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An Investigation of Optimized Operational Parameters for a Chicken Slaughtering System in Vietnam

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ABSTRACT

A 500 birds/hour chicken slaughtering system with improved designs was used to investigate optimized operational parameters of scalding and defeathering process under chicken characteristics in Vietnam. The experiment is designed based on Orthogonal Second-order Design. Results of analysis of variance presented that scalding temperature and distance between two defeathering bands have had a most significant effect on product quality. The optimal solutions showed that the optimized operation parameters are 1.8 (m3/20birds) in scalding water flow, 67 (0C) in scalding temperature and 80 (seconds) in scalding time for scalding machine; and 415 (mm) in gap between two defeathering bands, 340 (rpm) in defeathering disc velocity and 120 (seconds) in defeathering time for defeathering machine. The implementation results of the lines designed based on these optimized operational parameters have confirmed the appropriateness for the optimization values suggested.

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Nomenclature

q	*scalding water flow (m^3/bird)*
T	*scalding temperature (^oC)*
t_s	*scalding time (seconds)*
a	*distance between two deafthering bands (mm)*
n	*defeathering velocity (rpm)*
t_d	defeathering time (seconds)

1. Introduction

Poultry products and processing in the international market place has been introduced by Bilgili (2002). In Vietnam, there has been a significant increase in demands of poultry meat in recent years. According to the General Statistics Office of Vietnam in June 2010, poultry meat (live weight) gained 330,700 tons and the target for 2020 is 300 million tons of chicken (UN Food Wire News, 2010). In order to have hygiene meat, the necessary conditions involve in breeding animals, feed, breeding facilities, and especially appropriate slaughtering systems that can reduce the risk of virus contamination (e.g. H5N1) and other disease sources.

Over the past decade, some modern poultry slaughtering systems from Linko and Stork Company have been used quite well in Vietnam. The advantages of these systems are high productivity and automation. However, these technologies and equipment still have some disadvantages such as large scale and especially technical parameters that have not been fit to the chicken conditions ("Tam Hoang" chicken with the average weight of 1.8 kg) in Vietnam yet.

This paper will present the results of an experimental investigation for technical parameters in scalding and defeathering process of a 500 birds/hour chicken slaughtering system for Tam Hoang chicken. The objective of the investigation is to determine the values of operational parameters that make a certain minimum percentage of the hair weight remained on the chicken product under condition of skin undamaged. These operation parameters have been named to be "optimized operational parameters" in this paper.

1.1 A chicken slaughtering system 500 birds/hour

This section will introduce a chicken slaughtering system 500 birds/hour with improved designs. This system has been used for both purposes, producing and experimental investigating for optimized operational parameters.

Technology and equipment for poultry product has been introduced by Momtney *et al*., (1984) and also by Sams (2001). Analysis and technological rationalization of poultry processing lines has been described in Hung (2003). Designing a poultry processing line 500 birds/hour for the poultry condition in Vietnam has been published by Hung and Kovac (2003). Recent research on building small scale models for processing poultry in Vietnam has been provided by Hung (2006) and Hung (2010). Based on the critical review results and typical models of the modern poultry processing of Companies Linko and Stork, a 500 birds/hour chicken slaughtering system was designed, manufactured and installed for producing and experimental investigation. The schema of this system is shown in Figure 1.

