



Optimization of Broiler De-feathering Efficiency Using Response Surface Methodology

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Abstract

The present study addresses the need for more efficient, high-quality, and cost-effective poultry processing by focusing on the optimization of broiler de-feathering operations. De-feathering quality directly affects the broiler appearance, product value, and processing costs, yet settings are often chosen by trial-and-error which leads to incomplete feather removal, skin damage, and reduced efficiency. This study provides a data-driven solution, Response Surface Methodology (RSM) with a three-variable, five-level Central Composite Design to optimize key process parameters, including scalding time, de-feathering time, and bird weight, at constant scalding temperature of 85 °C. Twenty experimental runs were conducted using a fabricated de-feathering machine, and plucking efficiency was calculated from measured feather mass removal, and the boilers' weights. RSM produced a quadratic regression model with high predictive power, with coefficient of determination (R^2) of 0.9845. This indicates that more than 98 % of the variation in plucking efficiency is explained by the selected variables. ANOVA confirmed the model's overall significance (Model $F = 70.53$, $p < 0.0001$), with scalding time, de-feathering time, bird weight, all interaction terms, and all quadratic terms showing statistically significant effects on plucking efficiency ($p < 0.05$). Optimization using desirability functions identified the best operating parameter as 57.14 s scalding time, 50.17 s de-feathering time, 85 °C scalding temperature, and 6.77 kg bird weight which yielded a maximum plucking efficiency of 98.58 % and desirability of 1.0. The study demonstrates that informed control of de-feathering parameters via RSM-based modelling and optimization significantly enhances plucking efficiency, product quality, and process consistency.

Keywords: Response Surface Methodology, Process Optimization, Broiler De-feathering, Plucking Efficiency, Poultry Processing

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Nomenclature

RSM	Response Surface Methodology
CCD	Central Composite Design
ANOVA	Analysis of Variance
CV	Coefficient of Variation
PRESS	Predicted Residual Error Sum of Squares
FEA	Finite Element Analysis
2F1	Two-Factor Interaction model



1.0 INTRODUCTION

Poultry processing is a significant part of the worldwide agricultural industry [1], [2]. In particular, broiler chickens contribute a very large share of meat production and supply in many countries [3], [4]. In poultry processing, there is a stage of de-feathering. It ultimately affects the quality of carcass, efficiency of operation, throughput of the plant, and marketability of the product [5], [6]. De-feathering occurs immediately after scalding and is the mechanical removal of feathers using rotating drums with rubber fingers. The de-feathering process is the most sensitive part of poultry processing and affects a variety of parameters [3], [7]. Scalding time, scalding temperature, plucking finger arrangement and the bird characteristics such as weight and feather maturity are few important parameters that affects the process [8], [9]. Improper adjustment of these parameters may result in several unwanted results like incomplete feather removal, bruising, skin tearing, excessive energy consumption, etc. [10]. This affects the quality of products, increases the costs of operations, and reduces the efficiency of processes. In most poultry processing factories, the working parameters are chosen from practical experience or trial-and-error or average vendor values. In commercial farming operations, the size, age, and feather characteristics of broilers vary considerably within a flock. However, heuristic approaches often do not take this into consideration [11]. In light of the above constraints, there is a dire need for a scientific and statistical approach to optimize de-feathering parameters. An effective data-driven approach would ensure consistent reliability, reduce the occurrence of processing defects and enhance the economic viability of poultry operations. Response Surface Methodology (RSM) is a powerful statistical tool used for modeling and analyzing problems which are influenced by several variables. RSM offers a systematic approach for optimizing complex processes like de-feathering [12]. To satisfy consumer and regulatory expectations, de-feathering of broilers must be effective to have clean and attractive carcasses [13]. Relationship between processing parameters and de-feathering performance has been studied by several researchers. Recent studies investigated how the scalding temperature and time, bird weight and duration of defeathering affected both feather removal efficiency

