISO 4036 - M5	Hexagon thin nuts(unchamfered) - product grade B
19	32	AS 1427 - M5 x 25	ISO metric machine screws
20	1	Stopper	
21	1	ISO 4017 - M10 x 35	Hexagon head screws
22	4	ISO 4017 - M12 x 40	Hexagon head screws

Figure 1: De-feathering machine and its features

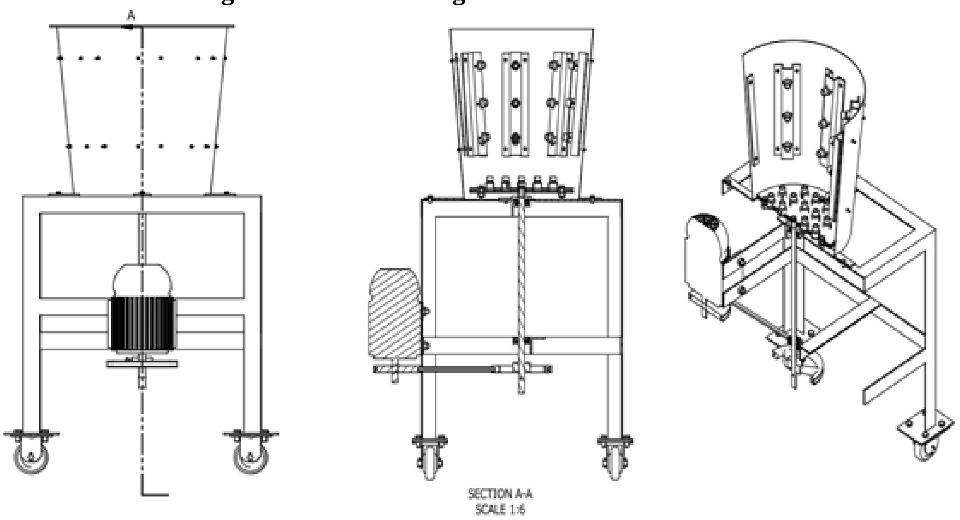


Figure 2: Sectioning of the de-feathering machine

2.1. Machine Fabrication

The fabrication sequence of the machine is as follows: construction of frame, installation of electric motor, erection of bearings/sheave on shaft, joining of rubber plucker plate and plywood with shaft, fabrication of rubber plucker basin and joining with frame, fixing of rubber pluckers, fixing of tyres, finishing and painting. The main frame of the machine is of over-all dimension 700 x 700 x 700mm. This was fabricated using angle iron of dimension 50 x 50mm. The main frame was being constructed in such a way that it would provide support for the electric motor, shaft, rubber plucker basin or plate, on which the de-feathering operation is taken place. The electric motor of capacity 1.1kW, 1400rpm by capacity was installed to provide adequate setting. A sheave of 160mm nominal diameter was fixed on the shaft of the motor which would transmit power to the shaft through the belt. The motor was being attached to the frame by using Hex head bolt and nut. The shaft of diameter 20mm and length 595mm was erected vertically at the centre of the main frame supported by two bearings and brazed at the top and bottom of the frame.

Attached to the shaft is a driven sheave of diameter 200mm which reduces the actual speed of the electric motor because it is greater than the sheave of the motor. The rubber plucker plate was then joined to the ply wood with bolt and nut. Plywood was joined with the rubber plucker plate to provide adequate strength because of the thickness of the plate. Likewise two flat bars were crossed joined to support the plywood. The plywood was to prevent the rubber pluckers in the plate from falling off. The plate was joined to the shaft end by using hexagonal bolt. The plucker basin is a frustum of a cone which has a top diameter of 500mm, bottom diameter of 400mm and a height of 500mm. The basin was developed from a galvanized steel plate. The top and the bottom of the basin are concentric with the rubber plucker plate.

Holes of diameter 29mm was drilled on the plate which was used to hold the rubber pluckers. Also, holes of diameter 29mm were being drilled on galvanized steel plate of diameter 360mm, thickness 1.4mm and plywood of diameter 360mm, 14mm. The rubber plucker is shown in Fig. 3a while the rubber plucker holder is shown in Fig. 3b. Small pieces of plates of dimensions 160mmx120mmx5mm were attached to the four stands of the mainframe as support. The tyres were then attached to the plate by using bolts and nuts.

