Bird Feather Removal Machine: Design and Development

Omoniyi Ezekiel B, Peter Oyekola, Onoriode Ovaha, Aezeden Mohamed, Nicholas Lambrache

Abstract: Poultry product have seen increasing consumers demand in recent times and processing of poultry meat is a pain staking process which is becoming extremely tasking and uneconomical given the increase in demand especially in the rural community where there is no ready access to sophisticated equipment. The Nigerian poultry sector is extremely fragmented as most poultry farmers dedicate a small setup space to satisfy small scale demand of less than 1,000 birds [1]. In commercial events, the development of a poultry de-feathering machine becomes of high priority to meet the demand for poultry products. This paper therefore advocates the implementation of the modified defeathering machine as a suitable substitute of the tradition system which is slow and tedious. This proposed system improves on the defeathering machine with the implementation of a boiling chamber for first stage scalding, and a hot spray channel directly in the plucking chamber.

Keywords: Defeathering, Poultry, Scalding.

I. INTRODUCTION

Scalding and picking machines, which are used basically for the processing of poultry products, although exist in several forms including small and huge machine types, are still not very popular within the Nigerian poultry processing business/industry, where this is basically due to their high design cost. Most of the poultry products in the Nigerian market today are have been processed manually. The manual processing method, which is slow and tedious, has remained uneconomic for large scale production [2]. The Nigerian poultry trade is estimated at about $600 million, with approximately 165 million birds producing 650,000MT of eggs and 290,000MT of poultry meat as at 2013 data [1]. Poultry meat is popularly consumed worldwide due to its low fat and calorific content. The relatively increased choice for chicken over some other type of meat recently has generated a lot of interest in its farming and in the poultry industry in general [2].

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With the growing Nigerian population and the need to meet the WHO protein, fat and calories requirements, it is expected that the poultry meat consumption rate will increase in the coming years, hence the need for low cost scalding and picking machines for processing of poultry products. Common challenges in poultry processing are the safety and health concern inclusive of tasks resulting in cuts or lacerations [3], exposure to cold and wet climates, repetitive motion disorders, slips, falls, dust, dermatitis, and noise [3] [4] [5]. To avoid mishap and infections from poultry cadaver which may occur during some of the processing operations there is a need for a user-friendly, reliable and efficient poultry processing devises [6] [7]. Bird processing involves catching and transport, killing and bleeding, scalding and picking (feather removal) [8], removal of the head, oily glands, and feet, disembowel, chilling, dissecting and deboning, packaging, storage and finally distribution. And of all this processes feather removal are the most time consuming and chancy [9]. Various machines have also been developed for the de-feathering process which can process large or few numbers of birds [10]. However, their demand and acceptance differ regionally. The Mueller poultry picker [11] for instance is electrically powered using a driving pulley mechanism in rotating a cylindrical drum embedded with rubber fingers matrix. The design also incorporates a collection bowl for the plucked feathers. Gordon [12] however designed the plucker using an electric motor with an extended two pulley shaft attached which allows for counter-rotation of drums. The drum holds the rubber fingers which pluck the feathers upon the rotation of the as seen in figure 1. The fingers assume positions radial to the drums, due to the centrifugal forces on the holders and fingers. The wiping motion of the ribbed surfaces of the fingers removes the feather from the carcass.

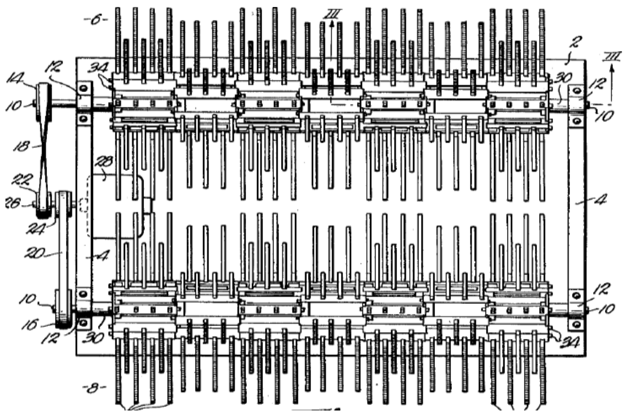

Fig. 1.Plan view of the Gordon poultry plucker

T F schlicksupp poultry plucker [13] had an advantage over others as it introduced a fan (vacuum) for removal of a plucked feather. The design was also the electric-based rotation of the drive shaft. The fan is in a casing which communicates with the plucking chamber if to draw the feathers from the latter chamber for discharge those through an outlet spout to any desired point.