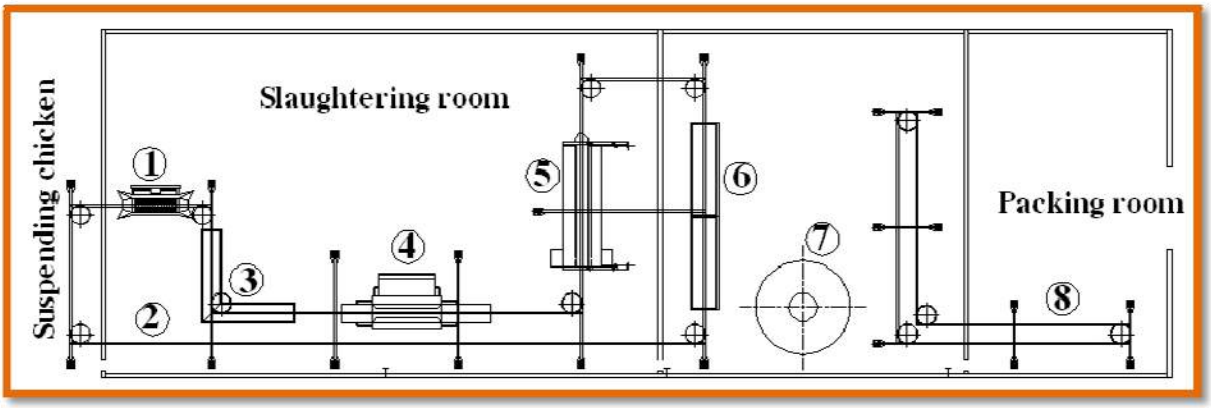

Figure 1: Scheme of the chicken sluaghtering system 500 birds/hour (Hung, 2010).

The system includes the following components: 1. Stunner; 2. The main over head conveyer; 3. Blooding tray; 4. Scalder; 5. Defeathering machine; 6. Eviscerating tray; 7. Equipment for sterilizing; and 8. Drying conveyor, in which, the overhead conveyor, stunner, continuous scalder, disk defeathering machine and sterilizing instruments are the main components. The most important operations of the poultry slaughtering system are scalding and defeathering because of their significant effects on the product quality.

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The scalding machine was designed based on the parameters of scalding temperature, water flow and time, shown in Figure 2. The scalding machine includes five main components: 1. Frame; 2. Hanger; 3. Scalding bin; 4. Chicken; and 5. Water level meter.

The defeathering machine, Figure 3, was designed based on the parameters of the distance between its two bands, velocity and time of defeathering. These parameters can be controlled automatically to meet product quality.

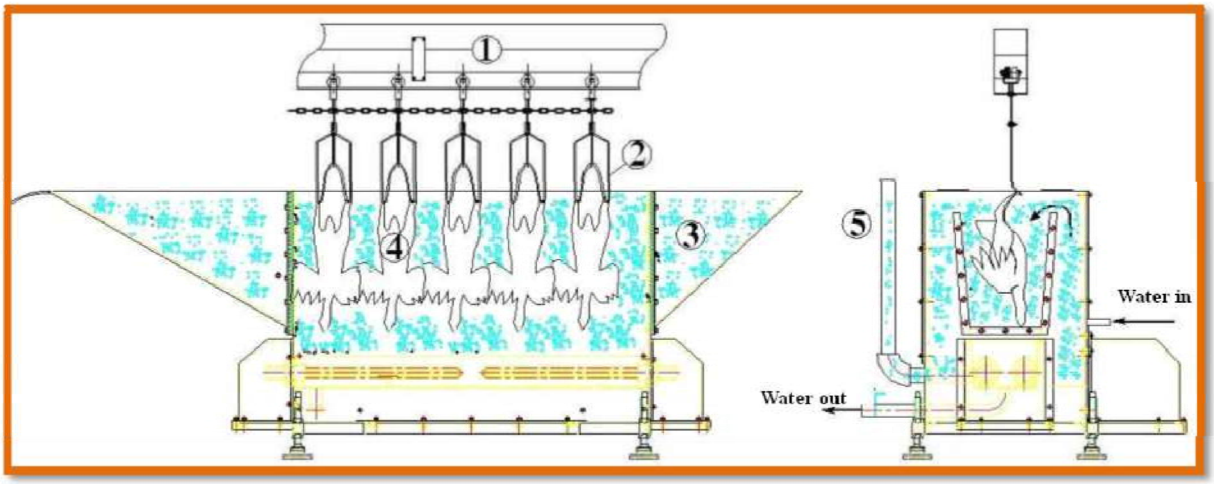

Figure 2: Principle of Scalding machine (Hung, 2010).

