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Development of Chicken (Gallus gallus domesticus) Defeathering Machine

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Abstract

Because of the increased demand of chicken meat, the non-vegetarians worldwide has imposed big responsibility on poultry chicken processing industry. The chicken defeathering machines were made with different capacities but they still need of improvement. This paper is focused on the fabrication of a drum type small scale chicken defeathering machine. The drum type chicken defeathering machine was made using locally available materials. Design calculations were done to ensure appropriate shaft diameter supporting the rotating plate as this could affect the efficiency of the machine. The drum of the machine was made detachable and inside of it was the riveted ring on drum surface located above rotating plate. In addition to this, the machine was designed with chute that is made of two layers to separate the removal of feathers and waste water. Handle and wheel caster were included for ease handling and transport from one place to another place. The machine was tested using 28 days old broiler chicken.

The machine was designed based on the identified problems on existing machine available from three local Dressing Plants namely Poultry Processing Plant in Municipality of Talavera, Nueva Ecija, Poultry Processing Plant in Barangay St. Nino, San Jose, Nueva Ecija and Poultry Processing Plant in Barangay Canitoan, Cagayan de Oro City. The identified problems of these existing machines were a) 10 percent of the chicken feathers was not removed, b) in a batch of 15 chicken, 2 pcs had broken legs; c) during the defeathering operation, workers have to pour manually 2 buckets (20-li capacity) of water, 3 d) unloading consumes about 60 seconds, and e) removing the feathers from the machine after operation was quite difficult.

The overall dimension of chicken defeathering machine after fabrication is 1250 mm x 1160 mm x 650 mm and with a weight of 95 kg. The machine was designed to a capacity of 800 heads per hour. The performance evaluation of the machine has defeathering efficiency of 99.01% and defeathering efficacy of 95.85% at angular speed of 348 rpm. Thus, in this study, a small chicken defeathering machine was developed by improving its performance based on the problems identified above so as to make it more useful and adaptable by small scale poultry processors and poultry farmers who wish to have an added income from a dressed chicken over a live chicken.

Key Words: defeathering efficacy, defeathering efficiency, defeathering machine, design, fabrication

Introduction

Global human population is estimated to reach 9.6 billion in 2050. It is projected that the demand for animal source food could grow by 70% between 2005 and 2050 and poultry meat is expected to have the highest growth at 121 percent (Alexandratos & Bruisma, 2012). In fact, the consumption of the poultry meat is increasing and it is now the second most consumed meat. Research on meat production worldwide indicates that poultry is the fastest growing livestock sector, especially in the developing countries (Delgado et al., 1999).

In the Philippines, the outlook for the chicken industry appears optimistic because the demand for chicken products is expected to increase (DA and NAFC, 2002). Cooked chicken meat, like fried chicken, is served in almost all fast food chains and restaurants in the Philippines, resulting to a demand of 1.6 million metric tons (MMT) per year of chicken meat. Because of the increased demand of chicken meat, poultry processing has faced challenges that are of safety and health concerns which include tasks that could result in cuts or lacerations, repetitive motion disorders, slips and falls, exposure to cold and wet climates, dust, dermatitis, chemicals, and noise (Barbut, 1998). To avoid accidents and infections from poultry carcasses that may occur during some of the processing operations, there is a need for user-friendly, reliable and efficient poultry processing devises (Ralph, 1980). There are important activities that are involved in the production of ready-to-cook (RTC) poultry, the large percentage of which are labor intensive and these contribute to the high cost of processed poultry meat in the market. According to Dickens and Shackelford 2 (1998), the identified production processes for eviscerated birds are (1) pre-slaughter; catching and transport; (2) immobilizing, killing, and bleeding, (3) feather removal: scalding and picking, (4) removal of head, oil glands, and feet, (5) evisceration, (6) chilling, (7) cut-up, deboning, and further processing, (8) aging, (9) packaging, (10) storage and (11) distribution. He further stated that the feather removal is the most time consuming and risky especially when it is done manually. Defeathering is the process of removing feathers from the skin of the poultry animal after scalding to prepare its meat for food (PAES 532, 2012). In various countries, there are defeathering machines that had been developed to handle large numbers of birds (Glenn, 1998). In the Philippines, the National Meat Inspection Service (NMIS) had reported that there are 85 accredited Poultry Dressing Plants in the Philippines, 40 of which is controlled by the San Miguel Foods, Inc. (DA and NMIS, 2018).

Materials and Methods

Design consideration. Based on the observations and informal interviews of small-scale processors of chicken in San Jose City and Talavera, Nueva Ecija, Table 1 indicated the identified problems that were considered in coming up with an improved design of a defeathering machine.

Table 1. Design considerations for the poultry defeathering machine.

PARTICULARS/PARAMETERS	DESIGN REQUIREMENT	DESIGN TARGET
Function	The machine should be able to remove the feathers of chicken	At least 98 percent of feathers removed
	Improved quality of poultry meat	Reduced damage for chicken meat bones
Material selection	Component parts that are in contact with the product are at food grade quality	Use stainless steels and silicon rubber plucking fingers in all parts that are in contact of the product
Capacity of machine	The machine should process 4 heads per minute	capacity of 10 heads per minute
Drudgery in pouring water during operation	Application of water should not be manually powered	Automatic application of water to clean poultry meat.
Cleaning of machine after operation	Ease of cleaning of machine	Discharge chute of feathers included in component parts.
Power	The machine should run 4 heads of chicken per minute using 2 hp electric motor	The machine should run 13 heads of chicken per minute using 1.5 hp electric motor

<u>Conceptual framework of the study</u>. The conceptual framework of the study, as shown on Figure 1, involved environmental scanning through browsing the Internet and conducting personal visit and informal interviews with small poultry processors. The problems identified led to the identification of the design considerations that improved further the performance of existing defeathering machines. The design process included the following tasks: (1) design conceptualization, selection of appropriate materials for the different component parts (2) that are available in the market, design calculations, preparation of detailed drawing, and finalizing the component specifications. Fabrication and assembly of machine were done in local machine shop based on the approved design plan. The development process included making modifications on identified component parts of the machine until the target defeathering efficiency was attained. Preliminary testing of the device was done to assess if the component parts were functioning properly and if the initial target standards were met. Otherwise,

modifications on identified components that possibly caused the failure to attain the desired defeathering efficiency were done.