and meat quality [14]. Proper control of these parameters is essential to achieve effective plucking of fur without damaging the skin. Likewise, Ogunnowo *et al.* [15] noted the need for careful management of scalding conditions that prevent microbially cross contamination and allow proper feather removal. Research has also been undertaken to develop mechanical solutions too. The design and construction of small-scale broiler de-feathering machine has been carried out. It was done for household uses because most of the time tearing of carcass happens during plucking of feathers manually and the machine was so designed to reduce it. In a different research, Adefuye *et al.* [16] designed and evaluated a chicken de-feathering machine from locally available materials, which can be used in rural or less resourceful settings. There are numerous research studies conducted on design and improvement of the physical properties of the de-feathering machines and parts. Fadeyibi *et al.* [17] investigated the influence of plucking parameters, including finger dimensions, base clearance, and finger pattern configurations (circular, pentagonal, and triangular). The researchers ran 27 tests to check how these factors affect throughput and plucking efficiency effects in a fixed time. In the detailed analysis of existing de-feathering technologies, Omotehinse and Amagre [18] presented an overview of designs of machines, their operational problems and opportunities. Moreover, Shung *et al.* [19] evaluated the effect of soft scalding (57°C for 120 seconds) and hard scalding (60°C for 60 seconds) on defeathering and quality of carcass in poultry strains; using a conventional experimental design. In broilers, results obtained from both scalding methods were similar. However, in adult and local chickens, hard scalding produced significantly better results; over 70% of the birds had desirable feather removal results. The key conclusion from the study was that age and dermal architecture, rather than body weight, govern scalding–defeathering effectiveness. Yet, it is clear that more effective de-feathering is dependent on a better scalding operation. Ghazy *et al.* [6] experimentally evaluated small-scale scalding and defeathering machines, varying scalding temperature, water flow, drum speed, band spacing and time to maximize defeathering and energy-use efficiency. Optimal conditions (by measured



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performance) were 68 °C, 0.7 m³/20 birds, 320 rpm and 105 s, which improved feather removal and rationalized energy use. Dogan *et al.* [20] conducted a systematic review/meta-analysis of processing stages and Campylobacter control, employing meta-analytic models. Defeathering was identified as a stage that tends to increase Campylobacter prevalence and concentration, whereas scalding and chilling reduce them. Thus, they concluded that defeathering optimization must consider both feather removal and microbial risk. Okafor *et al.* [21] designed and developed an efficient chicken defeathering machine using locally available materials to improve poultry processing quality, speed, and commercial viability. They relied on mechanical design calculation, material optimization, finite element analysis (FEA), performance testing where chickens are immersed in hot water before defeathering through rubber-finger mechanism. Based on the test results, the machine was able to remove feathers properly with no or minimum damage to the carcass with an impressive feather removal efficiency of 98.1% within an average period of about 20 seconds. These criteria make it suitable for commercial poultry processing. Casnor and Gavino [22], developed a small-scale drum-type defeathering machine using locally available materials. The author reported a defeathering efficiency of 99.01% and an efficacy of 95.85% at 348 rpm. Although these results demonstrate the potential of locally fabricated equipment, the reported operating point does not establish a statistically validated optimum across multiple interacting variables. Similarly, Bello *et al.* [23], evaluated a defeathering machine (plucker-fingered) using broilers, cockerels, and layers at a soaking temperature of 80°C for approximately one minute. Canvas or leather strip fingers performed better than rubber fingers, while a 2.4 kg broiler required approximately 60 seconds for defeathering. The findings emphasize the importance of plucker-finger material and bird characteristics. Also a performance evaluation carried out by Ogunnowo *et al.* [24], examined different poultry types and scalding temperatures using a 3 × 3 × 3 completely randomized design, and ANOVA. The reported results showed that 70°C produced the highest defeathering efficiency for broilers, at approximately 96%, whereas capacity peaked at 80°C. Other studies in literature further illustrate alternative approaches. Shi *et al.* [25], in a similar study identified 60°C for 4 minutes and

20 seconds as a suitable scalding condition for balancing feather removal and breast-meat quality in spent laying hens. Its applicability to broilers requires further evaluation because bird type and meat-quality responses may differ. Alim *et al.* [26] developed a fuzzy logic controller for a chicken feather-plucking machine, demonstrating the potential of intelligent control for managing scalding and plucking inputs. However, controlling machine operation differs from statistically determining optimal operating set points, particularly when quantitative removal-efficiency results and validated optimization models are limited. The numerous studies presented above have provided valuable information on machine performance and parameter effects in Broiler De-feathering. However, the present study aims at improving the result (accuracy and generalizability) of the present development of this technology by adopting RSM to systematically model the relationship and optimize the main operational parameters affecting broiler de-feathering effectiveness and quality improvement to advance poultry processing technologies. The unique contributions of the present study in the field of poultry processing optimization are as follows:

- (i). RSM was employed to optimize broiler defeathering parameters; which resulted in a highly quadratic predictive model that correlates scalding time, defeathering time, and bird weight with plucking efficiency.
- (ii). A statistically validated predictive model was established for broiler plucking efficiency, with model adequacy assessed using ANOVA, coefficient of determination, adjusted and predicted R², lack-of-fit analysis, and diagnostic plots.
- (iii). A practical operating window for maximizing broiler plucking efficiency was established through numerical desirability optimization, integrating the effects of the investigated process variables into a single optimized operating condition for poultry de-feathering.

