

## EVALUATION OF A MODIFIED CHICKEN DE-FEATHERING MACHINE

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### ABSTRACT

*Poultry is a domestic fowl reared for the production of eggs, meats and feathers. Consumption of poultry birds as a source of protein is on the increase due to the increase in world population. De-feathering of birds is one process which is time consuming and hectic. It is a process of removing the feather from birds and this is commonly done manually which results in waste of time and low output. Development of a poultry de-feathering machine is a process of producing a mechanical device for removing feathers from scalded birds. This study focuses on evaluation of a modified poultry de-feathering machine in order to improve the performance and efficiency of the machine. The machine consists of rubber tyre which do the actual plucking of the feathers. The de-feathering efficiency of the modified machine was found to be 95.65%. It was recommended that plastic should be used for the drum and wood for the sitting frame in order to reduce cost of production and subsequent de-feathering machine should be designed such that it can be powered by solar energy since electricity is unreliable and the cost of fuel is substantially high.*

**Keywords:** Poultry, De-feathering, Efficiency, Plucking fingers

### 1 INTRODUCTION

**P**oultry (domestic fowl) is a species of birds reared for the production of eggs, meats and feathers. Even though the term poultry is mostly used for chickens. It also includes other avian species like turkey, duck, guinea-fowl and geese. The processing of chicken is the sequence of treatments to which it is subjected to prepare it for consumption. Poultry production industry at one time could be described as the most successful in the livestock subsector. Commercial poultry production however increased tremendously in Nigeria in the last few decades. This business is attractive because birds are able to adapt easily, have high economic value and high rate of productivity that can result in the production of meat within eight weeks and first egg production within eighteen weeks of the first chick being hatched [1]. Poultry comes fourth among the major sources of animal proteins for human consumption in Nigeria. Poultry meat is popularly consumed among non-vegetarians world-wide due to its low fat and calorific content. 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 have to increase correspondingly to meet the effective protein requirement of the world [2]. Therefore, there is need for user-friendly, reliably and efficient poultry processing devices in order to meet up with ever increasing demand of poultry meat.

There has been an increase in the number of poultry processing industries in the country since the Federal Government of Nigeria as a policy measures to revive the economy encourages the local poultry farmers. There are numbers of important activities involved in the production of poultry meat, these activities are; slaughtering, scalding, de-feathering process, eviscerating, chilling, deboning, packaging and storing. De-feathering process is identified as highly technical and time consuming among the various numbers of poultry processing activities especially when carried out manually [2].

The energy audit of some poultry processing plants with specific survey of five different relevant unit operations revealed that scalding and de-feathering are the most energy intensive unit operations, accounting for 44% of the total energy consumption in the processing [3]. Also, 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 [2]. Manual de-feathering is considered insanitary and arduous, as well as unreliable, especially during festivities. The aforementioned problems lead to the conception of producing a poultry de-feathering machine. However, an attempt was made in the department of Mechanical engineering, Bayero University Kano to produce a chicken de-feathering machine using indigenous materials in order to solve the aforementioned problems. After test running the machine, the following problems were observed;

- i. The material used as fingers for plucking the feathers (teflon) was found to be hard and rigid, thus, injuring and shattering the carcass of the chicken instead of removing the feathers.
- ii. Also, the designed speed was observed to be far above the required speed.

Hence the main objective of this study is to redesign the working speed of the machine and to replace the de-feathering fingers of the machine with rubber type. Then finally to evaluate the performance of the modified machine.

## **2 MATERIALS AND METHODS**

The materials used for this study include; de-feathering machine, teflon, rubber tyre, stop watch, digital weighing machine, rubber tyre was used because of its flexibility and toughness. However, during the early stages of production of this kind of machine in Europe, there was a debate on the said machine whether the rubber fingers has any harmful effect on the carcass as regards to its consumption. But was confirmed that rubber use for such purpose do not have any significant effect on carcass [2]. Preliminary study was carried out by running the existing machine and testing it. Two sets of chicken, de-feathering test were carried out and it was observed that during the first run of the machine it damage the chickens while partially

de-feathering them. More so, not only does it damage the chickens, the fingers (teflon) of the machine were broken.