Figure 3a: Rubber plucker

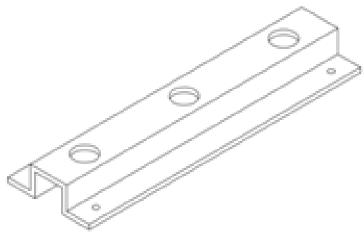


Figure 3b: Rubber plucker holder

2.2. Machine Operation

Scalded bird was conveyed manually without delay to the de-feathering machine. The machine consists of an electric motor transmitting torque to the sheave by a belt. Torque is transmitted to shaft supported by two bearing assembly. The shaft drives the rubber plucker plate rotating against a stationary frustum basin consisting protruding rubber pluckers as well as the rubber plucker plate. Rubber pluckers get a grip on the feathers as the plate is rotating against the basin, thus removing the feathers from the birds while the carcass are conveyed through this section.

2.3. 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, shaft and rubber plucker basin.

2.3.1. 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 1400rpm.In other to calculate the speed that would be transmitted to the shaft, the following analyses were been carried out:

$N_1D_1 = N_2D_2$ 1

where:

N_1 = speed of the motor, 1400rpm, D_1 = diameter of the motor sheave, 160mm,
N_2 = speed of the shaft/shaft sheave, D_2 = diameter of the shaft sheave, 200mm

$$N_2 = \frac{N_1 D_2}{D_2} = \frac{1400 \times 160}{200} = 1120rpm$$

Therefore, the speed that the motor will transmit to the shaft/shaft sheave through the belt is 1120rpm.

2.3.2. Belt Length and Width

Belt length was determined from this equation curled from [5]*:*

$l_b = ([d_f + d_m]1.5708) + (2l_{fm})$ 2

where,

l_b = length of belt, d_f= sheave pitch diameter for shaft = 180mm
d_m= sheave pitch diameter for motor = 140mm, l_{fm} = centre-to-centre distance of motor sheave and shaft sheave = 425mm

Therefore,

$$l_b = ([180 + 140]1.5708) + (2 \times 425)$$

$$l_b = 502.656 + 850$$
$$l_b = 1352mm$$

Standard pitch lengths of v-belts according to IS: 2494-1974, length of the belt is of type B because it is close to 1375mm. Dimensions of standard belts according to IS: 2494-1974, the top width of type B belt is 17mm.

2.3.3. Shaft Design on the basis of Strength

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. 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.4 shows the distributions of loads on the shaft in attempt to calculate the diameter of the shaft to be used.

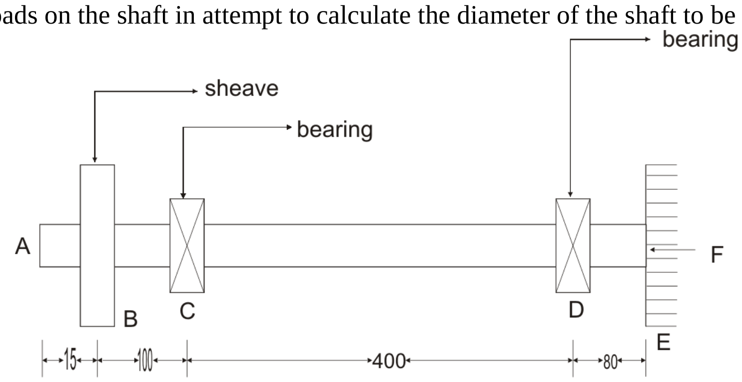


Figure 4: Axial, torsion and bending loads on shaft

When the shaft is loaded with torsion and bending loads only, [6] gave these expressions:

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

and

$$M_e = \frac{1}{2\left[M + \sqrt{M^2+T^2}\right]} = \frac{\pi}{32} \times \sigma_b \times d^3 \qquad 4$$

where,

T_e = equivalent twisting moment, M = maximum moment (Nm), T = torque transmitted (Nm), σ_b = bending stress (N/m^2), d = diameter of the shaft (m), τ = shear stress (N/m^2), M_e = 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

Using T_e, $d = 19mm$

Using M_e, $d = 20mm$

To choose the correct diameter out of the two, [6] suggested that the diameter of the shaft may be obtained by using both theories and the larger of the two values is adopted. Hence, the correct diameter of the shaft that was used in the construction of the de-feathering machine is 20mm and length is 595mm.