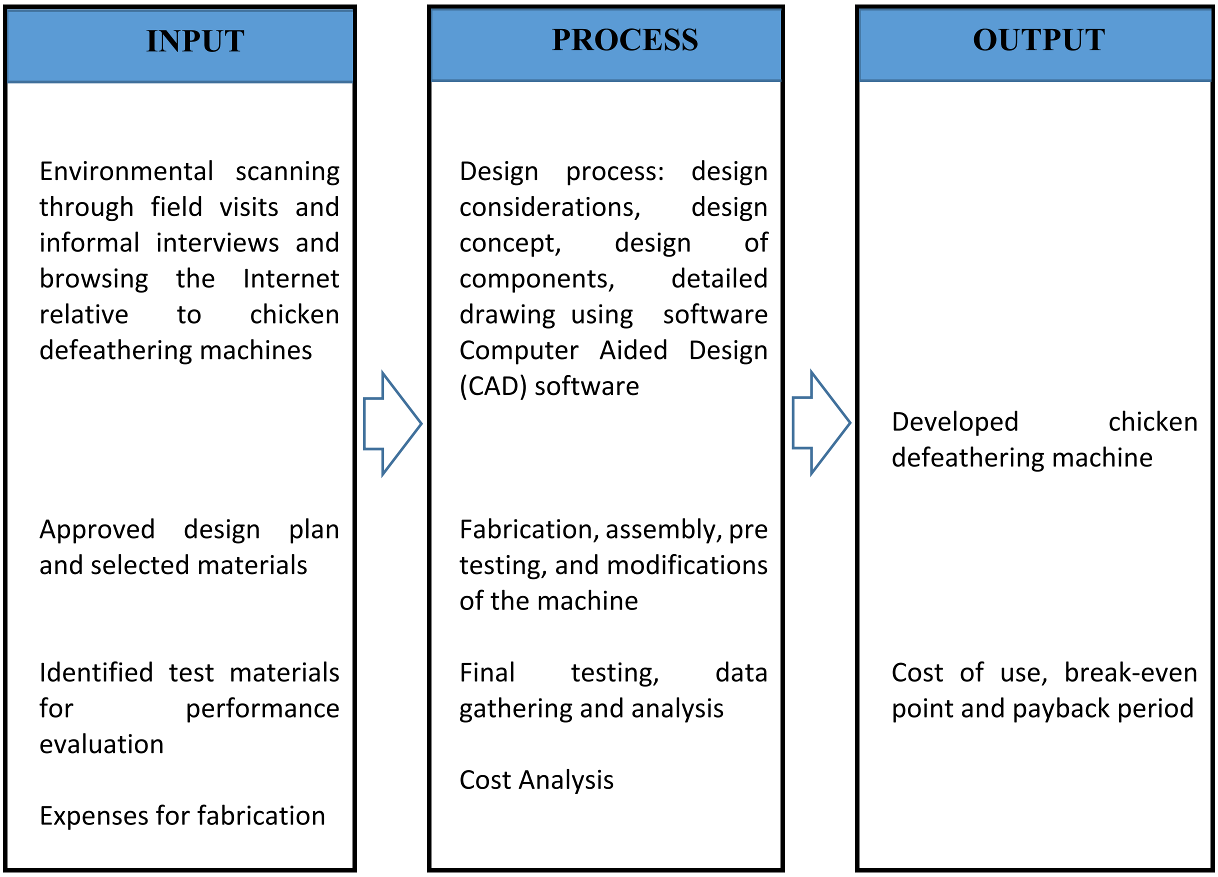

Figure 1. Conceptual framework of the study

<u>Design of the device.</u> In designing the device, design considerations were established based on the identified problems of existing defeathering machines, the design concept follows the principle of operation of vertical or drum type defeathering machines, and the design of the different component parts included the loading and forces acting on the component parts, selection of materials, properties of materials and calculation of sizes of component parts. The design plan was then prepared using the 3D Computer Aided Design (CAD) software.

The design calculations were guided by the equations provided below. The power required to rotate feather plate is given in equation 1. Equation 2 was used to calculate torque required for rotating feather plate.

$$P = \frac{2\pi \times N \times T}{60} \quad (1)$$

Where:P - power required to rotate feather plate, watts
T - torque required for rotating feather plate, N.m
N- rotational speed, rpm

$$T = F_T \times r \quad (2)$$

Where: T - torque required for rotating feather plate, N. mm
F_T - maximum shear force, N
r - radius of feather plate, mm

The diameter and height of the cylindrical plucking chamber was estimated based on a capacity of 10-15 birds per batch. Using the same cylinder diameter (D = 600 mm) as the existing machines, the height of the cylinder was estimated using equation (3):

$$Hc = H_{15} + Fb \quad (3)$$

Where: Hc - height of cylinder, mm
H_{15} - height in the cylinder when 15 scalded chicken was placed, mm
Fb - freeboard allowance, 100 mm

The freeboard allowance provides the expansion space the scalded chickens occupies when machine is in operation. The cylinder was supported by four T-locks equally-spaced along the outer diameter of the cylinder to make it detachable from the frame for easy maintenance and handling. A 20-mm diameter hole, spaced 105 mm horizontally and 85 mm vertically, was drilled in the sheet to hold the rubber pluckers. At this spacing, there are 74 pieces of silicon rubber pluckers with 28 mm fitment and 93.5 mm long installed in the plucking chamber while the feather plate spaced at 85 cm was mounted with 44 pieces of rubber pluckers. Selection of the materials for rubber pluckers were based on the PAES 532:2012. Water system using 20 mm PVC pipe with 8 holes spaced at 210 mm was installed at the inner and top portion of the cylinder supported by two adjustable hooks.Moreover, a 20 mm diameter pvc pipe was riveted inside the drum spaced 25 mm above the feather plate and a dimension of 210 mm high x 310 mm wide was drilled for door opener.

The distance between rubber fingers should be 60 mm to 90 mm from center to center based on PAES 531:2012. The rubber plucking fingers of the developed machine was spaced 103 mm horizontally and 85 mm vertically on its drum and 85 mm at the feather plate. The number of layers of rubber plucking fingers was estimated based on the actual observation of defeathering process of existing machine. The number of layers for rubber plucking fingers mounted on the drum of existing machines was four and spaced ranging 75 mm to 11 mm. The number of rubber pluckers at the drum was calculated using the Equation 5.

$$N_{RPD} = C_D \times N_L S_R \quad (5)$$

Where: NRPD - number of plucking fingers at the drum, pcs
C_D - circumference of the drum, mm
S_R - spacing of the rubber plucking fingers, mm
N_L - number of layers, layers

The rotating defeathering plate causes the movement of the scalded chickens inside the plucking chamber to enable the plucking process. The rotating feathering plate had a diameter of 560 mm and was made of made of non-corrosive materials (stainless steel 304) with a wall thickness of 2 mm. It was drilled by four holes at the center spaced at 6 cm using four hex bolt with a diameter of 10 mm for the hub support of shaft. At the edge of the plate, a stainless round bar with a diameter of 10 mm was welded and likewise 14 cm from the edge was welded by rolled flat bar. The diameter was derived from the clearance of drum and plate which was spaced 2 cm clearance. Rubber pluckers were likewise installed in the 20-mm diameter holes that were drilled 85 mm apart from center along the diameter. A total of 44 rubber pluckers were installed in the rotating defeathering plate. The equation

6 was used to calculate number of rubber pluckers and Equation 7 was used to calculate total number of rubber pluckers at the plucking chamber.

$$N_{RPFP} = C_{FP} \times N_{LFP} S_{RFP} \quad (6)$$

Where: NRPFP - number of plucking fingers at the plate, pcs
C_{FP} - circumference of the drum, mm
S_{RFP} - spacing of the rubber plucking fingers, mm
N_{LFP} - number of layers, layers

$$TP = NRPD + NRPFP \quad (7)$$

Where: TP - total number of plucking fingers at the drum and plate, pcs

At the top of drum chamber, a black plastic water pipe with a diameter of 20mm was installed supported by two hooks. The pipe was surrounded the top of the drum and it was drilled a hole diameter of 3mm spaced at 25 cm. A 25 mm diameter was drilled on the drum for the Tee coupling connected to control valve of and pressure gauge (150 psi) was also installed.

