Performance evaluation of a de-feathering machine with scalding tank

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Abstract: This study evaluated a de-feathering machine with scalding tank. The machine was evaluated in terms of machine plucking time, machine capacity and machine efficiency. A 3×3×3 completely randomized experimental design was carried out using three poultry birds (broiler, cockerel and layer) and three scalding temperatures (60ºC, 70ºC and 80ºC) at machine constant speed of 7.54 m s^{-1} and at three replicates. The average machine capacities were 175, 179 and 159 birds hr^{-1} for broiler, layer and cockerel birds respectively while the average machine efficiencies were 95%, 93% and 90% for broiler, layer and cockerel birds respectively. The machine plucking time reduced from 28 s to 19 s with an increase in scalding temperature from 60ºC to 80ºC for the different poultry breeds. The highest machine efficiency obtained were 96%, 94% and 95% for broiler, layer and cockerel birds respectively at 70ºC temperature. The machine capacity increased from 131 to 197 birds hr^{-1} with an increase in temperature from 60ºC to 80ºC for the different poultry breeds. The optimum machine capacity was obtained at 80ºC with values 194, 197 and 180 birds hr^{-1} for broiler, layer and cockerel birds respectively. The machine was able to de-feather two smaller birds but performed better with one bird at a time.

Keywords: de-feathering, scalding temperature, plucking time, efficiency and capacity.

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1 Introduction

The growing health concerns due to the consumption of smuggled poultry products have led to a ban on importation of frozen poultry especially turkey and chicken smuggled through illegal routes (National Agency for Food and Drug Administration and Control, 2015). The import prohibition list prepared by the Federal Government of Nigeria in line with its fiscal policies, frozen poultry product is one of the items included in the list (Nigeria Custom Service [NCS], 2013). The Poultry Association of

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Nigeria (2016) reported that "this ban has led to a 20% increase in Nigerian bird poultry production in the last one year boosting farmers earning and creating more job opportunities in the Nigerian industries". It was predicted that between 2012 and 2015, there would be an increase of about 23% growth in the poultry industry due to the rising standards of living and increase in population by Nigeria Agribusiness Report in its 3rd quarter 2011 edition (2011).

Adetola et al. (2012) reported that "an economical practice of mechanized poultry processing plant is widely accepted to replace manual removal of feathers by hand for poultry meat production thereby increasing the number of daily processed poultry meat. The use of de-feathering machine saves time, easy to operate and better plucking is achieved (Ogundipe, 2002). The average time of 5 minutes for a manual de-feathering a poultry bird according to David (1999), takes about 40 – 50 seconds to process by de-feathering machine. The use of de-feathering machine has contributed immensely to the number of productions of processed and hygienic chicken for consumption on both small and large scales.

Feathers of poultry bird carcass are defeathered mechanically after the feathers have been loosened by scalding (Arnold, 2007). According to Van Hung et al. (2011), the most important operations of the poultry processing are scalding and de-feathering because of their significance effect on the product quality and shelf life. The poultry bird will be scalded after slaughtering for de-feathering which the efficiency of feather removal is closely related with the scalding operation (Arnold, 2007).

Therefore, this paper was aimed at evaluating the performance of a developed de-feathering machine with scalding tank to encourage local small scale farmers to increase production.

2 Material and methods

The components of the de-feathering machine are electric motor (2 HP), de-feathering drum (0.06284 m^3), rubber fingers, solid shaft (20 mm), heating element (P = 5.87 kW hr), thermometer, scalding tank (0.06284 m^3), water valve, and water source.

The materials used for the performance evaluation of the de-feathering machine with scalding tank are as follows: de-feathering machine with scalding tank, twenty seven (27) live poultry birds consisting of nine (9) each broiler, cockerel and layer birds, thermometer and temperature regulator.

2.1 Experimental procedure

2.1.1 Sample preparation

The birds were sourced from Kuto Market in Abeokuta which is located approximately on latitude 7.1373° N and longitude 3.3515° E, Ogun State, Nigeria. The testing and the performance evaluation of de-feathering machine were carried out at the Central Workshop of the College of Engineering, Federal University of Agriculture Abeokuta which is located approximately on latitude 7.2297° N and longitude 3.4392° E, Ogun State, Nigeria.

After the arrival of the poultry birds, they were allowed to rest for a period of an hour to ease out the stress due to transportation.