2.4. Development of the Rubber Plucker Basin

The basin in Fig. 5 below which is a frustum of a cone was being developed in order to mark it out on the plate to be used for constructing the basin. The frustum of the cone was completed to give cone which is given in Fig. 6.

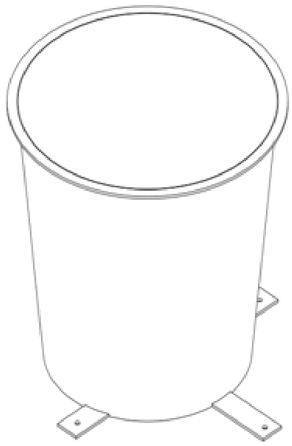


Figure 5: Plucking basin

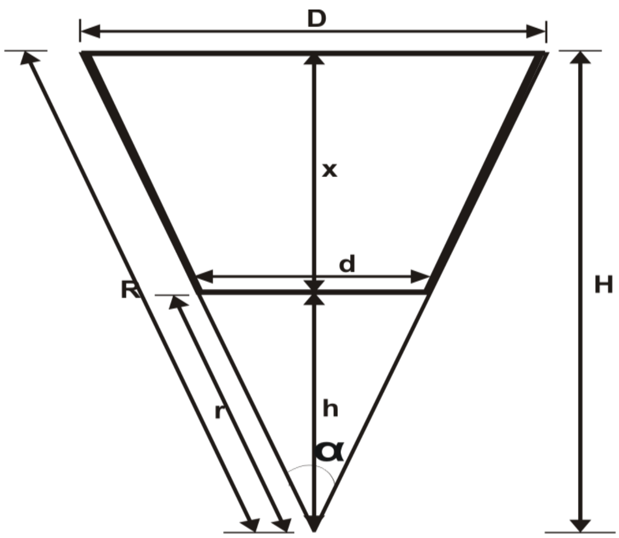


Figure 6: Development analysis of the rubber plucker basin

D = diameter of the top of the basin, 500mm, d = diameter of the bottom of the basin, 400mm
x = height of the basin, 500mm, H = height of the completed cone, h + x = h +500
R = slant length of the cone, r = slant length of the smaller cone, α = angle of the cone.