The sheave system comprises of two sheaves. The bigger being driven was mounted on the shaft of feather plate and the smaller sheave was mounted on the electric motor. Center distance was based on the distance between the drive shaft and driven shaft. The diameter of the sheave mounted on the drive was assumed to calculate the size of sheave mounted on driven shaft of feather plate. Equation 8 was used to determine size of sheave mounted on the driven shaft.

$$D_2 = N_1 D_1 N_2 \quad (8)$$

Where: N_1 - rpm of the motor (drive)
N_2 - rpm of the shaft of feather plate (driven)
D_1 - diameter of pulley (drive), mm
D_2 - diameter of pulley (driven), mm

The speed ratio was determined by dividing rotational speed of the drive to rotational speed of the driven. It was calculated using equation 9.

$$SR = N_1 N_2 \quad (9)$$

Where: SR - speed ratio
N_1 - rotational speed of drive, rpm
N_2 - rotational speed of driven, rpm

The Peripheral speed of the belt was determined using equation 10.

$$V = D_1 \times N_1 \, 19100 \quad (10)$$

Where: V - the peripheral speed, m/s
D_1 - diameter of pulley (drive), mm
N_1 - rotational speed of the drive, rpm

Given the diameter of the drive pulley, driven pulley and assumed center distance of the, the length of belt was calculated using equation 11.

$$LB = \frac{\pi}{2}(D1 + D2) + 2C + \frac{(D2-D1)^2}{4C} \quad (11)$$

Where: LB - the length of belt, mm
D_1 - diameter of pulley (drive), mm
D_2 - diameter of pulley (driven), mm
C - center distance, mm

Given the velocity and the diameter of the drive pulley, the power rating was taken from the Table 4 (V belt Manual-Bando) of coefficient of contact, Arc of contact ϴ = 139 degrees andcorrection factor of 0.89. The power rating of the belt and arc of contact was calculated using the equations 12 and 13.

$$Pr = Tr + Pa \quad (12)$$

Where: Pr- power rating, watt/belt
Tr- table rating, watts
Pa- additional power for speed ratio from the Table 4

$$\Theta = \frac{D_1 - D_2}{C} \quad (13)$$

Where: ϴ - arc of contact
C - center distance, mm
D_1 - diameter of pulley (drive), mm
D_2 - diameter of pulley (driven), mm

Corrected Power rating is the product of power rating, service factor, arc of contact correction factor and the belt correction factor. It was 0.92 correction factor of belt and service factor 1.1 was obtained from Table 4 of PAES 301:2000. Corrected power rating was calculated using the equation 14.

$$CP_r = P_r \times S_f \times \Theta_{cf} \times L_f \quad (14)$$

Where: P_r - Power rating of belt, hp
S_f - service factor
Θ_{cf} - arc of contact
L_f - belt length correction factor

The required number of belts was calculated using the equation 15.

$$N_B = \frac{P_D}{S_T} \times S_T \times C_{BL} \times C_{AC} \quad (15)$$

Where: N_B - number of belts, pcs
P_D - design Power, hp
S_T - standard Transmission, hp
S_T - belt length correction factor
C_{BL} - coefficient of belt length
C_{AC} - coefficient of arc of contact

The shaft was used to transmit power from one component to other component with a member like pulley mounted on it. The material used was made of mild steel. Shaft diameter was calculated based on Tordillo PSME CODE (1998). Equations 16, 17, 18, 19, 20, 21 and 22.

$T = P\ 60\ 2\pi N_2$ (16)

$T = (T_t - T_s)$

Where: T - torque, N
P - power transmission, watts
N_2 - driven shaft, rpm
T_t - tight side tension, N mm
T_s - slack side tension, N mm
r - radius of the main shaft pulley, mm

Assume $T_t = 3\ T_s$, therefore,
$T = T_t - T_s$
R

Equation 17 was used to calculate tangential force acting on the feather plate (Ft):

$F_t = T_r$ (17)

Where: F_t - tangential force, N
F_r - radial force, N
r - radius of the plate, mm

The radial force acting on the plate (Fr) and the assumed pressure angle of 20^0 was calculated using equation 18. Figure 2 was used to determine the bending moment and torsional moment using equations 19, 20, 21, 22, and 23.

\ $Fr = Ft \times \tan 20^0$ (18)

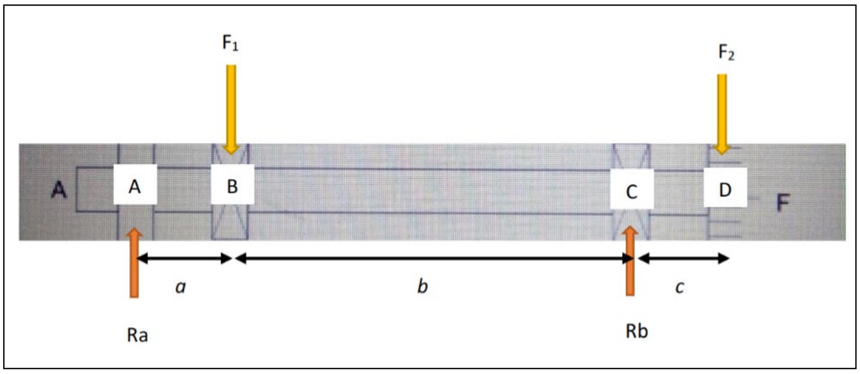

Figure 2. Diagram of forces acting on the shaft

The bending moment in horizontal plane:

Ma: $F_t (a) + F_2 (a + b + c) - Rb (a + b)$ (19)

Mc: $R_a (a + b) + F_2 (c) - Rb (b)$ (20)

The bending moment in vertical plane:

Ma: $F_r (a) + F_2 (a + b + c) - Rb (a + b)$ (21)

Mc: $R_a (a + b) + F_2 (c) - Rb (b)$ (22)