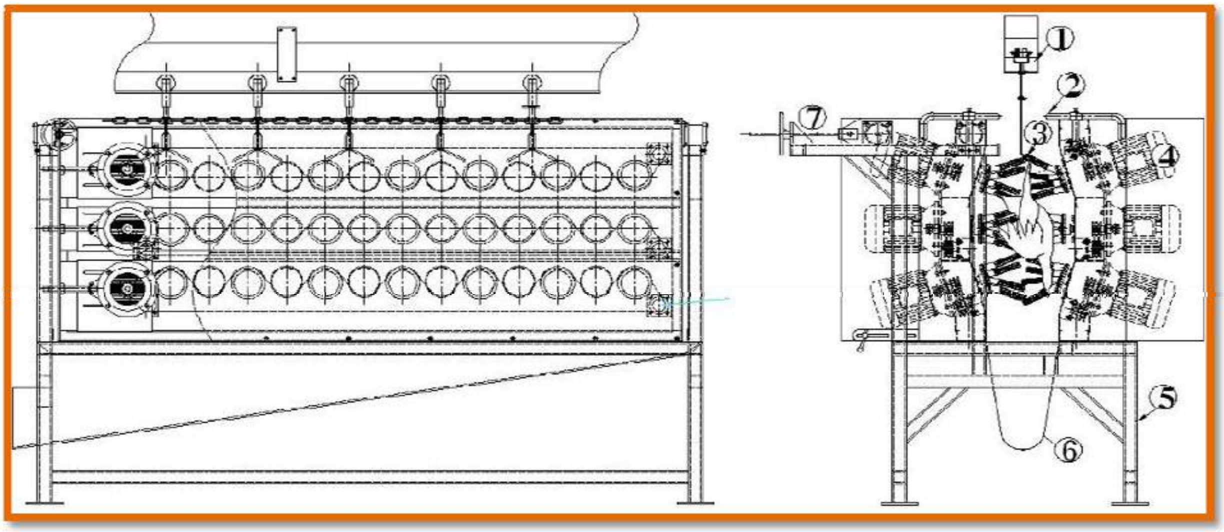

Figure 3: Principle of defeathering machine (Hung, 2010).

The scalding machine includes the main components: 1: Overhead conveyor, 2: Water sprayer; 3: Defeathering finger; 4: Motor; 5: Frame; and 6: Hair trough. A chicken slaughtering line 500 birds/hour installed KhanhHoa province, Vietnam, shown in Figure 4.

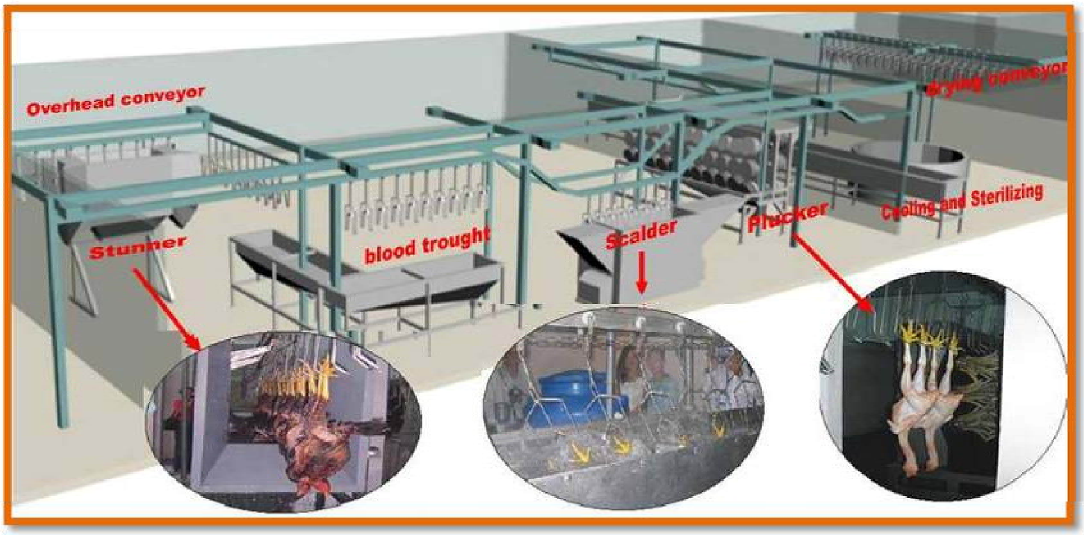

Figure 4: The chicken slaughtering system 500 birds/hour installed in KhanhHoa province.

This line is offered by Food Company Huong Giang. It is noted that in this line the operational parameters of stunner, scalding and defeathering machines can be adjusted to achieve a designed range of the experimental factors.

2. Materials and Methods

This section will present the experimental conditions and methodology for investigating the relationship between the operational parameters and chicken product quality in a chicken slaughtering process.

Experiments were conducted on the chicken slaughtering system *500 birds/hour* described in the above section. The tested chicken is the “Tam Hoang” chicken of seven weeks age and *1.8 kg* in average weight. The selected interfering factors for chicken feature are constant with *5%* in error.