After slaughtering, the carcass of the chicken was weighed with a digital weighing machine to record the initial weight of the chicken. The carcass was then scalded at a temperature of 67°C and holding time of eighty seconds (80s). This is in accordance with an investigation of optimized operational parameters for a chicken slaughtering system in Vietnam [4]. The carcass was then fed into the machine, after de-feathering and was removed and reweighed, the weight measured was recorded. The initial mass of the feather was gotten by subtracting the weight of the carcass after de-feathering from the weight of the carcass before de-feathering. However, the final weight was obtained by directly weighing the feathers removed by the machine.

Plate I shows the broken fingers after testing the existing machine while Plate II shows the carcass de-feathered by the existing machine.

The de-feathering efficiency of the existing machine was calculated using equation 1 below as given by [2]:

$$\text{De-feathering efficiency} = \frac{\text{mass output}}{\text{mass input}} \times 100\% \quad (1)$$



**Plate I:** Some broken fingers of the existing machine



**Plate II:** One of the chickens damaged by the existing machine

## 2.1 Design Calculations for the modified de-feathering machine

### 2.1.1 Shaft Design

Shaft design consist primarily of determination of shaft diameter to ensure satisfactory strength, stiffness and rigidity when the shaft is transmitting power to the various components linked up to the shaft. The shaft designed was subjected to combined twisting and bending moment which requires the shaft to be designed on the basis of the two moments simultaneously. The maximum shear stress theory (Guest's theory) was applied which is

suitable for ductile materials such as steel. According to [5] the maximum shear stress was calculated using the formula:

$$\tau_{max} = \frac{16}{\pi d^3} \sqrt{M^2 + T^2} \quad (2)$$

Where; M = maximum moment (Nm), T = torque transmitted (Nm), d = diameter of the shaft (m),  $\tau_{max}$  = maximum shear stress (N/m<sup>2</sup>),

The ASME code equation for solid shaft combined torsion, bending and axial loads by applying the maximum shear equation modified by introducing shock, fatigue and column factors as follows.

$$d^3 = \frac{16}{\pi \tau_{max}} \sqrt{(k_b M_b)^2 + (k_1 M_1)^2} \quad (3)$$

Where;  $M_1$  is torsional moment,  $M_b$  is the bending moment,  $\tau_{max}$  is the shear stress,  $k_1$  and  $k_b$  are the shock and fatigue factors applied to torsion and bending moment respectively.

### 2.1.2 Thickness of the belt (t)

The forces exerted at each end of the shaft are not only due to the weights of the pulley and flat disc, but also the forces acting due to the pretension in the belt. Leather fabric belt was used; the thickness of the belt was calculated using the formula:

$$t = d/30 = \frac{0.075}{30} = 0.0025m \quad (4)$$

### 2.1.3 Number of plies

The dimension for a ply of a leather belt including the inner layer is 1.5 mm and should not exceed 7 plies. Therefore, the number of plies was calculated using the relationship:

$$N_{ply} = \frac{2.5}{1.5} = 1.67, \text{ say } 2 \quad (5)$$

### 2.1.4 Belt width

The belt width was calculated using the formula:

$$\delta = \frac{F_1}{bt} \quad (6)$$

Where;  $\delta$  is the tensile pre stress in the belt,  $F_1$  the tangential driving force, b is the belt width and t is the belt thickness.

### 2.1.5 Effective allowable stress

Effective allowable stress ( $\delta$ ) was calculated using the formula:

$$\delta = d_{eff} C_V C_S C_0 C_\alpha \quad (7)$$

Where;  $d_{eff}$  is the normal effective stress determined under standard condition,  $C_V$  is the velocity factor (1.0),  $C_S$  is the Service factor (0.8),  $C_0$  is the coefficient which takes care of the mutual arrangement of the shaft (0.8) and  $C_\alpha$  is the coefficient which accounts for the effective angle of contact of the pulley.

### 2.1.6 Determination of pre tension in the belt

The formula below was used to determine the pretension in the belt

$$T_{pre} = \delta * b * t \quad (8)$$

Where;  $\delta$  is the tensile pre stress in the belt,  $b$  is the belt width and  $t$  is the belt thickness

### 2.1.7 Bearing Design and Specification

Rolling contact bearing design also involves proper selection and insertion of adequate number of balls between the races as separated by retainer's proper mounting so that the bearing satisfies the operating conditions. Ball bearing with permissible speed of 2500 rpm was used based on the diameter and speed of the shaft.