The diameter of shaft (d) is

$d_3 = 16\ \pi\tau\ \sqrt{(Kb\ Mb)2 + (Kt\ Mt)2}$ (23)

Where; d - diameter of shaft, mm
Kb - combined shock and fatigue factor applied to bending moment; kb=1.5
Kt - combined shock and fatigue factor applied to torsional moment; kt=2.0

Mb - bending moment, Nm
Mb - torsional moment, Nm

Required size of key

Knowing the diameter of shaft and the consideration of shearing failure of the key, it was considered length of shaft equal to length of hub. Equation 24 was used to determine the length of hub and equation 25 was used to determine width of hub.

$$l = 1.25\ d \tag{24}$$

Where: l - length of hub, mm
d - diameter of shaft, mm

$$w = \frac{2\ \pi\ d3ძ}{16ძRd} \tag{25}$$

Where: w - width of hub, mm
d - diameter of shaft, mm
ძ - shearing stress, N/m2

The feather collecting chute was consist of basin and chute. It was made of noncorrosive materials (stainless steel 304) with a thickness of 1.4 mm. The basin was 610 mm diameter and the chute has a volume dimensions of 240mm x 350 mm x 400mm. The chute was made of top and bottom layer. The top layer was for feather collector with a hole diameter of 4mm spaced at 11 mm and bottom layer was for water discharged. At the wall of the basin, the 8mm diameter was welded 25mm below the height of the wall as base of the drum. In addition to this, stainless tube with a diameter of 50 mm and 100 mm long was welded at the center of basin enclosing the shaft of plate. However, the slope of the chute connected from basin was faced at the right side of the machine and its slope was made to slide from a higher through which water and feathers pass to the chute and basin.

The slope was calculated using equation given in equation 26

$$\text{Slope} = \frac{\text{rise}}{\text{run}} \tag{26}$$

Where: S - slope, %
rise - difference in elevation between points
run - distance between the points

The frame was made of non-corrosive materials (304 stainless steel tube) with a diameter of 51 mm. Groove type wheel casters with a diameter of 76.2 mm was welded on each post of the frame. The electric motor was mounted on the plate welded at the side of the frame. Casing including the basin and chute was also welded at the frame. The force of the material used against load was calculated using equation 27.

$$F = \frac{A \times \tau}{FS} \tag{27}$$

Where: F - force, N
A - cross sectional area, mm2
τ - tensile strength of the material, N/mm2
FS - factor of safety, 4

Principle of Operation.The defeathering machine was designed to defeather up to 10 heads or 13 kilograms of chicken per batch. To operate the machine, the following steps are undertaken.

1. Preparation of chicken for defeathering
   a. Slaughtering of birds.
   b. Scalding – Dip the birds in the scalding tank with water at scalding temperature of 50-60°C for about 40 to 60 seconds. Test by pulling one of the 6 feathers in the chicken wing and if easily plucked, remove the birds in the scalding tank.
2. Switch on the defeathering machine and the water.
3. Drop the scalded chicken into the cylinder. Defeathering was undertaken by the rubber pluckers as the chicken is rotated by the rotating plate inside the cylinder.
4. Switch off the machine after 15 seconds.
5. Unload the dressed chicken.
6. Clean the machine.

Source of specimens. Preliminary tests were conducted after the fabrication of the machine to test if the different components were functioning properly and to become familiarized with the operational requirements for better performance. As part of the development process, modifications were done on components that were found to be causing low performance until the design targets are met or exceeded. Several test runs were done using broiler chicken of various ages and sizes, and different number of heads loaded per batch as shown on Table 2. During the first test run, efficacy was low since the chicken bones (legs and wings) were broken. It was observed that either the legs or wings were caught between the defeathering rotating plate and plucking chamber. Hence, a 25mm pvc pipe was riveted on the drum located 20 mm above the feather plate to reduce the clearance. After this modification, test run 2 was conducted and target efficiency and efficacy were attained. To establish the number of heads per loading, test runs 3 to 5 were conducted and results indicated that the machine could be operated at 290 and 345 rpm with 10 heads per load.

Table 2. Broiler chicken tested with different number of heads per batch.

TEST RUN NO.	NO. OF HEADS TESTED	AGE OF AVAILABLE CHICKEN (WEEKS)	AVERAGE WEIGHT PER CHICKEN, (KG)	NO. HEAD PER LOAD
1	2	65	1.3	1
	2	65	1.8	1
2	2	65	1.8	1
	2	65	1.8	1
	2	19	1.8	1
3	5	6	1.3	5
	5	6	1.3	5
	5	6	1.3	5
4	10	6	1.3	10
	10	6	1.3	10
	10	6	1.3	10
5	15	6	1.3	15
	15	6	1.3	15

Remarks: Passed- the efficiency and efficacy is above 98 % and 95 %, respectively
Failed – the efficiency and efficacy is below 98% and 95 %, respectively
Machine stopped- feather plate stopped rotating due to heavy load

The instruments and materials used during the evaluation of machine are listed on Table 3.

Table 3. Instrument and materials used during the evaluation.

ITEM	QUANTITY	USAGE/ PURPOSE
Camera	1	Photo and video documentation
Digital timer (range: 60 minutes) Accuracy: 0.1 second	1	Measure specific time of operation
Digital weighing scale: 20 kg capacity and 0.001g accuracy	1	Measuring weight of chicken
Steel tape	1	Measuring dimension of defeathering components
Weighing scale, capacity: 20 kg	1	Measuring weight of defeathering machine
Caliper: 0.05 mm accuracy, 200 mm length	1	Measuring dimension of defeathering components
Tachometer (contact type or photo electric type)range: 0 rpm to 5,000 rpm	1	Measuring rotating components
Digital clamp meter (for electric motor) 60 Hz, 220V	1	Measuring power consumption
Scientific calculator	1	Calculate data
Scalding tank	1	Heating samples
Permanent marker	1	Labeling samples
Thermometer	1	Measuring scalding temperature
Mini sound meter	1	Measuring Sound

Final Testing

The final testing was conducted after the remedial actions on encountered problems during pretesting was accomplished. The machine was finally tested using two rotational speeds of the plate at 290 and 348 rpm as treatments. The following were considered in the evaluation of the device:

1. Poultry Animal. Veterinary health certificate of poultry animals was requested from the poultry growers.
2. Equipment. The equipment like scalding tank with a volume of 109 liters, gas stove burner, LPG tank and poultry crate were used during final testing.
3. Operator. Three labors were hired from the poultry plant in Talavera, Nueva Ecija. The hired labors have skills in handling poultry processing like selection, slaughtering, scalding, defeathering, eviscerating, packaging, and evaluating physical condition of defeathered carcass poultry animals.
4. Tools. Knife was used for slaughter and plastic rope for binding feet of chicken before scalding process. Small size of hammer, socket wrench with bolt diameter of 14mm, 12mm and 10mm and Allen wrench with key size of 10mm were used for removing drive pulley and driven pulley. Also, they are used for the bolts of electric motor.
5. Speed. The rotational speed of the driven pulley such as 290 rpm and 348 rpm was used on the final test.
6. Storage. Disposable silver foil paper plates and plastics for packaging were used after defeathering process.