In tests, defeathering velocity was measured by the optical RPM meter, Figure 5a; and scalding temperature was measured by the Dataloger USB series 006p CMA, Figure 5b. The product quality was determined by percentage of the hair weight remained on the chicken product under condition of skin undamaged, shown in Figure 5c.

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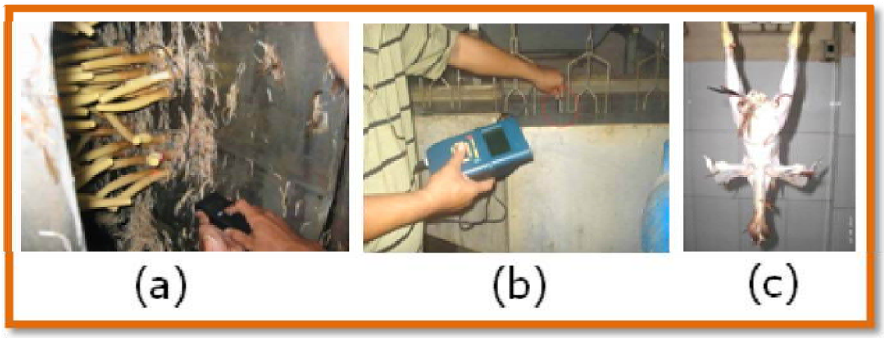

Figure 5: (a) Measuring defeathering velocity; (b) The datalogger used in measure scalding temperature; (c) Hair remained on the chicken product.

Investigation of the relationship between the operational parameters and chicken product quality is based on a “black box” model. In general, the input parameters of black box should include the operational parameters of three machines of stunning, scalding and defeathering. However, for stunner, the best operation parameters for Tam Hoang chicken have been suggested in Hung (2006): type of electric stunning with *1.5 – 1.8 Amperes*, *110 – 130 Volts* and *1.5 seconds* in time amount. Theorefore, here, the input parameters in black box have been selected as in Figure 6.

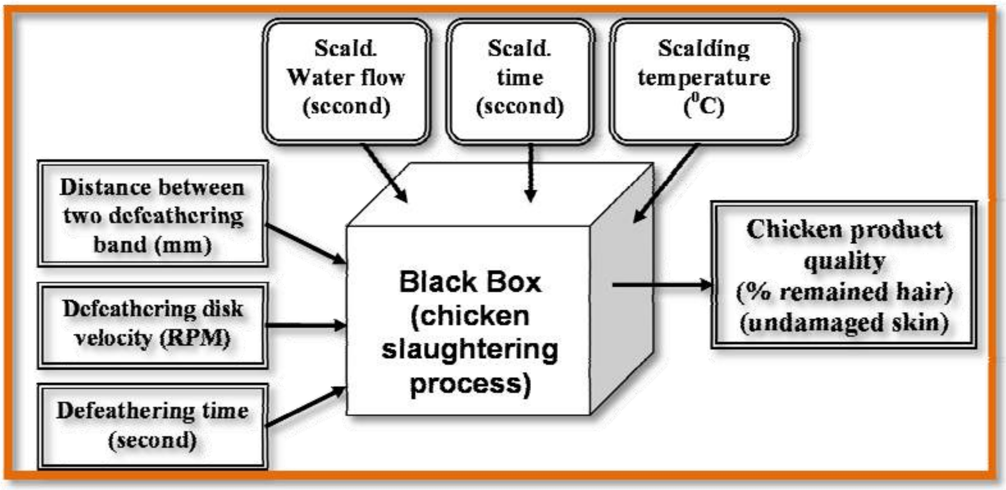

Figure 6: A black box model selected for investigation.

In this research, only the scalding and defeathering parameters that significantly affect to the chicken product quality are selected to be the input parameters described in Figure 6. The output parameter is chicken product quality that was determined by percentage of the hair weight remained on the chicken product under the condition of undamaged skin condition. It is acknowledged that the output parameters should include the economic criteria such as specific energy consumption. However, some initial tests showed that the effects of the investigated parameters to this criterion are not significant compared with the total slaughtering cost, therefore, it is neglected.

The experiment is designed based on Orthogonal Second-order Design (Box-Benken Design) (Zivorad, 2004), in which, the response surface is set up with three factors for each of process of scalding and defeathering. The total number of tests for each process is 15 (2^3+2*3+1) and is performed randomly. Analysis of variance (ANOVA) is treated by Statgrahics 7.0 software. The determined experimental model is an objective function in optimal problem. The optimization solutions are found based on the constrained gradient method (Rao, 1985; Hung, 1998) and Matlab software (Hung, 2008).