Analysis

H is determined by similar triangle

$$\frac{H}{h} = \frac{D}{d} \qquad 5$$

$$\frac{h + 500}{h} = \frac{500}{400}$$

h = 2000mm

H = 2000 + 500

= 2500mm

R is determined from the relation below

$$R = \sqrt{H^2 + \frac{D^2}{4}} \qquad 6a$$

$$R = \sqrt{2500^2 + \frac{500^2}{4}}$$

$$R = 2513mm$$

r is determined from the relation below

$$r = \sqrt{h^2 + \frac{d^2}{4}} \qquad 6b$$

$$r = \sqrt{2000^2 + \frac{400^2}{4}}$$

$$r = 2010mm$$

α is calculated from the relation below

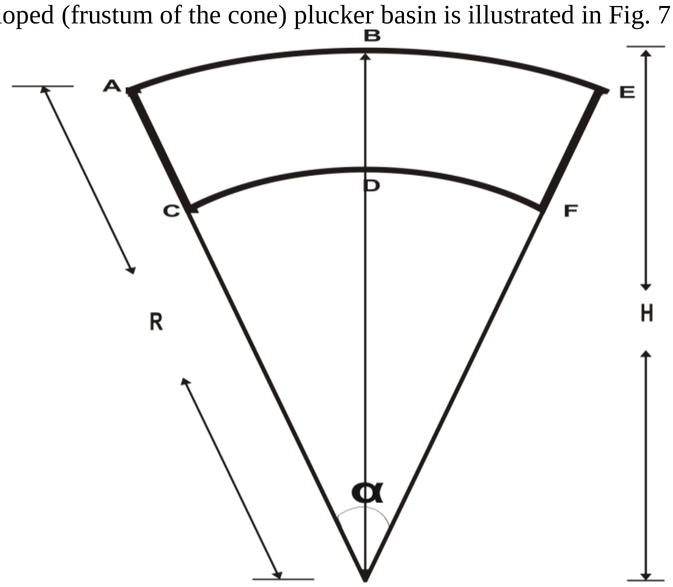
7

$$\alpha = 180\frac{D}{R}$$

$$\alpha = \frac{180 \times 500}{2513}$$

$$\alpha = 36°$$

The diagram of the developed (frustum of the cone) plucker basin is illustrated in Fig. 7 below



R = 2513mm, r = 2010mm, α = 36°

Figure 7: Diagram of the developed plucker basin

III. Results and Discussion

3.1 Material Balance Analysis

After slaughtering, the chicken was weighed with spring balance to record the initial weight of the chicken. Then the chicken was scalded at temperature of about 70ºc and holding time was between 45 and 60s. Chicken was fed into the machine and the weight of the output chicken was determined and recorded. This was done for three chickens. The results are given in the TABLE 1. The weight of the feather was determined by subtracting the weight of the chicken after plucking from the weight of the chicken before plucking.

Table 1: Time Taken in De-Feathering Operation and Weight Analysis

Trial	Chicken weight before plucking(a) (kg)		Chicken weight after plucking (b) (kg)	Weight of feathers (a-b) (kg)	Plucking time (sec)
	dry	wet			
1	1.665	1.875	1.537	0.252	15
2	1.682	1.896	1.326	0.320	8
3	1.838	2.043	1.589	0.249	10

$$Average\ feather\ removed\ = (0.252 + 0.320 + 0.249) = 0.274\text{kg}$$

$$Average\ de-feathering\ time\ = \frac{(15 + 8 + 10)}{3} = 11\text{sec}$$

$$Weight\ of\ feather\ removed\ per\ second\ = \frac{0.274}{11} = 0.025\text{kg/s}$$

3.2. Efficiency of the Machine

The efficiency of the machine was determined by using TABLE 2.

Table 2: Determination of the Efficiency of the Machine

S/N	Initial mass m_i(kg)	Final mass m_f(kg)	Efficiency $= \frac{m_i}{m_f} x\ 100$
1	0.281	0.252	89.68
2	0.334	0.320	95.81
3	0.2528	0.249	98.50

$$Average\ efficiency\ = \frac{(89.68 + 95.81 + 98.50)}{3}$$

$$Average\ efficiency\ = 94.66\%$$

3.3. Discussion on Efficiency

Different values of efficiency for the three trials made are significantly high. However, the third trial is exceptionally higher than each of the other two trials all because of one or two adjustments in the construction noted during the first two trials. The machine will continue to produce in replicate at higher efficiency consistently. Two efficiencies were used in this paper. These can be regarded as working and testing efficiencies. The working efficiency was expressed in terms of power input and power output of the electric motor. The testing efficiency on the other hand has to do with the results obtained which was expressed in terms of the mass (weight) of the chicken before plucking and mass (weight) of the chicken after the plucking.

$$Working\ efficiency = \frac{power\ output}{power\ input} \times 100 \tag{8}$$

$$Working\ efficiency = 98\%$$

$$Testing\ efficiency = \frac{mass\ output}{mass\ input} \times 100 \tag{9}$$

$$Testing\ efficiency = 94.66\%$$

Figure 8: Finished de-feathering machine

Figure 9: De-feathering Machine on Operation

IV. Conclusion

Considering the values of the two efficiencies, it can be concluded that higher efficiency can be predicted and obtained if high value is assumed for the working efficiency during design and construction .Also, the machine performed efficiently and effectively by releasing the chicken freely to the plucking plates and basin. However, holding the chicken with bare hand while plucking will cause unwanted scar and uneven plucking, also time can be wasted.

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