Fabrication and Assembly of the Machine

The fabrication of the machine was done when the detailed design and drawing showing the different component parts and materials needed including specification was approved. Canvass of locally needed materials was done in Nueva Ecija and Cagayan de Oro City before fabrication. The machine was fabricated in Cagayan de Oro City.

The first component of the machine that was fabricated was the frame. It was first fabricated to determine if it can withstand with load. On the other hand, the frame was carrying all other components. It was then followed by basin and chute that support the drum and plucking chamber which include feather plate and water system was the last component that was made. The fabrication of the drum was made duplicated. The first drum was made of galvanized iron (GI) sheet materials (gauge # 14) with a thickness of 2mm. The drum was used to test the performance of the arrangement of rubber pluckers before fabricating 304 stainless steel material.

The following tools were used in the fabrication: disc cutter, grinding tools, vise grip, clamp, electric drill wrench, hammer, bending machine, machine lathe, arc welding and measuring device.

Data gathered

Defeathering Rate

The defeathering rate of the machine was measured using the equation given in Poultry Defeathering Machine – Methods of Test PAES 532-2012. The defeathering rate is equal to the ratio of the number of poultry animals over the total time (hr) spent by themachine. The defeathering rate of the machine was evaluated using rotational speed 290 rpm and 348 rpm. This was evaluated using the equations 28 and 29.

$$DR = \frac{ND}{Tt} \quad 28)$$

Where: DR - defeathering rate, poultry animals / hr
ND - number of poultry animals defeathered, heads
Tt - total time, hr

$$Tt = Td + Tu \quad (29)$$

Where: Tt - total time, hr
Td - defeathering time, hr
Tu - unloading time, hr

Defeathering Capacity

The defeathering capacity of the machine was measured using the equation 30, but it was multiplied by live weight of poultry animals per head. The defeathering capacity was evaluated at rotational speed 290 rpm and 348 rpm.

$$DC = \frac{ND \times WL}{Tt} \quad (30)$$

Where: DC - defeathering rate, poultry animals / hr
WL- live weigth poultry animals, kg /head
ND - number of poultry animals defeathered, heads
Tt - total time, hr

Defeathering Efficiency

The defeathering efficiency is the ratio of weight of feathers plucked during defeathering and total weight of feathers given in Poultry Defeathering Machine – Methods of Test PAES 532-2012. Equations 31, 32 and 33 were used before calculating defeathering efficiency. Equation 34 was used to calculate efficiency of the machine.

Feather Weight Plucked, g

$$WPF = Wbd - Wad \quad (31)$$

Where: WPF - total weight of feathers plucked during defeathering, g
Wbd - initial weight of poultry animal before defeathering, g
Wad - final weight of poultry animal after machine defeathering, g

Total Feather Weight Unplucked

$$WUF = Wbd - Wamd \quad (32)$$

Where: WUF - total weight of feathers unplucked after machine defeathering, g
Wbd - initial weight of poultry animal before defeathering, g
Wamd - final weight of poultry animal after manual defeathering, g

Total Feather Weight

$$WT = WPF + WUF \quad (33)$$

Where: WT - total weight of feathers, g
WPF - total weight of feathers plucked during defeathering, g
WUF - total weight of feathers unplucked after machine defeathering, g

Defeathering Efficiency

$$Effd = \frac{WPF}{WT} \times 100\% \quad (34)$$

Where: Effd - defeathering efficiency, %
WPF - weight of feathers plucked during defeathering, g
WT - total weight of feathers, g

Defeathering Efficacy

The Defeathering Efficacy is the physical appearances observed on the carcass of chicken. Table 3 based from PAES 532: 2012 Defeathering machine-method of testing was used to determine defeathering efficacy of machine. The defeathering efficacy of the developed machine was evaluated by the workers of Talavera poultry processing plant and MS student major in Animal Science in CLSU.

Power Consumption

The power consumption with and without load of the machine was calculated using equation 35.

$$Pc = V \times I \quad (35)$$

Where: Pc - power consumption, watts
V - voltage, volts
I - current, amperes

Water Consumption

The water consumption of the machine during the defeathering process was calculated using equation 36.

$$Wc = \frac{Wa}{Td} \quad (36)$$

Where: Wc - water consumption, li/hr
Wa - water applied, li
Td - defeathering time, sec

Cost Analysis using the Device

A cost analysis was undertaken to determine the cost of using the defeathering machine. The assumptions were based from the operating characteristics established during machine testing and evaluation. The annual cost of using the defeathering machine included fixed cost and variable cost. The annual cost equation of Hunt (2001) was used in the analysis as follows:

$$AC = FC + \frac{VC \times N}{CS} \quad (37)$$

Where: AC - Annual cost, Php/yr
FC - annual fixed cost, Php/yr
VC- variable cost, Php / hr
N - numbered of defeathered chicken per year, heads
CS - defeathering capacity of the machine, heads / hr

A fixed cost is an expense that does not change as production volume increases or decreases within a relevant range. Fixed cost used in chicken defeathering machine includes costs of depreciation, increases on investment, and tax, shelter and insurance. It was computed using equation 38.

$$FC = D + IOI + TIS \quad (38)$$

Where: FC - annual fixed, Php / yr
D - depreciation, Php / yr
IOI - interest on Investment, %
TIS - tax, Insurance and Shelter, Php / yr

Straight line method of depreciation was used on expected machine useful life of 10 years. The machine useful life was based on Table of Estimated Useful Life of Property, Plant and Equipment given by Commission on Audit (COA) circular. Estimated salvage value is ten percentage of the initial investment cost. It was computed using equation 39.

$$D = \frac{IC + SV}{N} \quad (39)$$

Where: IC - Initial Cost of the defeathering machine, Php
SV - salvage value, Php
N - useful life, yr

Interest on investment was computed using equation 40.

$$I = IC + SV \times i \quad (40)$$

Where: i - loan interest rate, %

About three percent (3%) of the initial investment cost was allotted for tax, shelter and insurance.

Variable cost. This is the cost that varies in relation to the operation of the machine which include costs of electricity, labor, repair and maintenance and water. It was computed using equation 41.

$$VC = LB + EC + WC + R\&M \quad (41)$$

Where: LB - labor cost, Php/hr
EC - Energy Cost, Php/hr
WC - water cost, Php/hr
R&M - repair and maintenance, Php/hr

Labor cost. This was estimated using the daily minimum wage rate.
Repair and maintenance cost. This was estimated ten percent (10%) of the investment cost.