3. Results and Discussions

In this section, firstly, the experimental results for chicken scalding and defeathering will be provided. Then, based on the results of ANOVA, the effects of scalding and defeathering factors to hair remained on chicken product will be presented. Finally, based on the optimization solutions, the values of the optimized operational parameters of scalding and defeathering machines will be provided.

For scalding process, the output results corresponding to the input parameters are shown in Table 1.

Table 1: Experimental results of chicken scalding (Box-Behnken method).

Run	q m^3/20bird	T (^{0}C)	t_s (seconds)	Y1 (%)	Run	q m^3/20bird	T (^{0}C)	t_s (seconds)	Y1 (%)
1	1.7	64	90	0.1	8	1.7	60	120	4.42
2	2.0	60	90	6.28	9	1.7	68	120	1.42
3	1.4	64	60	3.84	10	1.4	60	90	8.68
4	1.7	64	90	0.16	11	1.7	60	60	9.47
5	1.4	64	120	1.72	12	1.7	68	60	0.2
6	2.0	64	120	0.48	13	2.0	68	90	1.04
7	2.0	64	60	2.3	14	1.4	68	90	1.62
					15	1.7	64	90	0.15

In Table 1, q is scalding water flow ($m^3/20bird$, means 20 birds conveyed through the scalding equipment at any time), T is scalding temperature (^0C), and t_s is scalding time (seconds) , and Y_1 is percentage of hair weight remained on chicken product affected by these scalding factors.

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For defeathering process, the output results corresponding to the input parameters are shown in Table 2.

In Table 2, *a* is distance between two defeathering bands (*mm*), *n* is defeathering velocity (*rpm*), t_d is defeathering time, and Y_2 is percentage of hair weight remained on chicken product with the constrained factor of undamaged skin.

Table 2: Experimental results of chicken defeathering (Box-Behnken method).

Run	a (mm)	n (rpm)	t_d seconds	Y_2 (%)	Run	a (mm)	n (rpm)	t_d seconds	Y_2 (%)
1	485	320	80	15.01	8	415	320	80	9.27
2	450	320	105	9.32	9	485	290	105	14.33
3	450	320	105	9.02	10	415	320	130	1.50
4	450	350	80	8.12	11	485	350	105	13.32
5	485	320	130	16.52	12	415	290	105	7.23
6	450	290	80	9.52	13	450	290	130	8.63
7	415	350	105	2.30	14	450	350	130	6.45
					15	450	320	105	9.89