The structure of the remainder of this paper is as follows. The sequence of Section 2 contains the materials and methodology adopted for the study, particularly the experimental procedures, process variables considered, experimental design matrix, application of Central Composite Design (CCD), and RSM for model development and validation. The experimental results



and statistical analyses such as model summary statistics, ANOVA results, development of regression model, response surface analysis, interaction effects of processing parameters and optimization of broiler plucking efficiency have been discussed in section 3. The main findings of the optimization study are presented in Section 4. The Section relates RSM's effectiveness in modelling and optimizing broiler defeathering parameters. Also, it discusses the reliability of the predictive model developed and practical implications of the findings. The study recommends future work on multi-response optimization and automation of poultry processing.

2.0 METHODOLOGY

This study employed RSM to optimize the process

parameters for effective broiler birds de-feathering. The independent variables considered in this study were scalding time, de-feathering time, and weight of the bird, while the scalding temperature was maintained at a constant 85°C. The response variable measured was plucking efficiency (%). The experimental design followed a three-variable, five-level CCD using Design Expert 11 software (Stat-Ease, Inc., Minneapolis, USA). A total of 20 experimental runs were conducted, which included 8 factorial design runs, 6 axial point runs (two for each variable), and 6 center point replications to improve the model accuracy. The fabricated poultry defeathering machine used for the experimental trials and a representative defeathered cockerel are shown in Figure 1. The range of values for the experimental variables is provided in Table 1.



Figure 1: Poultry De-Feathering Machine (before painting) and a De-Feathered Cockerel



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Table 1: Defeathering variable with their range of values

Independent variable	Symbol	Levels	
		-1	+1
Scalding time (s)	A	19.77	70.23
Defeathering time (s)	B	44.89	70.11
Weight of bird (kg)	C	4.15	7.85

The broiler birds used in this study were obtained from a local market at Okha Community, Ikpoba Okha Local Government Area of Edo State. The broiler birds were scalded and de-feathered using a fabricated de-feathering machine. Each broiler bird was weighed and its initial weight recorded. The bird was scalded in water maintained at 85°C for a specified duration based on the experimental design. After scalding, the bird was placed in the de-feathering machine, where it was de-feathered for the allocated time. The final weight of the bird after de-feathering along with scalding time and de-feathering time was checked and recorded as shown in Table 2a. The weight of broiler bird before de-feathering, weight of broiler bird after de-feathering, mass of feathers removed by machine and mass of feathers removed by hand were recorded in Table 2b. The plucking efficiency was determined using Eqn. 1; where total mass of feathers is given by Eqn. 2.

$$\text{Plucking Efficiency} = \frac{\text{Mass of feathers removed by de-feathering machine}}{\text{Total mass of feathers}} \times 100 \quad (1)$$

$$\text{Total mass of feathers} = \text{Mass of feathers removed by hand} + \text{Mass of feathers removed by machine} \quad (2)$$

Table 2a: Experimental Design Matrix for De-Feathering of Broiler

Run	Factors			Run	Factors		
	Scalding time (s)	Defeathering time (s)	Weight of bird (kg)		Scalding time (s)	Defeathering time (s)	Weight of bird (kg)
1	45.00	57.50	6.00	11	19.77	57.50	6.00
2	45.00	44.89	6.00	12	45.00	57.50	6.00
3	60.00	65.00	7.10	13	70.23	57.50	6.00
4	30.00	65.00	4.90	14	60.00	65.00	4.90
5	45.00	57.50	6.00	15	45.00	57.50	6.00
6	60.00	50.00	7.10	16	30.00	50.00	4.90
7	30.00	50.00	7.10	17	45.00	57.50	6.00
8	60.00	50.00	4.90	18	45.00	57.50	7.85
9	45.00	57.50	6.00	19	30.00	65.00	7.10
10	45.00	70.11	6.00	20	45.00	57.50	4.15



Table 2b: Experimental Design Matrix for De-feathering of Broiler

Weight (before de- eathering) (kg)	de-	Weight (after de- feathering) (kg)	Mass of feathers removed by machine (kg)	Mass of feathers removed by hand (kg)
6.00		3.07	2.930	0.066
6.00		4.66	1.340	0.066
7.10		6.32	0.780	0.066
4.90		3.77	1.130	0.066
6.00		3.76	2.240	0.066
7.10		2.52	4.580	0.066
7.10		6.09	1.010	0.066
4.90		3.74	1.160	0.066
6.00		3.66	2.340	0.066
6.00		5.13	0.874	0.066
6.00		5.18	0.818	0.066
6.00		2.91	3.090	0.066
6.00		4.79	1.210	0.066
4.90		4.22	0.680	0.066
6.00		3.46	2.540	0.066
4.90		4.10	0.799	0.066
6.00		2.83	3.170	0.066
7.85		6.70	1.150	0.066
7.10		6.28	0.821	0.066
4.15		3.25	0.899	0.066