Energy Cost. It was computed as the product of the power consumed of the machine and power rate charged by electrical service providers. This was estimated using the current price of electricity.
Custom Rate. Custom rate is the sum of unit cost of defeathering using the machine and markup percentage.

Unit cost of defeathering. This refers to the defeathering cost per unit weight of chicken using the machine. This was computed by dividing the annual cost (AC) by the expected annual weight of chicken.

Markup percentage. A percentage increase of the unit cost of defeathering in order to earn profit.

Breakeven Point. The break-even point and payback period was computed using equation 42 based from the optimum capacity of the machine at an estimated total hour of operation, cost of the machine and the custom rate of defeathering chicken.

$$BEP = \frac{FC}{CR-(VC/W)} \quad (42)$$

Where: BEP - break-even point, heads /yr
FC - fixed cost, Php / yr
CR - custom rate, Php / head (assumed to be Php 1 / head)
VC - variable Cost, Php / hr
W- defeathering Capacity, heads / hr

Statistical Analysis

Data gathered in this study was analyzed using Statistical Package for the Social Sciences (SPSS) version 21. The treatments used were rotational speed 290 rpm and 348 rpm of the feather plate. Independent Sample T-test was used to determine the differences between the treatment means. Table 4 shows the angular speeds as treatments during the final testing.

Table 4. Angular speed of rotating defeathering plate for the two treatments.

TREATMENT	ANGULAR SPEED OF DEFEATHERING PLATE (rpm)	PULLEY COMBINATION (transmission to system)
T1	290	51 mm to 305 mm
T2	348	51 mm to 254 mm

Results and Discussion

Output design

The chicken defeathering machine was developed using locally available materials and was fabricated adopting manufacturing technology. The major components of the machine include plucking chamber, rotating defeathering plate, water system, feather collecting chute, power and transmission system, and frame. The plucking chamber, rotating defeathering plate, frame and feather collecting chute were made of non-corrosive materials (stainless steel 304).

Plucking Chamber

The plucking chamber was made of non-corrosive materials (stainless steel 304) formed into a cylinder with open ends and equal diameter. Plucking chamber has a diameter of 600 mm and a height of 500 mm and it has placed a water system above on its freeboard. It is mounted with 74 pieces of silicon rubber pluckers with 28 mm fitment and 93.5 mm long and it was made of food grade materials. Figure 3 shows the Plucking chamber of the machine.

Figure 3. Plucking chamber

Rotating Defeathering Plate

The rotating defeathering plate was made of non-corrosive materials (stainless steel 304). This component causes the movement of the scalded chickens inside the plucking chamber to enable the plucking process. The rotating feathering plate has a diameter of 560 mm. It is supported by round bar that is made of stainless steel materials and flat bar under the plate. It is mounted with 44 pieces of silicon rubber pluckers with 28 mm fitment and 93.5 mm long and it was made of food grade materials. It is bolted at the hub of shaft located on its center. Figure 4 shows the rotating defeathering plate of the machine.

Figure 4. Rotating defeathering plate

Water system

The water system was installed at the top of the plucking chamber supported by two hooks. It was made of black plastic water pipe and galvanized iron (GI) coupling pipes. Pressure gauge and control valve was installed at the water system and it gives a discharge rate of 6.7 liters per minute. Figure 5 shows water system of the machine.

Figure 5. Water system

Power Source and Transmission

Prime Mover

The size of electric motor used was 1.1 kilowatts with rated rpm of 1740 and it was hitched at the stainless steel plate supported by hex bolts. The plate was adjustable and its position was vertically facing the ground.

Transmission Assembly

The transmission assembly was used in evaluating the performance of the machine. It was made of two combinations which is used as treatments. The first combination was the double groove pulleys with diameter of 51 mm and 305 mm. It was 275 mm apart (center distance) and B-39 V-belt was used for the transmission. At this combination, the drive pulley was inserted on a shaft diameter of 24 mm whereas the driven pulley was inserted on a shaft diameter of 30 mm. From the rated rpm of electric motor, the driven pulley produced 290 rpm. On the other hand, other combination was the 51mm and 254 mm double groove pulleys using B-35 V belt. This combination produced 348 rpm. Figure 6 shows the prime mover and transmission assembly of the machine.

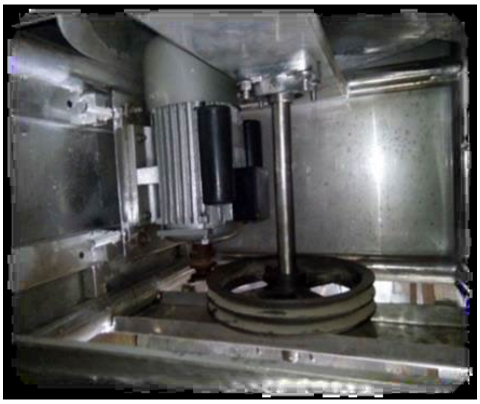

Figure 6. Transmission Assembly

Feather Collecting Chute

The feather collecting chute was consist of basin and chute. It was made of non-corrosive materials (stainless steel 304). At the center of the basin, stainless tube was welded at the center enclosing the shaft of plate and round bar was likewise welded at the wall of the basin which was used as base of the drum. The chute was made of top and bottom layer. The top layer was for feather collector and bottom layer for discharged water. The basin and chute has a total volume of 0.09 m3 and the slope is 30%. Figure 7 shows the feather collecting chute of the machine.

Figure 7. Feather Collecting Chute

Frame

The frame was made of non corrosive materials (304 stainless steel tube). Groove type wheel casters was welded on each post of the frame. The electric motor was mounted on the plate welded at the side of the frame. Casing including the basin and chute were also welded at the frame. The frame can withstand a load of 225 kilonewton (kN). Figure 8 shows frame assembly and casing of the machine.

Figure 8. Frame assembly and casing of the machine

In figure 9 it shows the fabricated chicken defeathering machine and in Table 5 and 6 show the detailed specification and pros and cons of the machine.

