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Research on production technology of smoked-dried salted pork leg meat to ensure food hygiene and safety

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Abstract

Salted and smoked pork leg products (Ham) have become prevalent in the world for a long time. Although these foods have appeared in Vietnam for a few years, consumers warmly received them due to their tasty specificity. The quality of this product group is affected by several technological factors, including the composition of salty solution and additives, the technique of bringing meat, the heat treatment process (drying, smoking, steaming), and storage conditions. Therefore, the research of production technology to ensure food safety and hygiene are essential. Furthermore, level 2 orthogonal experimental matrix and optimization of technological factors have been applied for the best product quality. The study provides a perfect example of the production technology of bringing and drying meat products to ensure food hygiene and safety for consumers, contributing to promoting the domestic meat processing industry to develop in the direction of industrialization, safety, and integration.

Keywords: *Pork leg meat, brine, smoked, drying, hygiene, food safety.*

1. INTRODUCTION

Salted, dried, and smoked meat products have recently become prevalent and have a history dating back thousands of years due to the immediate need to preserve meat materials. Salt, dried, and smoked products which were produced from the pig's thigh are very popular with the proper name "Ham". The production technology was divided into two groups, the long-term biochemical ripening group without heating (Cured Raw Ham), famous for this type of Parma Ham, and the second group with heating (Cured Cook Ham) [1]. These products are imported and produced by domestic companies in Vietnam, mainly heated, such

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as salted, dried, and smoked pork leg of "Duc Viet", "Ong gia Ika", etc. Although the product is very popular with consumers, the quality of some products on the market is not stable, especially if there is a deterioration, such as a viscous surface, a decrease in specific taste, and sometimes a slightly sour taste before the expiration date. The quality of this product group is determined by several factors, including the soaking process with salty solution, suitable brine temperature, and time play a role in stabilizing the quality and prolonging the shelf life of the product; heating processes such as drying, smoking, steam will determine the structure, taste and especially the safety of the product. The smoking process creates a specific flavor for the product through the composition of smoke. Steaming has the effect of making the skin structure of the product softer and crispier without being tough. In addition, steaming is also a complete heat treatment process. Therefore, this study aims to determine the composition of the brine solution, the conditions of soaking in the brine solution as well as the heating and drying process for product quality that is not only appreciated for the sensory aspects such as structure, taste but also especially meeting the requirements of food hygiene and safety, ensuring the health of consumers.

2. MATERIALS AND METHODS

2.1. Materials

Raw materials for the production of pork feet in fresh form have been boned, weighing from 0.45 - 0.5 kg and meeting Vietnamese standards TCVN 7046:2019 (meat is produced at ambient temperature and stored at a temperature not lower than 0°C).

Ingredients of brine solution: NaCl, $NaNO_2$, sodium tripolyphosphate (STTP), gelatin, modified starch, sugar, etc., used with the concentration according to regulations on management of food additives in Circular 24/2019/TT-BYT. These ingredients were purchased from the supplier of components suitable for use in food.

2.2. Methods

- Determination of total aerobic microorganisms according to TCVN 4884-1:2015 - ISO 4833-1:2013;
- Determination of pH according to TCVN 4835:2002/ISO 2917: 1999;
- Determination of moisture content according to TCVN 8135:2009;
- Method of evaluating the overall quality score according to TCVN 3215-79;
- Production process of salted, dried, smoked pork leg [2]:

Boneless fresh pork leg ⟶ Wash ⟶ inject of brine solution ⟶ **Meat Brining** ⟶ **Dry**/Smoking/Cooking ⟶ Chill ⟶ Packing/ Store at 0-4°C.

2.2.1. Experimental set-up method

2.2.1.1. Study on the suitable composition of meat brining

The study was conducted by keeping some ingredients unchanged and changing the main components such as salt, modified starch (MD), and gelatin, then evaluating product quality through quality criteria such as taste, color, and texture, etc,

2.2.1.2. Study on conditions of meat brining

The meat was brined in different modes:

- Sample 1: meat brining at the ambient temperature of 26 - 30°C for 10 hours;
- Sample 2: meat brining at a temperature of 8 - 10°C for 24 hours;
- Sample 3: meat brining at a temperature of 2 - 4°C for 24 hours.

Evaluation of product quality was conducted according to physicochemical criteria (pH, moisture), microbiological, and organoleptic to find the most suitable temperature and time of meat bringing for the final product.

2.2.1.3. Study on the heat treatment process

The product is heated continuously in three stages: drying, smoking, and cooking. The drying process is the prime heating process. The long time of drying has a direct impact on the condition and safety of the product. Level 2 orthogonal experimental matrix was designed with nine experiments and two variables: drying temperature (X1), and drying time (X2) to find the temperature and drying time to ensure product safety (Table 1).

Table 1. *Level 2 orthogonal experimental matrix*

Exp No	***Drying temperature - X_1 (^oC)***	***Drying time - X_2 (hour)***
1	60	2
2	80	2
3	60	4
4	80	4
5	60	3
6	80	3
7	70	2
8	70	4
9	70	3

(X_1: 60 - 80^{o}C; X_2 : 2 - 4 hour)

The product quality was evaluated through 3 objective functions: Total aerobic microorganisms (Y1), which assesses the level of microbial contamination of the product; Mass loss (Y2) which assesses the degree of mass loss during drying; Sensory quality score (Y3) - assesses sensory quality by the scoring method.

Orthogonal experimental matrix level 2 with two variables and multi-objectives was processed by Design Expert 7.0 software, and the results would find the optimal values of variables for the best product quality on all parameters.