The consistency of every run was ensured by performing the experimental trial under controlled conditions. The data collected were analyzed through RSM to develop the relationship between the independent variables and the response variable. A second-order polynomial regression model was developed to predict the plucking efficiency in terms of independent variables. Then, ANOVA was used to assess the statistical significance of the model and its parameters. The process parameters were optimized with desirability function approach using Design Expert 11 software. Additional tests were conducted under predicted optimized conditions to validate the optimal settings. The experimental outcome were compared with the exhibited outcomes, to the accuracy and reliability of the developed

model. Also, model adequacy was assessed using diagnostic plots including normal probability plots, residual plots and response surface plots. The goodness of fit was assessed using the coefficient of determination (R^2) and adjusted R^2 values. For the same purpose, lack of fit tests and significance tests of model terms were performed to substantiate the developed model.

3.0 Results

The presentation of result for broiler process parameters optimization based on the experimental design matrix in Table 2 is shown in Table 3.



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Table 3: Experimental Result for De-feathering of Broiler Birds

Run	Factors			Response	
	Scalding time (s)	Defeathering time (s)	Initial Weight of bird (kg)	Plucking Efficiency (%)	
				Actual	Predicted
1	45.00	57.50	6.00	97.80	97.59
2	45.00	44.89	6.00	95.30	95.76
3	60.00	65.00	7.10	92.20	92.34
4	30.00	65.00	4.90	94.50	94.54
5	45.00	57.50	6.00	97.14	97.59
6	60.00	50.00	7.10	98.58	98.49
7	30.00	50.00	7.10	93.88	93.43
8	60.00	50.00	4.90	94.60	94.51
9	45.00	57.50	6.00	97.26	97.59
10	45.00	70.11	6.00	92.98	92.58
11	19.77	57.50	6.00	92.53	92.84
12	45.00	57.50	6.00	97.91	97.59
13	70.23	57.50	6.00	94.82	94.58
14	60.00	65.00	4.90	91.15	91.55
15	45.00	57.50	6.00	97.47	97.59
16	30.00	50.00	4.90	92.37	92.18
17	45.00	57.50	6.00	97.96	97.59
18	45.00	57.50	7.85	94.58	94.76
19	30.00	65.00	7.10	92.56	92.60
20	45.00	57.50	4.15	93.16	93.04

Based on the data presented in Table 3, the plucking efficiency during the broiler de-feathering process varied between 91.15% and 98.58%. The maximum efficiency of 98.58% was achieved with a scalding time of 60.00 seconds, a de-feathering time of 50.00 seconds, and a broiler weight of 7.10 kg. In contrast, the minimum

efficiency of 91.15% occurred at the same scalding time of 60.00 seconds but with a longer de-feathering time of 65.00 seconds and a broiler weight of 4.90 kg. Table 4 provides a summary of the model statistics related to plucking efficiency in the de-feathering process.



Table 4: Model summary statistics of broiler defeathering process

Source	SD	R ²	Adjusted R ²	Predicted R ²	PRESS	
Linear	2.31	0.1860	0.0333	-0.2080	126.43	
2FI	2.19	0.4054	0.1310	-0.4955	156.52	
Quadratic	0.4029	0.9845	0.9705	0.9175	8.63	Suggested
Cubic	0.3216	0.9941	0.9812	0.9681	3.34	Aliased

*SD=Standard Deviation

Coefficient of determination, R^2 , is a statistical measure of how well the variance of the dependent variable is explained by the independent variable(s). It shows how well the experimental conditions and their interactions explain the observed variations in response values. The closer the value of R^2 is to 1, the more accurate the process is represented. It has been used by several studies in literature to assess the goodness of fit of a regression model [27], [28], [29], [30]. The quadratic model the present study had a low standard deviation of 0.4029 and a high R^2 value of 0.9845 for broiler

defeathering efficiency as shown in Table 4. The cubic models were taken as aliased under the response surface methodology with the assumption that the effect of the cubic terms is negligible. The “adjusted R^2 ” is 0.9705, the “predicted R^2 ” is 0.9175, and the difference between these is less than 20%, which is indicative of a good level of agreement between the predicted and experimental values of plucking efficiency. This relationship is further confirmed in the plot of predicted versus actual data in Figure 2, where the two sets of data align closely.