The live weights of the birds were measured prior to slaughtering. The dead weight was measured using digital scale and the blood was allowed to drain completely to avoid contamination of scalding water.

2.1.2 Experimental design

A $3\times3\times3$ Completely Randomized Design (CRD) was used with three (3) replicates of three (3) varieties of poultry birds (Broiler, Cockerel and Layers) and three levels of temperature (60°C, 70°C and 80°C).

Data obtained for the three varieties of poultry bird breeds at three levels of scalding temperature were analyzed using the analysis of variance (ANOVA) of Statistical Package for Social Science (IBM SPSS 23), statistical software at 5% significant level. Separation of means of values was done by the use of Least Significance Difference method.

The correlation between scalding time and machine plucking time was determined by using Pearson Correlation Coefficient.

2.1.3 Testing procedure

The birds were mounted on the scalding tank with the use of a dunker/chicken hanger attached to a wheel and axle system used to lower the chicken in and out of the scalding tank where scalding took place at different scalding temperatures of 60°C, 70°C and 80°C. The temperature was measured with the use of thermometer whose range is from 0℃ to 100℃ and regulated using a thermostat. The wheel and axle was swung up and down to ruffle the feathers to allow heat to reach the feather follicles under the skin.

After scalding, de-feathering operation, which is the removal of feather from the skin of bird, was carried out at 7.54 m s^{-1} machine speed immediately. The chickens were lowered into the de-feathering chamber where the rubber fingers remove the feathers. The removed feathers were collected from the feather outlet and the processed chicken was taken out. Figure 1 shows the fabricated de-feathering machine with scalding tank.

Note: 1.Finger; 2.Electric motor (2 HP); 3.De-feathering drum (0.06284 m^3); 4. Feather outlet; 5.Handle; 6.Wheel and axle; 7.Wire; 8.Scalding tank (0.06284 m3); 9.Frame; 10.Immersion heater (5.87 kw)

Figure 1 The fabricated de-feathering machinewith scalding tank

The performance evaluation of the machine was carried out by using three type of poultry birds (broiler, cockerel and layer) and three scalding temperatures (60°C, 70°C and 80°C) at machine constant speed of 7.54 m s^{-1} and at three replicates. The parameters measured were live weight (kg), dead weight (kg), scalding time (s), machine plucking time (s), weight after plucking (kg), feather weight plucked by machine (kg), feather weight plucked by hand (kg) and hand plucking time (s). The performance indices were carried out using Equations 1 and 2.

$$Defeathering\ efficiency, e_m = \frac{W_m}{W_m + W_h} \qquad (1)$$

Where; e_m = machine efficiency;

W_m = feather mass plucked by machine, kg;

W_h = feather mass plucked by hand, kg.

$$Defeathering\ capacity, M_c = \frac{3600_m}{M_t} \qquad (2)$$

Where; M_c = machine capacity, birds hr^{-1};

$$M_t = machine\ plucking\ time, s$$

3 Results and discussion

Table 1 shows the average values of measured parameters at a machine speed of 7.54 m s^{-1} and at different scalding temperature for the poultry birds. The measured parameters are shown in Table 1 which are the feather weight plucked by machine, feather weight plucked by hand and machine plucking time.

They are parameters required to compute machine efficiency and machine capacity using Equation 1 and Equation 2 respectively. At scalding temperature 60ºC and 80ºC, the machine plucking time for broilers and layers were the same but less than the machine plucking time for cockerel. At scalding temperature 70ºC, the machine plucking time for broiler and cockerel were the same but higher than the machine plucking time for layer. The machine plucking time for the three scalding temperatures were very close to each other. The time variation in machine plucking time for the three poultry birds could have been the differences in their age, stress, toughness of skin, fasting period before killing and the nature of feather. The mass of the feather plucked by machine was highest for broiler, followed by cockerel and least for layer at any scalding temperature used. The difference in the mass of the feather plucked by hand for the three poultry birds at any scalding temperature used is infinitesimal.