The plucking chamber however used strips of steel, at its outer edge is appreciably wider or thicker than the main portion of the strip and on the periphery or outer portion of the strip, the surface is given a convex curvature, and the sides of the outer portion of the strip are given a concave curvature. This shape of strip provides relatively sharp gripping edges at both sides of the outer portion of the strip to effectively grip the feathers when the convolutions are brought together which, of course, is the contracted condition of the plucker, so as to effectively grip and draw the feathers from the fowl and when the convolutions are separated, the feathers are released which sometimes cause skin tear [14].

Roy smith chicken plucking device [15] introduced a simple motor-driven pulley for the cylindrical picker drum whose surface provided a multiplicity of spaced, transversely disposed of, radially projecting picker elements. The picker elements are soft rubber disc having outwardly presented lip portions that penetrate the feathers by the movement against the birds to uproot the feathers out of the skin. This design, however, does not utilize the pulling action as seen in [11] [12].

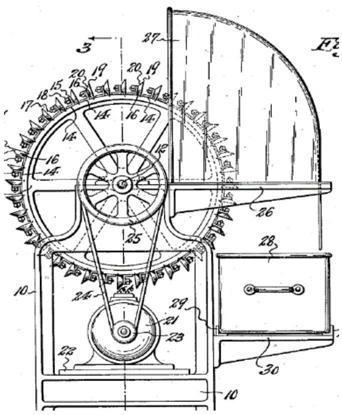

Fig. 2.Smith plucking apparatus

Raleigh F. Lane prototype [16] had an electrically driven long shaft attached with rubber fingers at the end, the bird is held and maneuverer manually by the operator for efficient plucking. The yard bird chicken plucker [17] also incorporated direct drive connection to the rotating plate. The materials in contact with the chicken were made using stainless steel, and incorporated hose supplied water into the machine.

From the foregoing, it is obvious that several attempts have been made to improve the methods for processing poultry products through the design of several types of scalding and picking machines. However, there is need to extend the current state-of-the-art, since most of the scalding and picking machines presented are extremely expensive. Hence, in this paper a new modified low-cost scalding and picking machine is proposed.

II. METHODOLOGY

The construction of the machine started with the design of the frame and then the installation of the electric motor gears. This was followed by adding the bearings/sheave, fitting of plucker plate and then the basin on the machine. Finally, the finishing work is carryout and then tested, before it was painted.

The frame which houses the main motor (1.5KW), shaft and plucking chamber, was fabricated using steel angle ASTM A36. The basin is made from a galvanized steel plate, where the choice of these materials was based on their non-reactive effect on consumable materials and the need to prevent food poisoning due to chemical penetration into the product [18]. Details of the materials used for the fabrication of the new proposed modified scalding and picking machine and properties are shown in Table 1.

Table 1: Material property table

Part	Function	Material	Reason
Frame	supporting structure of the machine	Steel Angle	Strength
Shaft	Transfer torque to the disk	Mild steel	Torsional strength
Plucking chamber	Holds the fingers and ensures rotary contact is made with the poultry bird	galvanized steel	Lightweight and food-safe material.
rubber fingers	Removes bird feathers	Polypropylene	Food safe plastic.

A. Design and operation

In designing the scalding and picking machine, several holes were drilled on the plate and the plucking chamber, which holds the rubber puckers. When powered is switched on, the electric motor is expected to transmit rotational energy with the aid of pulley to the shaft and the base plate in the de-feathering chamber, to pluck the feathers from the bird. The removed feathers are then channelled through the designed passage for onward collection. The time taken to pluck the feather of the bird is recorded as well as the weight of the bird before and after the feather has been removed through scalding and high-speed rotation in the designed machine. The 3D design of the scalding and picking machine for de-feathering poultry bird machine have been designed using CATIA V5 software package where the parts of the machine were adequately simulated before final assembly. Details of the 3D design of the machine frame and fully assembled parts are shown in Figures 3 to 7 respectively.

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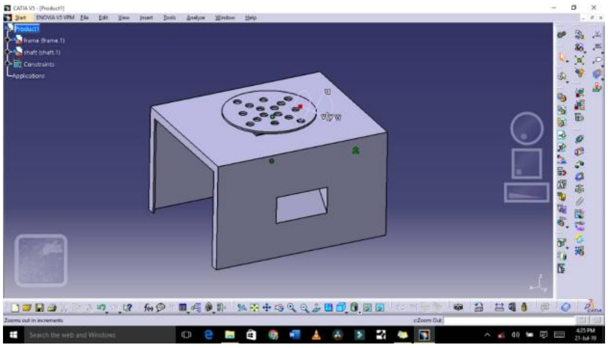
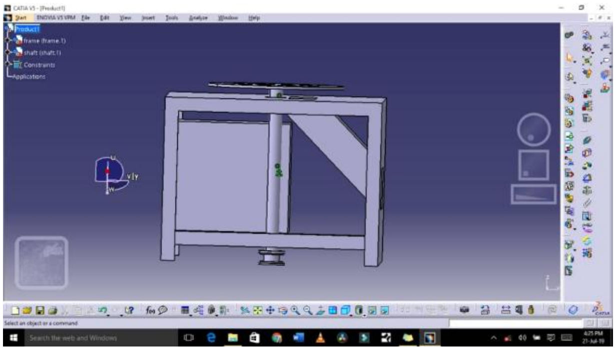