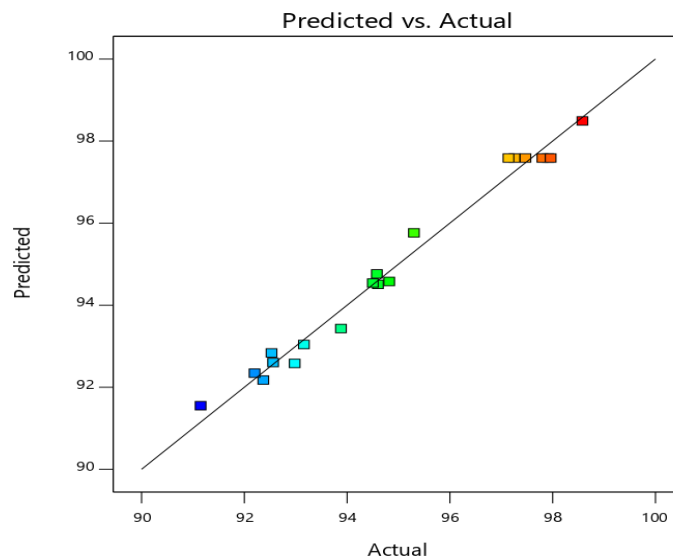


Figure 2: Actual Versus Predicted Plot of Broiler De-feathering Process



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ANOVA was employed to confirm the significance and adequacy of the models. Mean square values were obtained by dividing the sum of squares for each source of variation by their respective degrees of freedom, which helped estimate the model's error variance. A p-value below 0.05 indicates that the observed effect is

statistically significant and unlikely to have occurred by chance, meaning the corresponding model term has a meaningful impact on the response at the 5% significance level [31], [32]. Table 5 presents the ANOVA results for the plucking efficiency in broiler defeathering

Table 5: ANOVA for Model of De-feathering Process

Source	Sum of Squares	df	Mean Square	F-value	p-value
Model	103.04	9	11.45	70.53	< 0.0001*
A - Scalding Time	3.66	1	3.66	22.56	0.0008*
B - Defeathering Time	12.23	1	12.23	75.32	< 0.0001*
C - Weight of bird	3.58	1	3.58	22.03	0.0008*
AB	14.15	1	14.15	87.18	< 0.0001*
AC	3.73	1	3.73	22.96	0.0007*
BC	5.09	1	5.09	31.34	0.0002*
A ²	27.11	1	27.11	167.04	< 0.0001*
B ²	21.00	1	21.00	129.40	< 0.0001*
C ²	24.46	1	24.46	150.67	< 0.0001*
Residual	1.62	10	0.1623		
Lack of Fit	1.01	5	0.2028	1.66	0.2948
Pure Error	0.6092	5	0.1218		
Cor Total	104.66	19			

*=significant

Table 5 reports a high Model F-value of 70.53 and an extremely low p-value (less than 0.0001), signifying that the quadratic model for broiler defeathering efficiency is statistically significant. This suggests that the model is reliable for predicting plucking efficiency. P-values below 0.05 indicate that the corresponding model terms are statistically meaningful. As shown in Table 5, all primary

variables - scalding time (A), defeathering time (B), and bird weight (C) - had a strong influence on plucking efficiency, with respective p-values of 0.0008, 0.0001, and 0.0008. Among these, defeathering time had the most pronounced effect, as indicated by its lower p-value. Interaction terms (AB, AC, and BC) also significantly affected plucking efficiency, with p-values of 0.0001,



0.0007, and 0.0002, respectively. Additionally, the quadratic terms (A^2 , B^2 , and C^2) were all highly significant, each having p-values less than 0.0001. The lack of fit p-value for the quadratic model was 0.2948, which exceeds 0.05. Since the lack of fit exceeds the threshold of 0.05 the models confirmed suitable.

RSM develops empirical models using coded variables to illustrate the relationships and interactions between input factors and the response. Coefficients for individual factors indicate their influence; coefficients for interaction terms and quadratics indicate interactions between factors and quadratic effects. A second order polynomial model is presented in Eqn. 3, that relates the broiler plucking efficiency to the independent variables (A, B and C) coded.

$$\begin{aligned} \text{Plucking Efficiency} = & 97.59 + 0.5178A - 0.9462B \\ & 1.33AB + 0.6825AC - 0.7975BC - 1.37A^2 - \\ & 1.21B^2 - 1.30C^2 \end{aligned} \quad (3)$$

The signs of the coefficients in a regression model indicate the direction of the relationship between the response and the independent variables: A positive coefficient indicates that as the independent variable increases, the response increases; A negative coefficient indicates that as the independent variable increases, the response decreases [33], [34], [35]. The factors of scalding time (A), bird weight (C) had positive effects and the de-feathering time (B) had negative effect on plucking efficiency in grill de-feathering as observed in Equation 3. There were four interactions of which only AC had a positive effect on plucking efficiency, with AB and BC having negative effects. The factors with the largest coefficient values were de-feathering time (B), and bird weight (C) had the smallest effect. All quadratic terms (A^2 , B^2 and C^2) were negative and impacted broiler plucking efficiency. Further details of the model's performance metrics are provided in the Fit Statistics summarized in Table 6.