Table 1 Average values of measured parameters at a machine speed 480 rpm and at different scalding temperature for the poultry birds

Scalding temperature (ºC)	Poultry bird breeds	Live mass (kg)	Dead mass (kg)	Scalding time (s)	Machine plucking time (s)	Mass after plucking (kg)	Feather mass plucked by machine (kg)	Feather mass plucked by hand (kg)	Hand plucking time (s)
60	B	1.63	1.58	133	22	1.40	0.23	0.02	75
	L	1.27	1.22	113	22	1.13	0.13	0.01	63
	C	1.65	1.60	113	28	1.38	0.16	0.02	66
70	B	1.80	1.70	23	22	1.50	0.30	0.01	22
	L	1.37	1.28	23	21	1.20	0.17	0.01	23
	C	1.42	1.33	21	22	1.13	0.28	0.02	20
80	B	1.60	1.55	18	19	1.40	0.20	0.01	16
	L	1.20	1.23	17	19	1.05	0.13	0.01	18
	C	1.63	1.58	20	20	1.40	0.23	0.02	20

Note: Where B = Broiler, L = layers and C = Cockerel

Table 2 shows the average values of performance indices of the machine at different scalding temperature for poultry bird breeds and at machine speed 480 rpm. It is shown that the machine capacity (birds hr^{-1}) across the scalding temperature increases from 60ºC to 80ºC for the three poultry birds. The machine de-feathering capacity (birds hr^{-1}) was highest for layer, followed by broiler and least for cockerel. The machine capacity is inversely proportional to the machine plucking time which means that the machine capacity increases as the machine plucking time decreases and vice visa. Therefore, the difference in the machine capacities of the poultry birds is as a result of the variation in machine plucking time of the poultry birds. The machine efficiency obtained for the machine is just slightly different from each other for the poultry birds at different temperature. The machine efficiency was highest for broiler, followed by layer and least for cockerel. The machine efficiency increases from 60ºC to 70ºC and then decreases from 70ºC to 80ºC scalding temperature. Nevertheless, the highest machine efficiency was obtained at 70ºC scalding temperature for the poultry birds used. The machine efficiency was affected by the mass of the feather plucked by machine and mass of the feather plucked by hand. The mass of the feather plucked by machine was highest at 70ºC scalding temperature for any poultry birds used. More so, the weight of broiler's feather plucked by machine was the highest, followed by cockerel's feather and least for layer's feather. This means that breed of poultry birds affects the weight of such poultry bird feathers.

Table 2 Average values of performance indices of the machine at different temperature for poultry bird breeds.

Poultry bird breeds	Temperature						Average machine capacity (birds hr^{-1})	Average machine efficiency (%)
	60ºC		70ºC		80ºC			
	Machine capacity (birds hr^{-1})	Machine Efficiency (%)	Machine capacity (birds hr^{-1})	Machine Efficiency (%)	Machine capacity (birds hr^{-1})	Machine Efficiency (%)		
Broiler	165	94	167	96	194	94	175	95
Layer	167	90	174	94	197	94	179	93
Cockerel	131	81	166	95	180	93	159	90
Average	154	88	169	95	190	94		

Table 3 shows the analysis of Variance for machine capacity using the independent variables (poultry bird breeds and scalding temperature). Scalding temperature had significant effect at $p<0.05$ on the machine capacity (Column 6). This means that the number of birds processed per any given time will depend on the scalding temperature of the water. Also, the poultry bird breeds had significant effect at $p<0.05$ on the machine capacity (Column 6). This means that the type of poultry birds will also affect the number of poultry birds processed in a given time. The interaction of the type of poultry bird and scalding temperature had no significant effect at $p\geq0.05$ on the machine capacity of the de-feathering machine (Column 6). This means that there is no influence of type of poultry bird as affected by the scalding temperature on the number of poultry birds processed in a given time.

Table 3 Analysis of variance for machine capacity (Birds hr^{-1})

Source of Variation	Df	SS	MS	F	P-value	F crit
Scalding temperature	2	6276.07	3138.04	7.17	0.01	3.55
Poultry bird breed	2	3472.52	1736.26	3.97	0.04	3.55
Interaction	4	433.04	108.26	0.25	0.91	2.93
Error	18	7878.00	437.67			
Total	26	18059.63				

Table 4 shows the analysis of variance for machine efficiency using the independent variables (poultry bird breeds and scalding temperature). Scalding temperature had significant effect at $p<0.05$ on the machine efficiency (Column 6). This means that the machine efficiency will be different for at least at two different scalding temperatures. Also, the poultry bird breeds had no significant effect at $p\geq0.05$ on the machine efficiency. This means that the machine efficiency is likely to be the same for any poultry bird for the de-feathering machine. The interaction of scalding temperature with poultry bird breeds had no significant effect at $p\geq0.05$ on the machine efficiency (Column 6). This means that the influence of poultry bird breeds as affected by scalding temperature has no significant effect on the machine efficiency.