(a)



(b)

Fig. 3.Frame design showing (a) Feather removal channel (b) water boiling unit

B. Considerations or design factors

Generally, several factors have been taken into consideration in determining the most suitable design. On some other occasions, some of these factors will become more critical and crucial, and if its conditions are satisfying, its focus supersedes others for instance, strength of an element is important in determining geometric configurations and dimensions for individual parts and this factor is mostly favoured at the expense of aesthetics. In this case it can be said that strength is an important design factor.

Figure 4 shows the important design factors considered in this paper;

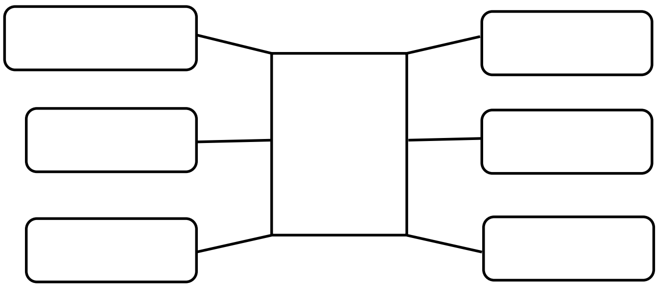


Fig. 4.Design factors

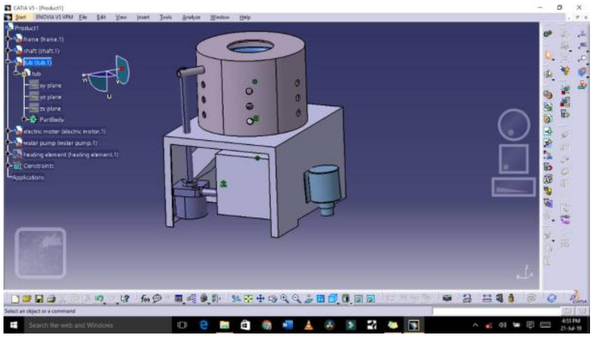


Fig. 5.Isometric view showing boiling unit and pump

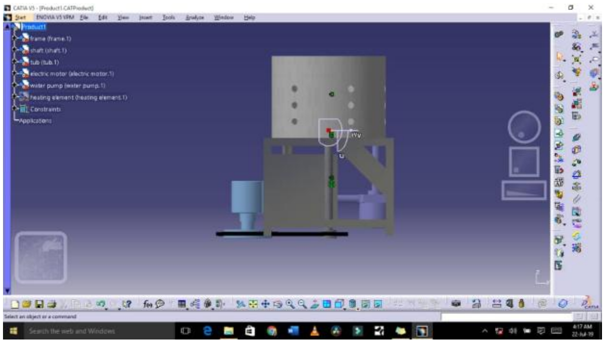


Fig. 6.Side view of the complete unit

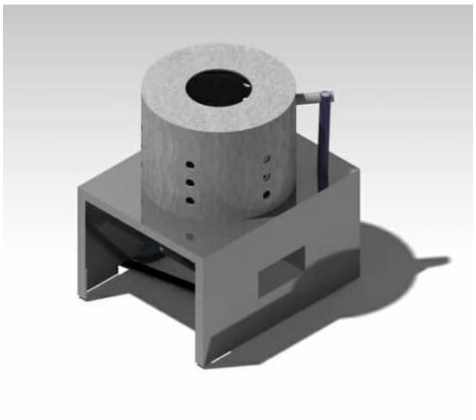


Fig. 7.Rendered representation of the finished machine

C. Design calculations

Having preselected a 1.5KW (2 HP) electric motor [19], the speed of the rotating base plate was estimated and controlled using speed regulator in other to achieve smoother finishing with minor bruise on the poultry product

$$N_1 D_1 = N_2 D_2 \quad (1)$$

Also, the length of the belt used in the pulley can be calculated

$$L = \frac{\pi}{2}(D_1 + D_2) + 2C + \frac{(D_1 - D_2)^2}{4C} \quad [20] \quad (2)$$

Where, D_1 and D_2 are the diameter of driver and driven pulley and C is the centre to centre distance.

The angular velocity (ω) was estimated by

$$\omega = \frac{2\pi N_2}{60} \quad (3)$$

The centrifugal force required is

$$f_c = mf = m\omega^2 r \quad [21] \; [18] \quad (4)$$

Where, m is the average mass of the birds and r is the radius. From the simulated model, the static structural analysis of the rotating shaft of specification shown in figure 6(a) indicated high translational displacement vectors base of the shaft when the motor rotates at 600RPM with a distributed load of 1.6Kg as shown in figure 8.