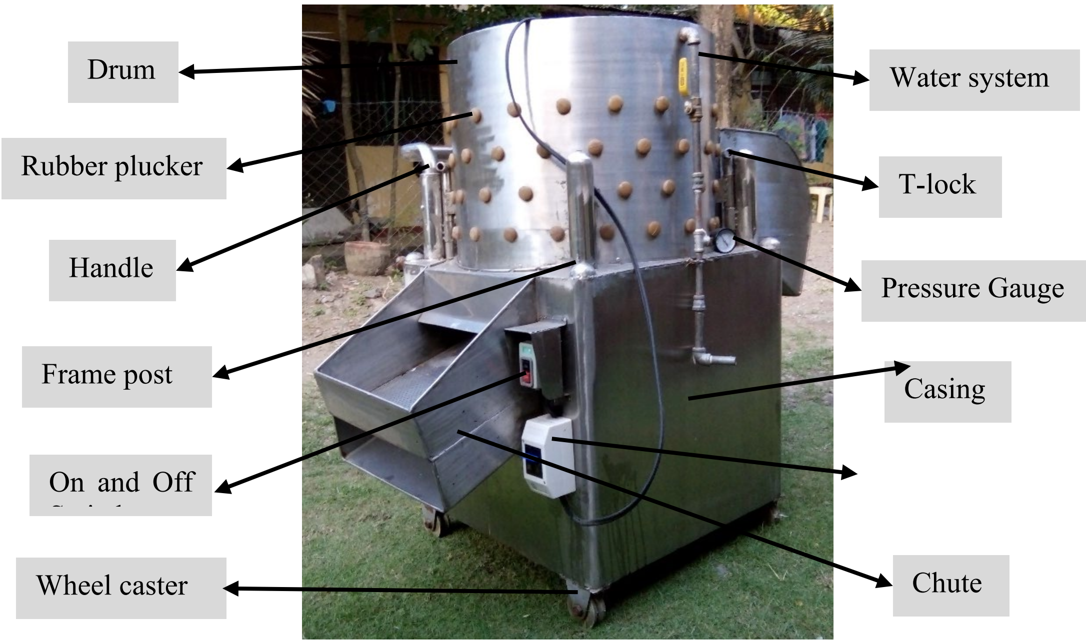

Figure 9. Fabricated Chicken Defeathering Machine

Table 5. Specification of the defeathering machine.

COMPONENTS		SPECIFICATION
Machineoverall dimension		
	length, mm	1250 mm
	width, mm	650 mm
	Height, mm	1160 mm
	Weight, mm	95 kg
Prime Mover		
	Brand	Super Power Mindong
	Model	YC 90L-4
	Type	Single Phase Induction Motor Full Copper Winding
	Rated Power	1100 watts
	Volts	220 volts
	Rated Speed	1740 rpm
Transmission system		
	Electric Motor to the Main Shaft the main shaft	V-belt and Pulley
Transmission Accessories	Drive and driven Pulley	50.8 mm Ø and 254 mm Ø Double groove pulley
	Shaft diameter	30 mm
	Belt	B-35 V-belt
Plucking Chamber		
	Material	304 Stainless Sheet (3 mm thick)
	Diameter	600 mm
	Height	500 mm
Ring	PVC pipe	25mm Ø
Rubber Plucker		
	Type	Fine pluckers (for chicken)
	Size	28 mm fitment x 93.5 mm finger length
	Material	Silicon
Handle	Material	Stainless Tube 21.3 mm Ø, Sch. 5
Water system	PVC pipe	20mm Ø x 2000 mm
Body Frame	Material	Stainless Tube 51mm Ø, Sch. 10
Wheel Caster		
	Diameter	76.2 mm roller wheel
	Type	Single Groove caster
Machine Performance Parameters		
	Capacity, heads per hour	800
	Efficiency, %	99.01
	Power Consumption, watts	1796. 67
	Noise Level, dB	86.10

Table 6. Pros and cons of the designed chicken defeathering chicken.

ADVANTAGE	LIMITATIONS
Made of stainless materials	Limited to 10 heads of chicken per batch at angular speed of 348 rpm
Mounted with silicone rubber pluckers	Requires standard scalding temperature of chicken
Easily transport and maintenance	
Fast feather removal	
Fast unloading of dressed chicken	
Separate water from feathers	
Less water consumption	

Fabricated Defeathering Machine

The actual fabricated design of the chicken defeathering machine and some of the actual fabrication process is shown in Figure 10.

Figure 10. Construction of chicken defeathering machine

Performance Characteristics of the Machine

Data gathered in this study was analyzed using Statistical Package for the Social Sciences (SPSS) version 21. The treatments used were rotational speed 290 rpm and 348 rpm of the feather plate. Independent Sample T-test was used to determine the differences between the treatment means. Table 7 shows the data gathered for the final testing and Table 8 for the angular speeds as treatments during the final testing.

Table 7. Data Gathered for Final Testing.

Treatment	Rep	Scalding Temp	Scalding Time	Initial Weight	Final Weight	Unplucked Weight	Speed with load	Power Consumption with load	DefeatheringTime
T_1	R_1	59.70	50.7	1290	1190	1.21	295	1518.00	45
290	R_2	62.50	46.3	1264	1160	1.24	294	1544.40	45
rpm	R_3	59.85	42.8	1268	1190	1.19	290	1576.67	45
T_2	R_1	62.21	43.1	1280	1170	1.22	326	1793.00	45
348	R_2	60.76	50.9	1269	1150	1.25	332	1782.00	45
rpm	R_3	61.55	46.1	1275	1190	1.27	325	1815.00	45

Table 8. Angular speeds of rotating defeathering plate.

	Angular speed of defeathering plate	Pulley Combination
Treatment		
T_1	290	51mm to 305mm
T_2	348	51mm to 254mm

Defeathering rate, capacity and water consumption

The defeathering rate, capacity and water consumption of the machine at defeathering time of 15 seconds found that both the angular speed at 290 rpm and 348 rpm can process 800 heads per hour or 1019 kg per hour and water consumption of 403.2 liters per hour, respectively.

Defeathering efficiency and efficacy

Table 9 presented the results of the defeathering efficiency where it indicated that the machine has 98.71 percent and 99.01% percent efficiency at 290 and 348 rpm of the defeathering plate, respectively. It is apparent that the higher defeathering efficiency was recorded at higher plate speed. Evidently, the t-test analysis shown on Appendix Table 8 indicated non significant difference between two treatment means. On the other hand, the defeathering efficacy referred to the physical appearance of defeathered chicken using Table 4. Results of the defeathering efficacy indicated that the machine has 95.50 percent and 95.83 percent efficacy at 290 and 348 rpm of the defeathering plate, respectively. It is apparent that the higher defeathering efficacy was recorded at higher plate speed. Evidently, the t-test analysis shown on Table 10 indicated non significant difference between two treatment means.

Table 9. Defeathering efficiency and efficacy as affected by angular speed 290 rpm and 348 rpm of feather plate.

TREATMENT	EFFICIENCY	EFFICACY
290 rpm	98.71	95.50
348 rpm	99.01	95.83

Table 10. T-Test Comparison of Defeathering Efficacy as Affected by Angular Speed 290 rpm and 348 rpm.

	T1 12" and 2" 290rpm	T2 10" and 2" 348rpm	t-value -0.459	p-value ^{ns}0. 670
Mean	95.50	95.83		
Standard Deviation	1.0	0.76		

Legend: ns = non significant at 0.05 level of significance

Power Consumption

The power consumption referred to the power consumed during defeathering process. Table 11 presented the results of the power consumption where it indicated that the machine has 1546. 36 and 1796. 67 watts at 290 and 348 rpm of the defeathering plate, respectively. It is apparent that the higher power consumption was recorded at higher plate speed. Evidently, the t-test analysis shown on Table 12 indicated highly significant difference between two treatment means.