Table 6: Fit Statistics of the Plucking Efficiency of Broiler De-Feathering

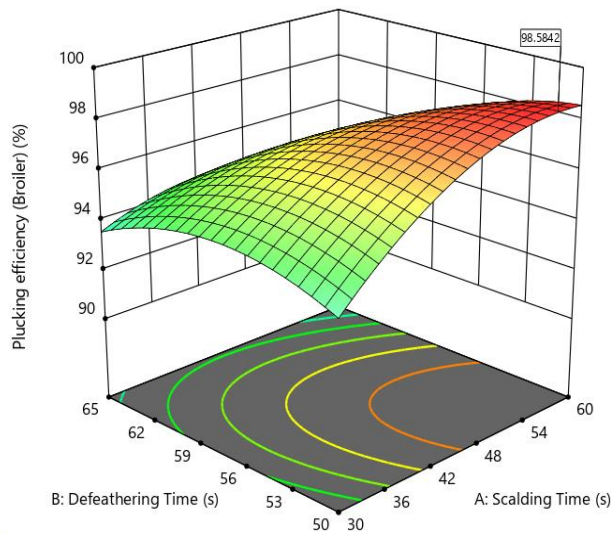
Statistics	Value
Standard deviation (%)	0.4029
Mean (%)	94.94
C.V (%)	0.4244
R^2	0.9845
Adjusted R^2	0.9705
Predicted R^2	0.9175
Adequate Precision	24.363

As shown in Table 6, the coefficient of variation (CV) for the broiler defeathering plucking efficiency is 0.4244, which falls within an acceptable range. Since CV expresses the standard deviation as a percentage of the mean, lower CV values indicate greater consistency and repeatability. A high CV typically suggests large variability around the mean, which can hinder the development of a reliable response model [36], [37]. The model's suitability was also evaluated using the R^2 . The high R^2 value of 0.9845 indicates that over 98% of the variation in plucking efficiency can be explained by the model, confirming its strong predictive ability [38], [39], [40]. The difference between the adjusted R^2 (0.9705) and predicted R^2

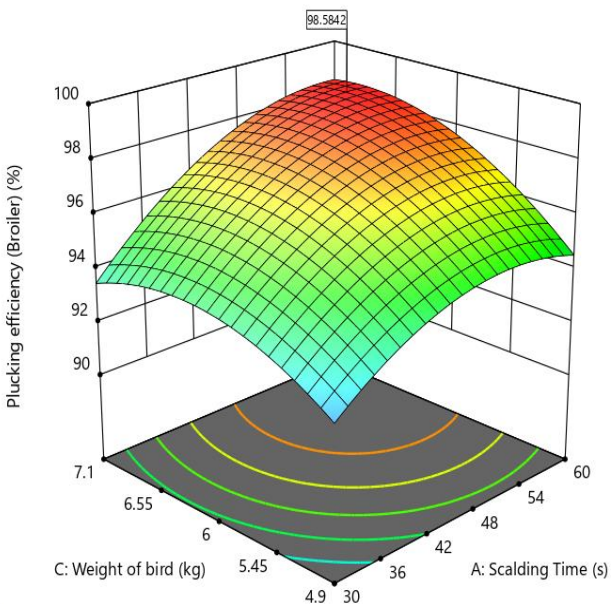
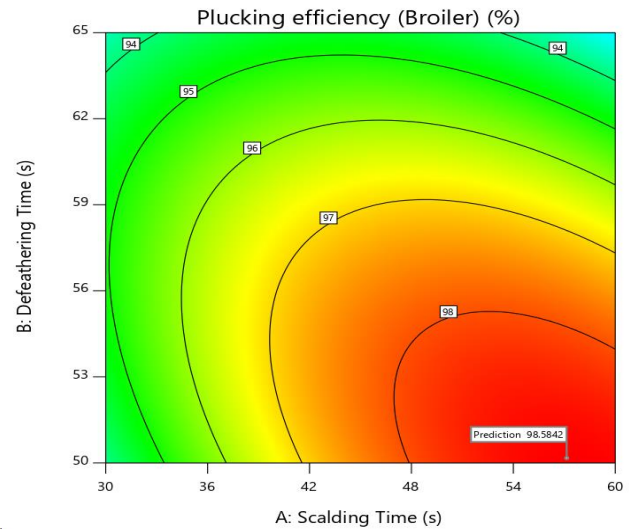
(0.9175) is less than 0.2 (or 20%), demonstrating good agreement between experimental and predicted values, which supports the validity of the response surface methodology in analyzing the broiler defeathering process. Adequate precision, which measures the signal-to-noise ratio, had a value of 24.363 - well above the acceptable threshold of 4, indicating a strong signal and confirming the model's effectiveness in navigating the experimental design space for bird defeathering. The three-dimensional response surface plots and two-dimensional contour plots in Figure 3 depict the influence of variable interaction on the plucking efficiency of the broiler defeathering process.