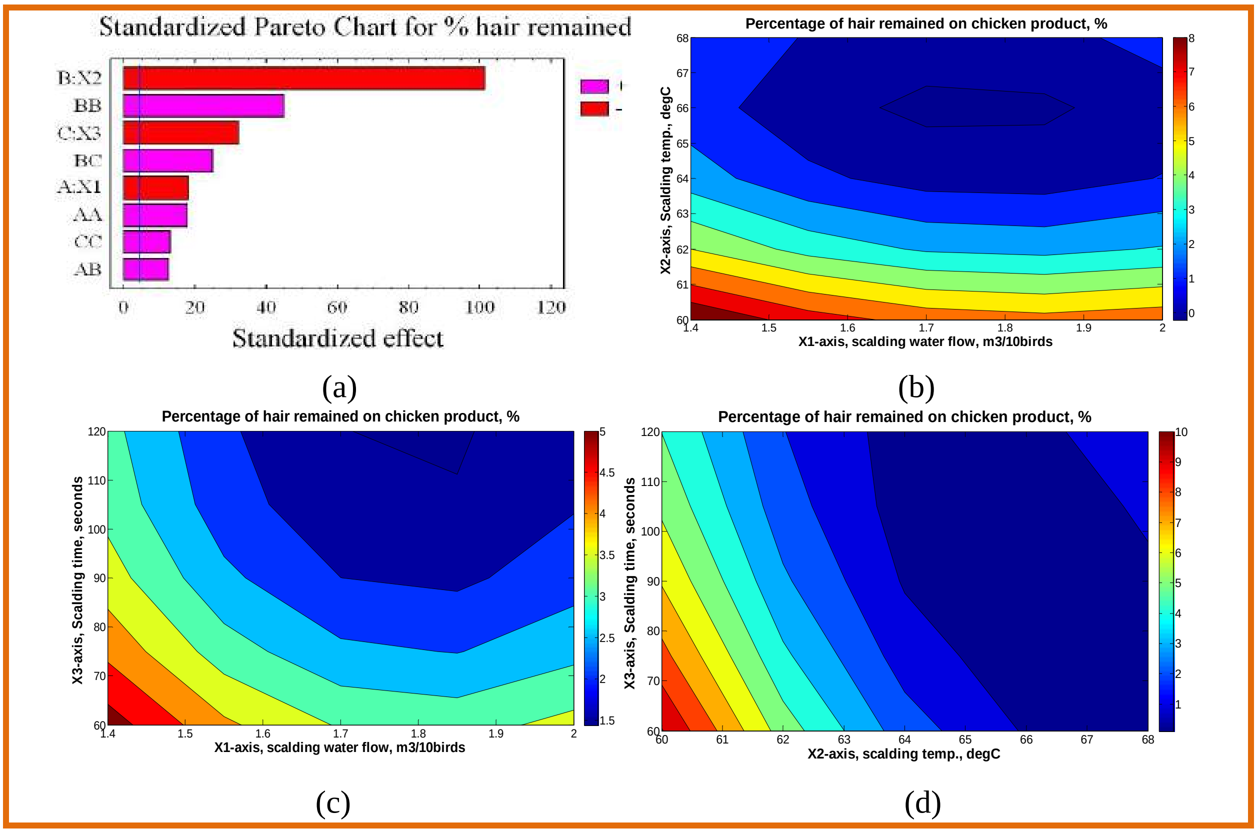

Figure 7: (a) Pareto Chart for hair remained affected by scalding parameters (b), (c), (d). Respone surfaces of the dependence of hair remained affected by scalding parameters.

The experimental data was treated by ANOVA detailed in Appendices 1 and 2. After eliminating the unreliable coefficients and checking the conformability, the regression equations and of scalding and defeathering process; and response surfaces of the investigation are drawn.

For scalding process, the effects of scalding water flow (*q*), temperatue (*T*) and time (t_s) to percentage of hair weight remained on chicken product (Y_1) can be described by the following equation (1) and Figure 7a.

$$Y_1 = 995.97 - 74.1824*q - 26.8314*T - 1.02463*? + 13.7546*q^2 + 0.379167*q*T + 0.00833333*q*t_s + 0.189401*T^2 + 0.0130625*T*t_s + 0.000789352*t_s^2 \quad (1)$$

The response surfaces of the investigation can be described in Figures 7.b, c, and d.

In Figure 7, factors X1, X2 and X3 are the scalding water flow, scalding temperature and scalding time, respectively. Figure 7.a showed influence level of scalding factors on product quality in a designed value range for the operation parameters. The scalding temperature has had a strongest effect to product quality; the next are scalding time and scalding water flow in order. It is noted that product quality is in inverse relationship to scalding temperature. Figures 7.b, c and d, showed that in range of *1,6 – 2* (m^3*/20birds)* of scalding water flow, *65 – 68* (^0C) of scalding temperature and *90 – 120 (seconds)* of scalding time, percentage of hair weight remained on chicken product after defeathering is less than *2%* and undamaged skin.

For defeathering process, the effects of defeathering velocity (*n*), time (t_d) and distance between two defeathering bands (*a*) to percentage of hair weight remained on chicken product (Y_2) can be described by the following equation (2) and Figure 8(a).

$$Y_2 = 269.065 - 1.27435*a + 0.434145*n - 1.23724*t_d + 0.000933333*a*n + 0.000265143*a*t_d + 0.0000929042*a^2 - 0.000139658*n^2 \quad (2)$$

The response surfaces of this investigation can be described in Figures 8(b),(c), and (d).

