Development and Performance Evaluation of a Chicken De-Feathering Machine for Small Scale Farmers

Adeyinka A. Adesanya
Department of Agricultural and Bioresources Engineering, Federal University, Oye-Ekiti, Ekiti, Nigeria.
Email: adeyinka.adesanya@fuoye.edu.ng

Olawale J. Olukunle
Department of Agricultural and Environmental Engineering, Federal University of Technology Akure, Nigeria
Email: wale_olukunle@yahoo.com

***Abstract*—A chicken de-feathering machine was designed and fabricated de-feathering machine for small scale poultry processors. The objectives of this work are as follows: To evaluate the performance of the machine, to select relatively cheap materials whose service area is applicable to the design and to reduce the overall cost of the machine. In the bid to achieving these objectives, the machine was fabricated using food grade plastic drum for the de-feathering chamber, wood for the frame, and tapered rubber for the plucking fingers. 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%.**

***Index Terms*—chicken de-feathering, design, small scale processors.**

I. Introduction

[1] Following the ban on the importation of poultry products by the Federal Government of Nigeria as policy measures to revive the economy and encourage the local poultry farmers, there has been an increase in the number of poultry processing plants in the country [1] A poultry processing plant is an integral part of an extensive poultry-farming venture comprising also the breeder flocks, hatchery, feed mill, broiler flocks and other related services. However, these areas of poultry business are mostly owned and controlled by a single organization. [1] Many government agencies are encouraging poultry farming and even short term training courses are organized regularly. By implication, poultry farms are increasing steadily. Meanwhile, such farms have generated considerable employment opportunities in semi urban and rural areas. It is imperative to point out that marketing of poultry birds is expensive and death of birds during transit is the main bottleneck. This challenge compels most of the poultry farms to concentrate on nearby markets even if it means lower prices. Instead, if these birds are processed after dressing and packed in tins then transportation is easier, shelf life of the product increases and the product is more hygienic [1].

In addition, the use of plucking machine in poultry processing (bird of any kind) as contributed tremendously to the successful processing of dressed and hygienic chicken for consumption and it also minimizes disease infection. It overcomes the drudgery, time consumption and discouragement associated with hand plucking. Against this background, this work seeks to design and fabricate a de-feathering machine for small scale processors. To evaluate the performance of the machine, select materials which are relatively cheap and whose service area is applicable to the design. With this, the overall cost of the machine is reduced.

II. Materials and Method.

A. Materials for Construction.

[2] The materials used for the construction of the de-feathering machine are: high density food grade plastic drum, wood for the frame, tapered plucking rubber for the plucking fingers and solid steel for the shaft.

B. Design Analysis

1) 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.

C. Plucking Chamber Design

The plucking chamber is a frustum, circular in shape. The plucking chamber was opened at both ends. The diameter of the of the upper opening is 50.80 cm while

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the diameter of the lower opening is 36 cm. Twenty four holes were strategically drilled on the walls of the chamber and on the rotating plate. The diameter of each hole is 21mm.

1) Volume of plucking chamber

The volume of the plucking chamber was determined using this equation according to [3],

$$V = \frac{1}{3}(R^2 - r^2)\pi h \quad (1)$$

where,

V = Volume of the frustrum; R = Radius of the upper opening = 0.508m; r = Radius of the lower opening = 0.36m; h = height of the drum = 0.356m.

Volume of the plucking chamber = 0.0722 m^3

2) Hopper capacity

The plucking chamber capacity is determined from the equation according to [4],

$$P_c = \rho V \quad (2)$$

where,

ρ = Density of chicken sample = 1113 kg/m^3; V = Volume of plucking chamber = 0.0722 m^3

Plucking chamber capacity, Pc = 80 kg.

D. Force Required for Feather Removal

The force required for feather removal F_c is determined from the equation according to [5].

$$F_c = M\,\omega^2 r \quad (3)$$

where

M = Mass of the rotating plate = 0.7kg;

ω = Angular velocity of the pulley = 124 rpm

r = Radius of the pulley = 0.007m;

The force required to remove the feather,

F_c = 75 N.