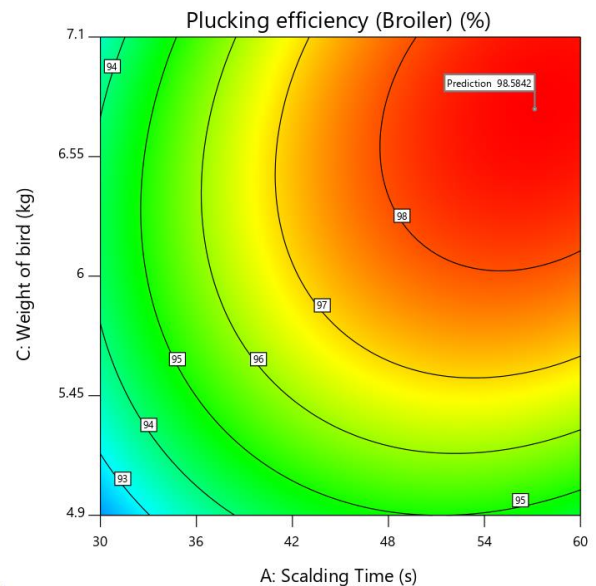
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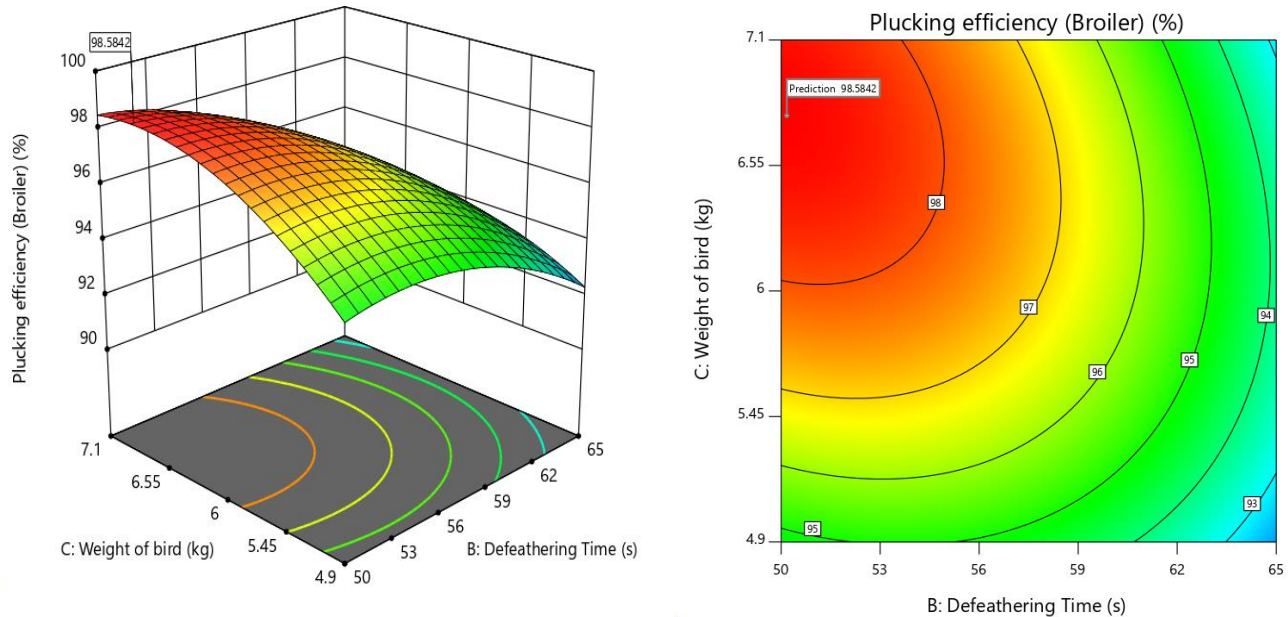