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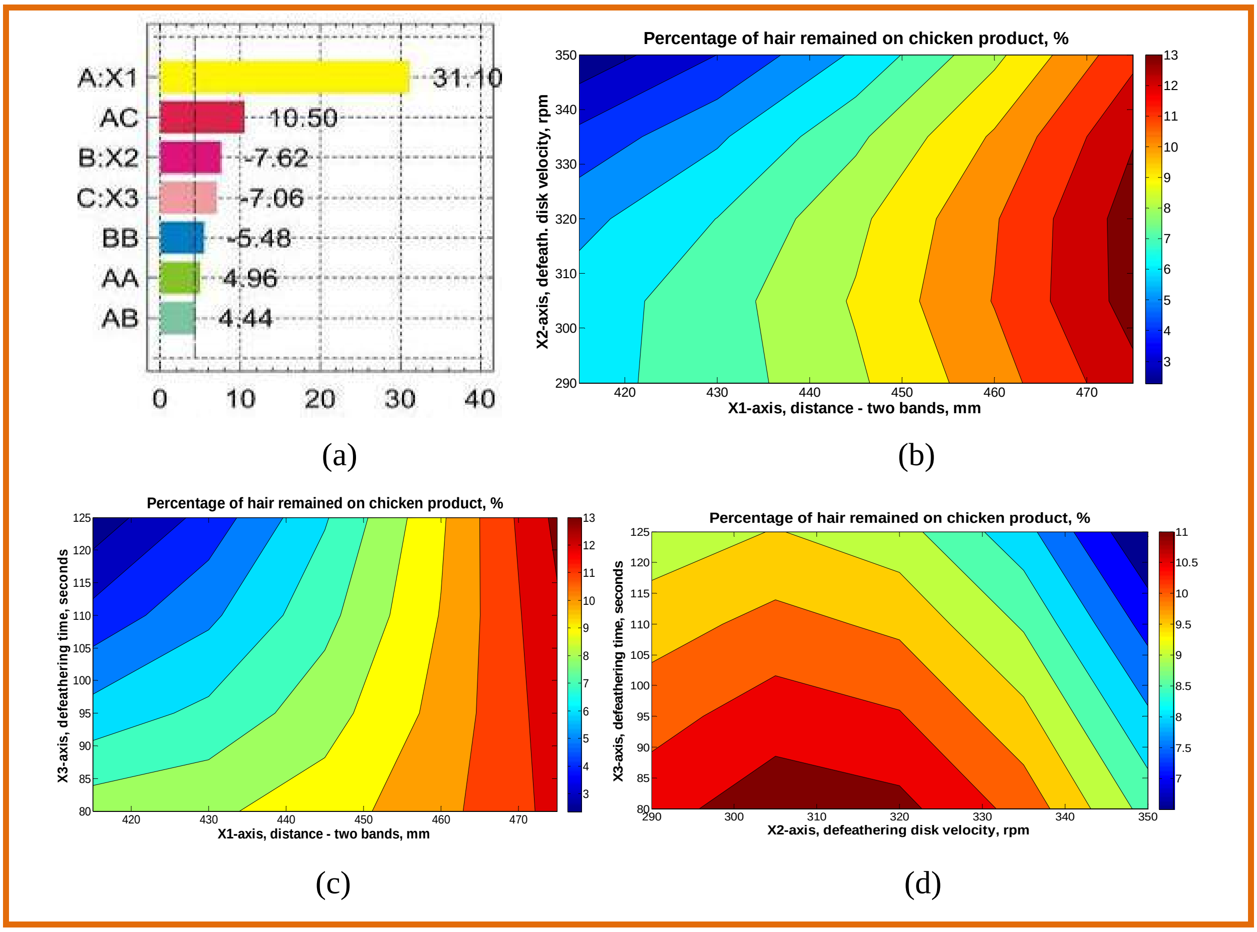

Figure 8: (a) Pareto Chart for hair remained affected by defeathering parameters (b), (c), (d). Respone surfaces of the dependence of hair remained affected by defeathering parameters.

In Figure 8, factors X1, X2 and X3 are the distance between two defeathering bands, defeathering disc velocity and defeathering time, respectively. Figure 7.a showed influence level of defeathering factors on product quality in a designed value range for the operation parameters. The effect of the X1 on product quality is much more significant than that of the X2 and X3. Figures 8.b, c and d, showed that in range of *415 - 430 (mm)* of the gap between two defeathering bands (included length of defeathering finger), *340 – 350 (rpm)* of defeathering disc velocity and *120 – 130 (seconds)* of defeathering time, percentage of hair weight remained on chicken product is less than *2%* and undamaged skin.

In order to meet the chicken product quality required by requirement of chicken product market (percentage of hair weight remained on chicken product under *95%* and undamaged skin), the appropriate values and values optimized operational parameters of the scalding and defeathering machines are shown in Table 3.

A practical evaluation for the values provided in Table 3 showed that the product quality satisfied the required criteria.