E. Design of Shaft

Since mild steel is used for the shaft, maximum shear stress theory is used for the design of shaft diameter and it is stated below according to [5];

$$d^3 = 16/\pi\tau\sqrt{(K_b\,M_b)^2 + (K_t\,M_t)^2} \quad (4)$$

where;

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

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

M_b = Bending moment (Nm);

M_t = Torsional moment (Nm)

τ = Allowable shear stress

F. Shear Failure Analysis of the Defeathering Chamber

The shear stress of the de-feathering chamber is determined by the equation below according to [6];

$$\tau = 16M_t/\pi d^3 \quad (5)$$

$$M_t = WR \quad [7] \quad (6)$$

W = Weight of the chamber = 56.60 N; R = Mean diameter of the Chamber = 0.43 m

M_t = 28.75 Nm ; τ = 1791 N/m^2

G. Power Requirement of the Machine

The total power (P_t) requirement of the machine is the sum of power required to rotate the feather plate (P_r) and the power required to de-feather (P_d) the chicken. It is represented below according to [7]:

$$(P_t) = (P_r) + (P_d) \quad (7)$$

1) Power required to rotate the feather plate

The power required to rotate the feather plate is determined by the equation according to [7],

$$P_r = W_p\,R_p\,\omega_p \quad (8)$$

where

W_p = Weight of the rotating plate = 6.77 N; Rp = Radius of the rotating plate = 0.1m

ω_p = Angular velocity of the rotating plate.

$$\text{But } \omega_p = 2\pi N/60 \quad (9)$$

ω_p = 146.62 rad/s

Power required to rotate the feather plate = P_r = 99 W

2) Power required to de-feather

Power required to de-feather the bird is determined the equation below according to [7];

$$P_d = T_s\omega_d \quad (10)$$

But $T_s = \pi d^3\tau/16$;

where,

P_d = Power required to de-feather the bird;

T_s = Torque of the de-feathering chamber.

ω_d = Angular velocity of the de-feathering chamber = 146.62 rad/s ; D = Mean diameter of the de-feathering chamber = 0.434m

τ = Shear stress of the de-feathering chamber = 1791N/m^2; Ts = 28.75 Nm

P_d = 4215 W; Power to de-feather = 4215 W

Total Power = P_r + P_d = (99 + 4215)W = 4314W = 4.314 kW

1horse power HP = 0.746kW; Total power in horse power = 5.78 HP

An electric motor of 7.5 HP can conveniently power the machine.

H. Description.and Working Principles of the Machine

The de-feathering machine consists of the following basic units; the de-feathering chamber, the rotating plate and the frame. The feather plate is located at the base of the plucking chamber. The electric motor is located at the side of the frame.

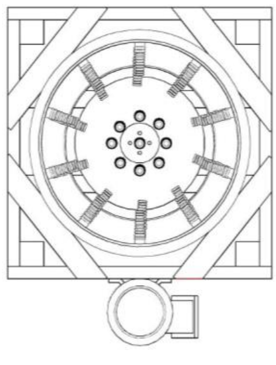

Figure 1. The Plan View of the Machine.

Scalded bird was conveyed manually without delay to the de-feathering machine. The shaft drives the rotating plate against the stationary de-feathering chamber consisting protruding rubber pluckers. Rubber pluckers get a grip on the feathers as the plate is rotating against the chamber. This causes feather removal from the chicken. After the de-feathering process, the bird was removed and the feather residues collected at the base of the machine.

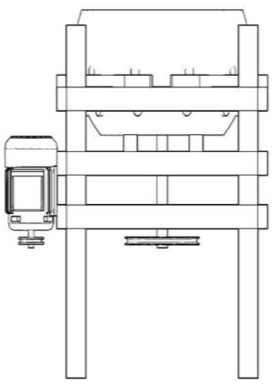

Figure 2. The Front View of the Machine

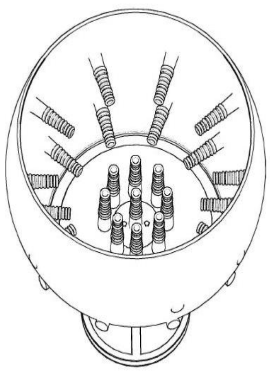

Figure 3. The Internal View of the Machine Showing the Plucking Rubber Arrangement.

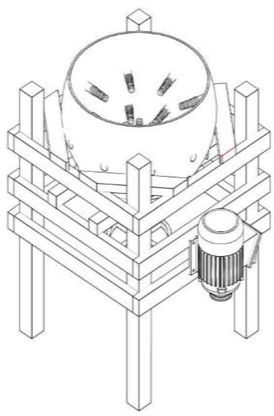

Figure 4. The Isometric Drawing of the Machine

III. PERFORMANCE EVALUATION OF THE SYSTEM

The constructed chicken de-feathering machine was tested to evaluate its performance. Materials used for the testing include knife, boiling ring, thermometer, chicken, stop watch, weighing balance and a vessel for boiling water. Water was boiled and the temperature of the water was controlled to about 60℃. The chicken was slaughtered while the machine was powered with a 7.5HP electric motor. The slaughtered chicken was immersed into the warm water and was left in the water for 15 seconds. The bird was now transferred into the de-feathering chamber. The bird was de-feathered after 30 seconds.