Table 2: Material properties of steel shaft

Properties	Values
Material	Steel
Young's Modulus	2×10^{011} Nm^2
Poisson's ratio	0.266
Density	7860 Kgm^3
Coefficient of thermal expansion	1.17×10^{-005} ^0K
Yield strength	2.5×10^{008} Nm^2

Fig. 8. Shaft geometry

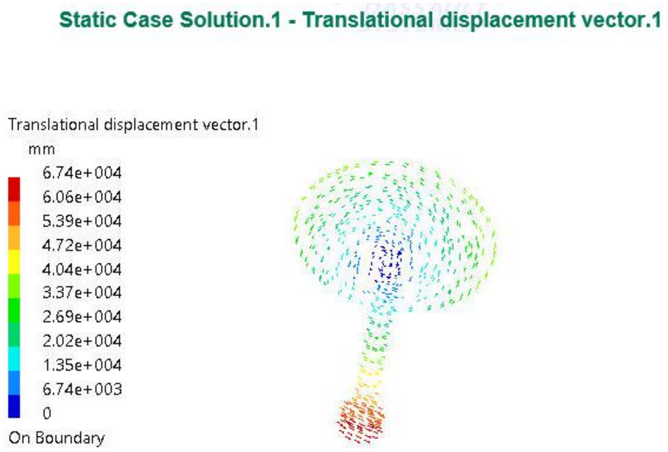


Fig. 9. Rotational forces on shaft

D. Scalding Temperature

Scalding temperature, time and plucking force all influence the de-feathering rate as well as skin appearance. For this reason, the boiling chamber was integrated in the design. The lagged vessel incorporated a water heating element and a thermometer to periodically monitor the temperature. The hot water is also channelled directly to the plucking chamber using water pump and pipes. This is to spray hot water at the designated temperature directly during the feather removal process. The chicken used for experiments was then scalded at varying temperature from 50°C to 80°C.

III. ANALYSIS AND DISCUSSION

After the fabrication and construction of the machine, various tests was done, and results taken for running time. For a successful de feathering, the bird must be scalded in the right temperature to avoid damage to the skin of the birds during de feathering.

Table 3: Time and weight analysis

Test No.	Initial weight (kg)	Final weight (kg)	Weight of feather removed (kg)	Time (s)
1	1.60	1.47	0.13	45
2	1.60	1.49	0.11	30
3	1.70	1.54	0.16	35
4	1.56	1.40	0.16	29
5	1.69	1.52	0.17	30

From Table 3 the average feather removal time was estimated as 32.5 Seconds. This value indicated that the removal rate for this design is 107birds/h. However, this value absolutely depends on the operator's judgment or satisfaction since the birds are rotating at high speed, and it therefore becomes difficult to adequately observe when all feathers have been removed. The type of bird also affects the removal rate as this value applies to chicken.

From [19] study, manually feather removal rate was estimated at 12birds/h. This therefore highlights the advantage of this design as an average output rate of 360birds/h was achieved. The machine was designed to accommodate two birds per process.

From physical observation, with low scalding temperatures it becomes difficult to completely remove the feathers hence higher motor speed is required to reduce scalding time. Similarly, for higher scalding temperatures, there is a risk of the skin being cooked. This in turn makes feather removal difficult as the feather appeared to cut out parchment of skin tissue from the chicken. The optimum temperature required to achieve acceptable results however depends on the type of bird being processes.

For the locally breed chicken, substantial plucking force difference was noticed between 75^0C and 80^0C while for temperatures greater than 80^0C, the required plucking force remained fairly constant. For Exotic birds, the optimum recorded temperature ranged between 65^0C to 75^0C.

After testing, improvements were made to the current design. First, rotating parts were adjusted for the reduction of noise and vibrations in parts such as the belts. To achieve this, dampers were installed on the motor, Alignment of shaft was done, and the bearings were all replaced.

IV. CONCLUSION

In this study, design of a poultry plucker machine was carried out as a low cost means of bird processing.

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The design focussed on improving the efficiency of this existing feather removal machine by incorporating a boiling unit. The results gotten for the experiments were found to be dependent on time, scalding temperature and rate of feather removal. De-feathering at a low speed tends towards lower efficiency than at high speed and optimal scalding temperature was determined experimentally to be dependent on the type of bird being processed. The machine efficiency could significantly improve with the use of a more efficient construction methodology and design adjustment.
The modification possesses obvious advantage over regular methods of depluming chickens as there was minimum damage to the bird's skin while operating within the optimum temperature range. Also, the use of hot water sprayed directly into the plucking chamber tremendously reduced skin damage of the bird.

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