### 2.1.8 Power Required to Drive the Machine

Power required was determined by using the formula:

$$P = (T_1 - T_2) \times V \quad (9)$$

Where:  $T_1$  is the tension at the tight side of the belt,  $T_2$  is the tension at the slack side of the belt and  $V$  is the peripheral velocity of the belt.

### 2.1.9 Re-design of de-feathering finger

Rubber of specific strength was used as the de-feathering plucking finger. The allowable tensile stress of the rubber was 1.1 N/mm<sup>2</sup>. Based on the specifications required for the material, i.e. flexibility, toughness, rigidity and availability of material, rubber tyre was used. In an attempt to ensure large number of chickens processed in short time, the machine was designed with an estimated maximum capacity for ten (10) chickens.

### 2.1.10 Re-design of de-feathering speed

The working speed of the machine was redesigned to be 340 rpm. This was in accordance with an investigation of optimized operational parameters for a chicken slaughtering system in Vietnam [4]. To arrive at the above speed, the formula below was made use of.

$$N_2/N_1 = D_1/D_2 \quad (10)$$

Where;  $N_1$  is the speed of the driving pulley,  $N_2$  is the speed of the driven pulley,  $D_1$  is the Diameter of the driving pulley and  $D_2$  is the diameter of the driven pulley.

### 2.1.11 Belt Length

Length of belt was calculated using the formula;

$$L = \frac{\pi}{2} (D_1 + D_2) + 2c + \frac{(D_1 - D_2)^2}{4c} \tag{11}$$

Where; C is the centre distance between the two pulley and is calculated using the formula;

$$C = \left( \frac{D_2 + D_1}{2} \right) + D_1 \tag{12}$$

The estimation of angle of contact of an open belt drive is express as;

$$\theta = 180 - 2\alpha \tag{13}$$

$$\alpha = \sin^{-1} D_2 - D_1/2c \tag{14}$$

$$\theta = 104.28^\circ \tag{15}$$

### 3 RESULTS AND DISCUSSION

#### 3.1 Results

Tables 1 and 2 show the performance of the modified and existing machines respectively.

Table 1. Performance of the modified machine

No. of Trials	Chicken weight		Chicken weight after de-feathering (kg)	Weight of feather (initial) (kg)	De-feathering time (sec)	Weight of feather (kg) (final)
	Dry	Wet				
1	1.522	1.749	1.442	0.307	30	0.299
2	1.836	2.121	1.653	0.468	35	0.436
3	2.072	2.264	1.875	0.389	40	0.375

Table 2. Performance of the de-feathering machine before modification

No. of Trials	Chicken weight		Chicken weight after de-feathering (kg)	Weight of feather (initial) (kg)	De-feathering time (sec)	Weight of feather (kg) (final)
	Dry	Wet				
1	1.620	1.831	1.153	0.678	10	0.216
2	1.531	1.749	0.980	0.769	11	0.242

#### 3.2 Discussion of results

The modified machine was tested three consecutive times, with chickens of different weights. There was a tremendous improvement in the efficiency of the modified machine. The de-feathering efficiency of the modified machine was found to be 95.65% which is greater than the efficiency of the existing machine of 31.36%. Since flexibility and toughness are the properties required for the de-feathering finger material, rubber tyre was used, elastomer would have been a better option but was not used because of its high cost, rubber tyre was better than

the teflon used in the existing de-feathering machine. The result obtained also show that the weight of the chicken after de-feathering with the modified machine was greater than the weight of the chicken after de-feathering with the machine before modification. Plate III and Plate IV show the modified de-feathering machine and the chickens de-feathered by the machine respectively.



Plate III: The modified de-feathering machine



Plate IV: Two chickens de-feathered by the modified machine

#### **4 CONCLUSION**

The problems observed during preliminary testing of the existing machine were addressed. These problems include; damaging the chicken carcass and partially de-feathering it, de-feathering speed far above the required, breaking of de-feathering fingers upon operation. The modified machine was found to have higher de-feathering efficiency. Plastic should be used for the drum and wood for the sitting frame in order to reduce cost of production and subsequent de-feathering machine should be designed such that it can be powered by solar energy since electricity is unreliable and the cost of fuel is substantially high.

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