Table 3: The operation parameters of the scalding and defeathering machines for Tam Hoang chicken.

Parameters	Unit	Appropriate value	Optimized value
Scalding water flow	m^3/20bird	1.6 ÷2	1.8
Scalding temperature	^{0}C	65÷68	67
Scalding time	seconds	80÷120	80
Distance between two deafthering bands (length of defeathering finger 200mm)	mm	415÷430	415
Defeathering velocity	rpm	340÷350	340
Defeathering time	seconds	120÷130	120

The values of optimized operational parameters have been used to design a new chicken slaughtering system 500 birds/hour. This line was offered by Celin Thai Company, Binh Thuan Province. The product quality from this line has reconfirmed the appropriateness for the values of optimized operational paramaters suggested. Furthermore, the project of chicken slaughtering line 500 birds/hour has been awarded a Vietnamese prize of science and technology.

4. Conclusions

An experimental investigation for optimized operational parameters of scalding and defeathering process for Tam Hoang chicken was conducted on a chicken slaughtering line 500 birds/hour. Design of experiments was based Box-Benken method. ANOVA was performed to evaluate effects of the operation parametes on product quality. Results presented that scalding temperature and distance between two defeathering bands have had a most significant effect on product quality. The optimal solution based on constrained gradient provided the values optimized operation parameters: *1,8 (m^3/20birds)* in scalding water flow, *67 (^0C)* in scalding temperature and *80 (seconds)* in scalding time for scalding machine; and *415 (mm)* in the gap between two defeathering bands (included length of defeathering finger), *340 (rpm)* in defeathering disc velocity and *120 (seconds)* in defeathering time for defeathering machine.

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A practical evaluation for the optimization values was performed. Results showed that the product quality is to meet the required criteria (percentage of hair weight remained on chicken product under *95%* and undamaged skin). The stable operation and product quality of the lines which were designed based on the optimized operation parameters have confirmed the appropriateness for the values suggested.

The values of operation parameters suggested for chicken slaughtering line 500 birds/hour seems to be fit to the scale of line of under 1000 birds/hour. An analysis and technological rationalization for many different scales have being investigated.

5. Acknowledgements

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Appendices

Appendix 1:

Result of Analysis of Variance for percentage of hair weight remained on chicken product affected by scalding parameters

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
A:Water flow	4.1472	1	4.1472	4013.42	0.0002
B:Temperature	75.4606	1	75.4606	73026.40	0.0000
C:Scald.Time	7.54661	1	7.54661	7303.17	0.0001
AA	5.65823	1	5.65823	5475.71	0.0002
AB	0.8281	1	0.8281	801.39	0.0012
AC	0.0225	1	0.0225	21.77	0.0430
BB	33.908	1	33.908	32814.22	0.0000
BC	9.82823	1	9.82823	9511.19	0.0001
CC	1.86348	1	1.86348	1803.37	0.0006
Lack-of-fit	0.006625	3	0.00220833	2.14	0.3345
Pure error	0.00206667	2	0.00103333		
Total (corr.)	136.114	14			

R-squared (adjusted for d.f.) = 99.9821 percent

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Appendix 2:

Result of Analysis of Variance for percentage of hair weight remained on chicken product affected by defeathering parameters

Source	Sum of Squares	DF	Mean Square	F-Ratio	P-value
A:Distance between two defeath.bands	188.95680	1	188.95680	967.52	.0010
B:Defeath.velocity	11.32880	1	11.32880	58.01	.0168
C:Defeath.Time	9.72405	1	9.72405	49.79	.0195
AB	3.84160	1	3.84160	19.67	.0473
AC	21.52960	1	21.52960	110.24	.0089
AA	4.81081	1	4.81081	24.63	.0383
BB	5.86804	1	5.86804	30.05	.0317
Lack-of-fit	3.43306	5	.68661	3.52	.2362
Pure error	.39060	2	.19530		
Total (corr.)	250.701040	14			

R-squared (adj. for d.f.) = 0.969496

Dr.Nguyen Van Hung received his doctoral degree in Mechanical Engineering from Slovak University of Agriculture in Nitra, Slovakia Republic. He is now Vice Dean of the Faculty of Engineering, and Head of Department of Mechatronics, Nong Lam University, Vietnam. His research is focused on Agricultural Engineering, especially pertinent to improvement of agricultural process and machinery.

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