(a)



(b)





(c)

Figure 3. Effect of Interaction on Plucking Efficiency: (a) Scalding Time and Defeathering Time, (b) Scalding Time and Weight of Bird (c) Defeathering Time and Weight of Bird

Figure 3(a) depicts the effect of the interaction between scalding time and defeathering time. The interaction between scalding time and defeathering time (AB) on broiler plucking efficiency, with bird weight held constant, is illustrated in the plot. It reveals that increasing both scalding and defeathering times leads to a reduction in plucking efficiency. Figure 3(b) shows the combined effect of scalding time and bird weight (AC) on plucking efficiency when defeathering time remains unchanged. The plot indicates that greater scalding time and heavier bird weight contribute to improved plucking efficiency. In

Figure 3(c), the interaction between defeathering time and bird weight (BC) is examined while keeping scalding time constant. The results show that increasing both defeathering time and bird weight simultaneously results in a decline in the plucking efficiency of the broiler defeathering process. A numerical optimization method using desirability functions was applied to enhance the responses (bird plucking efficiency) during defeathering. The study concludes that the optimal conditions are those that maximize plucking efficiency. The summarized optimization conditions can be found in Table 7.

Table 7: Optimal conditions for plucking efficiency of broiler bird during defeathering

Defeathering variables	Optimal values
Scalding time (s)	57.14
Defeathering time (s)	50.17
Scalding temperature (°C)	85
Weight of bird (kg)	6.77
Plucking efficiency (%)	98.58
Desirability, <i>d</i>	1.00



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Table 7 indicates that the highest plucking efficiency of 98.58% was achieved with a scalding time of 57.14 seconds and a defeathering time of 50.17 seconds, using 6.77 kg of bird. This resulted in a desirability score of 1.000, signifying a 100% likelihood of achieving this optimal plucking efficiency during the defeathering process.

4.0 CONCLUSION

The present study employs an experimental and statistical approach to systematically investigate the effects of broiler defeathering process parameters, including scalding time, defeathering time, and bird weight, on plucking efficiency. The defeathering process was carefully carried out using a fabricated defeathering machine under controlled operating conditions, while the process response was evaluated in terms of plucking efficiency. Through the application of RSM and CCD, predictive models were developed to establish the relationships between the processing variables and the defeathering performance. Experimental and predicted results were compared, and the analysis revealed a strong agreement between both data sets. The significance of the process variables and their interaction effects was evaluated using ANOVA, while model adequacy tests confirmed that the lack of fit was statistically insignificant. Consequently, the present study is highly relevant to poultry processing engineering, particularly in process optimization, quality improvement, and operational efficiency enhancement in broiler processing systems. The following conclusions can be drawn:

- (i). RSM model accurately optimizes broiler defeathering process which indicates that scalding time, defeathering time, and bird weight significantly influence plucking efficiency. The relationship between process parameters and response is complex, owing to the fact that interaction effects and quadratic terms of the variables were found to be statistically significant.
- (ii). The performance of the developed model statistically further proves its robustness and predictability. The value of R^2 which is 0.9845 indicates

that over 98% variability in broiler plucking efficiency can be explained by the model. Also, the adequacy of the developed model for predictive optimization of broiler defeathering operations is further affirmed by the closeness of the adjusted R^2 (0.9705) and predicted R^2 (0.9175) values.

(iii). The best defeathering specifications were found to be 57.14 seconds of scalding time, 50.17 seconds of defeathering time, a scalding temperature of 85°C, and a bird weight of 6.77 kg which yield a maximum plucking efficiency of 98.58%. Feather removal and carcass quality can be improved in poultry processing industries using these optimum conditions.

The results of the present study enhance poultry processing technology as it provides predictive and optimization framework to improve defeathering of broiler at controlled process parameters. The response surface plots, contour diagrams, and desirability functions produced by the developed model can effectively minimize processing defects and operating costs while improving product quality and industrial productivity in poultry processing systems. Future research should expand the application of this optimization technique to multi-response evaluation of carcass quality, energy use, processing throughput, and microbial safety for improved assessment of poultry processing performance under industrial operating conditions.

CRedit authorship contribution statement

Samuel Ayodeji Omotehise: Conceptualization, Supervision, Methodology, Data analysis, Writing – original draft. Uyioghosa Samuel Ailon: Writing – review & editing.

Availability of Data and Materials

The data is available on request

Declaration of interests

The authors affirmatively declare that they have no competing financial interests or personal relationships that could have influenced the work reported in this paper.



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