The machine efficiency was calculated using this equation,

$$(1 - \text{mass of flesh removed} \times 1\text{- mass of feather at the } 30^{th} \text{ second.}) \times 100 \ [8] \qquad (11)$$

Mass of flesh removed = 0g, mass of feather at the 30^{th} second = 0.05

The machine efficiency = 95%

IV. RESULTS

Table I shows the rate of feather removal per time.

TABLE I. FEATHER REMOVAL RESULT

S/NO	SPPED (rpm)	MASS OF FEATHER REMOVED(g)	TIME(s)	MASS OF FLESH REMOVED (g)
1	300	38.35	5	0
2	300	31.72	10	0
3	300	25.15	15	0
4	300	19.25	20	0
5	300	12.5	25	0
6	300	0	30	0
		TOTAL = 126.97		

Table I shows the rate of feather removal at a constant speed of 300 rpm and time interval of 5 seconds. The scalded bird was placed into the machine and the feather removed was collected and weighed. The mass of feather removed after 5 seconds of the operation was 38.35 g. 31.72 g of feather was removed over the next 5 seconds. Maintaining the time interval, the mass of feather removed was 21.15 g, 19.25g, 12.5 g and 0g respectively. The total time taken for the operation was 25 seconds while the total mass of feather removed was 126.97 g.

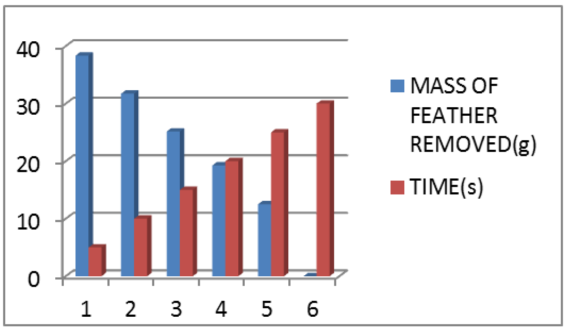

Figure 5. The graph of time(s) against mass of feather removed(g)

Fig. 5 represents the graph of mass of feather removed against time. The graph depicts that as time (in seconds) increases, the mass of feather removed (in grams) decreases. The mass of feather removed at the first 5 seconds was the highest (38.35 g) while the last 5 seconds of the operation recorded 0 g of feather removed. Conclusively, this result indicates that the bird has been totally de-feathered at the 25th second of the operation.

V. Conclusion

The efficiency of the machine is a function of time and the rate of feather removal. De-feathering machine operating at a low speed will have a lower efficiency than when the speed is relatively fast. The machine efficiency was found to be 95% while the machine is capable to de-feather a bird per 30 seconds. The construction of the de-feathering machine is a very important innovation for the small scale poultry industry because it reduces the stress encountered during manual de-feathering. The output per time is increased and hygiene can be guaranteed. Greater energy is consumed during manual de-feathering while the de-feathering machine consumes relatively low energy.

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Adeyinka Augustine Adesanya hails from Ijebu-East Local Government area, Ogun State of Nigeria. He graduated from Federal University of Technology, Akure. He is an avid reader and a prolific writer. He is currently a graduate and research assistant of Agricultural and Bioresources Engineering at the Federal University Oye-Ekiti, Nigeria. His area of interest is basically on Machine and designs. He has to his credit the design of post-harvest and agro processing machines for small and medium scale farmers. He is a passionate intellectual researcher who has diversified experience ranging from the banking sector to other sectors. He is a founding member of THINK POSSIBILITY FOUNDATION, initiated to building generational leaders. He had his NYSC at the Central Bank of Nigeria, Cooperate Headquarters, Abuja. Presently, He is working on the design of electrical sensor to determine optimal working capacity and efficiency of various post-harvest machines. He is a lover of good music; football and reading motivational books. He is unmarried and has to his credits many unpublished books, awaiting publication.

Olawale John Olukunle is a professor of Agricultural Engineering at the Federal University of Technology Akure. He specializes in the design of machine systems for farm power and machinery processing of agro-allied products. Prof. Olukunle has made significant contributions to the development of Federal University of Technology Akure, Particularly in the areas of teaching, research and community development. He is presently the leader and senior pastor of Christ Praise Chapel, an emerging penticostal organization. He is happily married to Dr. (Mrs) Oluwatoyin Folake Olukunle.