Table 11. Power consumption as affected by angular speed 290 rpm and 348 rpm of feather plate.

TREATMENT	POWER CONSUMPTION
	watts
290 rpm	1546. 36
348 rpm	1796. 67

Table 12. T-Test Comparison of Power Consumption with Load as Affected by Angular Speed 290 rpm and 348 rpm.

	T1 12" and 2" 290rpm	T2 10" and 2" 348rpm	t-value -12.808	p-value **0. 000
Mean	1546.36	1796.67		
Standard Deviation	29.38	16.80		

Legend: ** = highly significant at 0.05 level of significance

Cost Analysis

The cost analysis was tackled to evaluate the benefit that a consumer may obtained by using the developed chicken defeathering machine. The machine was evaluated using the break even area per annum to remunerate operation cost and payback period to recover the acquisition cost. The assumptions were based from the operating characteristics established during machine testing and evaluation. Table 13 shows the operating costs of the machine and assumptions.

Table 13. Operating costs of the machine and assumptions.

PARTICULARS	DEFEATHERING MACHINE
Purchase Price (P)	39,700.00
Salvage value (%)	10.00
n, years	5.00
Power Cost, P/kw-hr	10.56
Power consumption, kw-hr/hr	1.80
R&M, % P/100 hr	2.00
rate of interest, %	20.00
TIS, %	4.00
Labor cost, P/day	300.00
Annual Hours, hr/year	
Capacity, head/hr	800.000
A. Fixed Cost Items	
Depreciation	7,146.00
Int on Inv	4,367.00
TIS	1,588.00
Total Annual FC,P/yr	13,101.00
B. Variable Costs	
Power Cost	19.01
R & M	7.94
Labor	37.50
Total VC, P/hr	64.45

Based on the computed capacity of the machine, variable cost and assumed utilization of the machine, the computed defeathering cost of the machine is Php 0.08 per head. Considering a custom rate of Php 5 per head of chicken, the computed break-even point is 2663 heads per year. Hence, defeathering process using the machine in more than 2663 heads per year justifies ownership of the machine. The owner also may engage in custom service operation for additional income or profit. Figure 24 shows the cost curve of the machine.

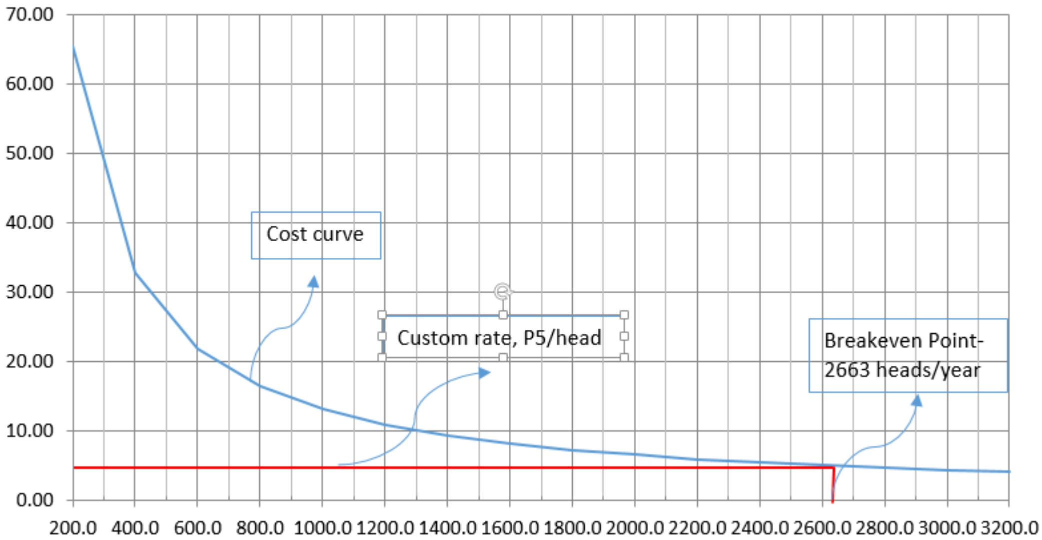

Figure 11. Break-even point using the chicken defeathering machine

Further cost analysis yielded an expected income of Php 944, 532 per year and a payback period of 15 days for the defeathering cost.

Conclusion

Defeathering process of poultry animals is one of the difficult stages in poultry processing. It is the fast way in removing feathers of scalded chicken. It takes an hour for a large number of birds when done manually.

The developed chicken defeathering machine offered several advantages over existing defeathering machines of similar principle of operation. The machine has met the required standard defeathering efficiency and efficacy. This machine can provide opportunities for small scale poultry growers to venture into selling dressed chicken in order to increase their farm gate prices, as composed to live chicken, hence, realizing some income from their products. This machine is therefore the best way to increase production of poultry meat. The performance parameters of the machine adds to knowledge that can be shared with students, researchers, professors, and other stakeholders.

Extensive environmental scanning relative to the defeathering process was done to finalize the design concept, design considerations, and the needed design specification based on the prospective users of the machine. The design plan was drawn using 3D computer aided design (CAD) software. Fabrication of the machine was done in a local machine shop and it was guided using the approved design drawings and with the supervision of the researcher.

The device was designed and fabricated using locally available materials. The overall dimension of defeathering machine is 1250 mm x 1160 mm x 650 mm and has a 73 weight of 95 kg. The major components of the machine include plucking chamber, rotating defeathering plate, water system, feather collecting chute, power and transmission system, and frame.

The working performance of the machine was evaluated using two angular speeds, 290 rpm and 348 rpm as treatments. Each of the treatments was replicated three times and it was analyzed using independent sample t-test of Statistical Package for the Social Sciences (SPSS) software version 21.

The machine has the capacity of 800 heads per hour and it consumes 403 liters of water per hour.

The performance of the machine revealed that the angular speed 348 rpm gave the highest defeathering efficiency of 99.01 percent and defeathering efficacy of 95.85 percent. Independent sample t-test of defeathering efficiency and efficacy were found to be not significantly different as affected by different angular speed. This can be attributed to the fact that the angular speed of the feather plate was set at a speed of 348 rpm.

The cost analysis using on defeathering machine indicated a break-even point of 2663 heads per year based on the defeathering machine cost of Php 39,656.5 (covering materials and labor cost), machine capacity of 800 heads per hour and manual labor cost of Php 300 per day. Using the machine in more than 15 days justifies the ownership of the machine. Moreover, the owner may also engage in custom service to gain additional profit. The cost analysis also indicated an expected income of Php 944, 532 per year and a payback period of 15 days for the machine cost.

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