Table 4 Analysis of variance for machine efficiency

Source of Variation	SS	Df	MS	F	P-value	F crit
Scalding temperature	218.74	2	109.37	7.38	0.00	3.55
Poultry bird breeds	102.74	2	51.37	3.47	0.05	3.55
Interaction	159.48	4	39.87	2.69	0.06	2.93
Error	266.67	18	14.81			
Total	747.63	26				

Table 5 shows the summary of separation of means for machine capacity, machine efficiency, scalding time and machine plucking time. The means of machine capacity for broiler and layer are not significantly different from each other but they are significantly different from the mean of machine capacity for cockerel (Column 3). This means that the number of poultry birds that will be processed in a given time may likely be the same for broiler and layer but will be different for cockerel. The means of machine capacity for 60ºC and 70ºC are not significantly different from each other but they are significantly different from the mean of machine capacity for 80ºC. This means that the number of poultry birds that will be processed in a given time may likely be the same for scalding temperature at 60°C and 70°C but will be different for scalding temperature at 80°C.

In Table 5, the means of machine efficiency for the three poultry birds used are not significantly different from each other (Column 4). The means of the machine efficiency at 70°C and 80°C scalding temperatures are not significantly different from each other but they are significantly different from the means of machine efficiency at 60°C scalding temperature (Column 4). This means that the scalding temperatures higher than 60°C may likely have the same machine efficiency.

Table 5 Summary of separation of means by least significant difference (LSD) for machine capacity, machine efficiency, scalding time and machine plucking time

Independent variable	Level of factor	Dependent variable	
		Machine capacity (Birds hr^{-1})	Machine efficiency (%)
Poultry bird breeds	Broiler	175.11[a]	94.33[a]
	Layer	179.33[a]	92.89[a]
	Cockerel	153.44[b]	89.67[a]
Scalding temperature (°C)	60	154.33[a]	88.33[a]
	70	163.33[a]	94.89[b]
	80	190.22[b]	93.67[b]

Note: Means with different letters are significant but means with the same letter are insignificant at 0.05

Table 6 shows the correlation between scalding time and machine plucking time. This is to show the relationship between the two parameters. In Table 6, the Pearson Correlation Coefficient between scalding time and machine plucking time is 0.500 which shows strong relationship between the two parameters at 0.01 level. This means that the two parameters depend on each other. A decrease or an increase in one will lead to a decrease or an increase in another respectively.

David (1999) said that "it takes an average time of 5 minutes and 40-50 seconds for manual and machine processing to de-feather a bird respectively." The machine plucking time for the poultry bird breeds used ranged from 22 - 28 s, 21 – 22 s and 19 - 20 s at 60°C, 70°C and 80°C respectively. The machine plucking time for the de-feathering machine tested was lower than the one given by David (1999) indicating better plucking performance. Adesyinka and Olukunle (2015) carried out evaluation on a developed de-feathering machine at 60°C scalding temperature and at 0.22 ms^{-1} machine speed using unknown breed of poultry bird. The machine capacity and the machine efficiency obtained were 1 bird per 25 seconds (144 birds per hour) and 95% respectively. The machine capacity of the machine tested was higher as compared with the machine evaluated by Adesyinka and Olukunle (2015) while the machine efficiency was slightly lower.

Abubakar et al. (2018) also tested a modified de-feathering machine. The de-feathering efficiency was found to be 95.65% at unknown speed and unknown scalding temperature. The de-feathering efficiency was slightly higher than the de-feathering machine tested.

Adefuye et al. (2021) evaluated poultry bird de-feathering machine using three poultry birds (broiler, layer and cockerel). The machine de-feathered broiler chicken of mass 1.8 kg, layer chicken of mass 2.0 kg and cockerel chicken of mass 3.0 kg in 22 s, 28 s and 50 s respectively. The efficiency of the machine was computed to be 80.1%, 82% and 83.3% for broiler, layer and cockerel respectively. The machine plucking time for the de-feathering machine tested was lower than the one tested by Adefuye et al. (2021). Also, the machine efficiency of the machine tested was higher than the one tested by Adefuye et al. (2021). The machine tested was of better performance as compared with the other de-feathering machine mentioned.

Adenigba et al. (2022) tested the fabricated machine at three operating speeds of 200 rpm, 280 rpm and 360 rpm and at five scalding temperatures which were room temperature (25°C – 26°C), 30°C, 50ºC, 70ºC and 100ºC. It was established that “feather retention rate and defeathering time decreased with an increase in operating speed, while plucking efficiency increased with speed”. An analysis of variance (ANOVA) was carried out on the data collected. It was showed that the defeathering speeds had no significant effect while scalding temperature had significant effect on the evaluation parameters. The feather retention and de-feathering time decreased with an increase in scalding temperature. The results obtained by Adenigba et al. (2022) were in-lines with the de-feathering machine tested.

Table 6 Correlation between scalding time and machine plucking time

		Scalding time	Machine plucking time
Scalding time	Pearson correlation	1	0.500**
	Sig. (2 tailed)		0.08
	N	27	27
Machine plucking time	Pearson correlation	0.500**	1
	Sig. (2 tailed)	0.08	
	N	27	27

Note: **correlation is significant at the 0.01 level (2 tailed)

4 Conclusion

The poultry bird breeds had significant effect on the machine capacity but not on the machine efficiency. The highest machine capacity was obtained for layer at any scalding temperature than other breeds while the highest machine efficiency was obtained for broiler at any scalding temperature than other breeds. The scalding temperature had significant effect on the machine capacity and machine efficiency of the machine. The highest machine capacity was obtained at 80ºC for any poultry bird breeds used while the highest machine efficiency was obtained at 70ºC for any poultry bird breeds used. The fastest machine plucking time was obtained at 80ºC for layers and broilers poultry birds. The de-feathering of all the poultry breeds were effectively achieved by the machine with no visible damage to the skin of the birds and therefore the market value is preserved in terms of skin quality which makes it suitable for use in industrial poultry processing plants.

References

Abubakar, M. S, A. S. Muhammed, and A. O. Salihu. 2018. Evaluation of a modified chicken de-feathering machine. *Nigerian Journal of Engineering Science and Technology Research*, 4(1): 1 - 7.

Adefuye, O. A, K. A. Adedeji, L. O. Fadipe, Z. M. Arowoka, O. A. Mohammed. 2021. Design, fabrication and performance evaluation of chicken de-feathering machine. *International Journal of Research and Review*, 8(12): 703-711. DOI: https://doi.org/10.52403/ijrr.20211285

Adenigba, A. A, A. A. Adedeji and A. C. Aboloje. 2022. Design, fabrication and performance evaluation of a three-phase poultry bird de-feathering machine. *Iconic Research and Engineering Journals,* 5(10): 268 – 277.

Adetola, S. O., A. S. Onawumi, and E. B. Lucas. 2012. Investigation into mechanized de-feathering process and optimal scalding temperature of exotic and local birds in southwestern Nigeria. *Transnational Journal of Science and Technology*, 2(3): 87-96.

Adeyinka, A. A, and O. J. Olukunle. 2015. Development and performance evaluation of a chicken de-feathering machine for small scale farmers. *Journal of Advanced Agricultural Technologies,* 2(1): 71 – 74.

Arnold, J. W. 2007. Bacterial contamination on rubber picker fingers before, during and after processing. *Poultry Science*, 86(12): 2671-2765.

David, R. A. 1999. You can build your mechanical plucker. (whizbang). http//www.FAO.org. Accessed 28 06 2021.

National Agency for Food and Drug Administration and Control. 2015. NAFDAC warns against consumption of imported chicken, turkey. Available: The Guardian publication of June 2015. Accessed 28 06 2021.

Nigeria Agribusiness Report. 2011. 3rd Quarter, ‘research and markets: The forecasts for meat production remain unchanged.’ *Transnational Journal of Science and Technology,* April 2012 edition vol. 2, No.3. Accessed 28 06 2021

Nigeria Custom Service (NCS). 2013. ‘Import Prohibition

List' 02 05 2013. Accessed 28 06 2021.

Ogundipe, S. O. 2002. Nigerian Journal of Animal Production Farm Mechanization Section. *Animal Production Association of Nigeria*, 23: 102-103.

Poultry Association of Nigeria. 2016. Tagged: "Role of poultry industry in economic revival of Nigeria''. Available at: http://www.busineesday.ng/agriculture/article/poultry. Accessed 12 05 2023.

Van Hung, N., D. H. Minh, and D. T. Son. 2011. An investigation of optimized operational parameters for a chicken slaughtering system in Vietnam. *International Transaction Journal of Engineering, Management, and Applied Sciences and Technologies*, 2(4): 423-436.