The smoking temperature and time with oak sawdust were fixed at 75 - 80°C for 15 minutes to create the smoke flavor and color.

The steaming time should not be too long because it will reduce the firm texture of the product; therefore, a time at 95 - 100°C was fixed for 30 minutes.

3. RESULTS AND DISCUSSION

3.1. Study on meat brining composition

3.1.1. Optimization of salt concentration

The NaCl content has a dominant influence on the texture, and the water-holding capacity especially affects the product's taste. When the NaCl content changes, the moisture content of the product does not change much, but the surface of the slices has a clear difference. It can see through the sensory evaluation, the salt concentration affects the color and taste of the product. Sensory evaluation results of meat samples with different NaCl concentrations (dried and smoked with the same mode) are shown in Table 2.

Table 2. *Sensory evaluation of salted, smoked pork leg samples with different salt concentrations*

Samples	***Concentration of NaCl (%)***	***Sensory evaluation***
1	9	Due to the slightly high salt content, the color of the meat tissue is dark, the slice surface is a bit dry, and the taste is quite salty, not suitable for the taste of domestic consumers.
2	8	Bright pink color, medium juicy of the slice surface, moderate salty taste, having the highest rating of the three samples.
3	7	Bright pink color, high wetness on the slice surface, light taste.

With the taste of Vietnamese consumers, the NaCl concentration of 9% was not suitable (slightly salty). The NaCl concentration of 7% gave a slightly bland taste, the concentration of 8% gave the most harmonious taste, and the higher the salt concentration, the more likely the product is to prolong the shelf life due to the antibacterial effect of salt. Therefore, a salt concentration of 8% is the most suitable concentration.

3.1.2. Optimization of modified starch and gelatin content

In the composition of the meat brine solution, MS and gelatin have a tremendous impact on the structure and water-holding capacity of the product. To choose the optimized content, the concentrations of these two additives were changed in the brine solution, and evaluate the product quality after being injected, brined, dried, smoked, and cooked in the same mode. The sensory evaluation results are shown in Table 3.

Table 3. *Sensory evaluation of salted, smoked pork leg samples with different concentrations of modified starch and gelatin*

Samples	***Content of modified starch (%)***	***Content of gelatin (%)***	***Sensory evaluation***
1	0	0	The product texture is very discrete because there will be no adhesion between the muscle bundles, forming many holes, and the slice surface is dry.
2	3	1	The product texture is quite good, and there is a high degree of adhesion between the muscle bundles, but due to the high concentration of gelatin, the slice surface is dense and sticky.
3	**3**	**0.5**	**The product texture is good, between the muscle bundles has high adhesion, and the surface of the slice has a wet succulence.**
4	2	0.5	The product texture is quite good, there is adhesion between the muscle bundles, and the slice surface is a bit dry.
5	4	0.5	The product texture is quite good, the muscle bundles have high adhesion, and the solid slice surface has high wet adhesion and slightly viscous.

The results show that gelatin and MS have a beneficial effect on increasing the connection and water-holding capacity of the product. However, if the concentration is too high, the product will become sticky.

Choose the content of 3% modified starch, and 0.5% gelatin is the most suitable condition.

3.2. Studying the process of meat brining and heat treatment

3.2.1. Optimization of meat brining conditions

Meat brining was proceeded at different temperatures and times for three samples in Table 4, then dried, smoked, and cooked these samples with the same mode, then the finished product was evaluated for the following criteria: physicochemical, microbiological, and organoleptic; therefore, the results are shown in Tables 4, Table 5, Figures 1, and Figure 2 as follows [3-4].

***Table 4**. Some physicochemical parameters and total aerobic microorganisms of salted, smoked pork leg samples with at different meat brining conditions*

Samples	***1 (26 - 30°C/10h)***	***2 (8 - 10°C/24h)***	***3 (2 - 4°C/24h)***
pH	5.9	**6.3**	6.3
Moisture (%)	70.12	**71.90**	68.12
Total aerobic microorganisms (CFU/g)	1×10^6	**5×10^3**	2×10^3

The results showed that the pH of sample 1 decreased slightly because the meat was brought at a high temperature of 26 - 30°C, causing the fermentation process to make the meat sour with PH 5.9. Samples 2 and 3 were brined at low temperatures that control microorganisms quite well. Sample 2 has PH 6.3, and moisture is 71.9% for a soft product structure, good bonding, and quite similar to some types of cooked "Ham" from Brazil and Spain with pH is 6.3 - 6.4 and a product moisture content is 73.7 - 74.9% [3-4].

***Table 5.** Sensory evaluation scores of* salted, smoked pork leg *samples at different temperatures and times of meat brining*

Samples	***Temperature/Time meat brining***	***Sensory evaluation***
1	(26 - 30°C)/10h	The meat is soft, the fat layer is soft, and the color is clear due to too much penetration of the salt solution. The taste is uncharacteristic, slightly sour taste.
2	(8 - 100°C)/24h	The meat has a characteristic aroma, characteristic pinkish-red muscle tissue color, well-structured white fat, harmonious flavor.
3	(2 - 4°C)/24h	The meat is fragrant, the muscle tissue color is light pink, the structure is good, the taste is slightly pale.

***Figure 1.** Image of TAM colonies with 10 $^{-4}$ dilution of salted, dried, and smoked pork leg samples at different conditions from left to right are 26 - 30°C, 8 - 10°C and 2 - 4°C*

From the results obtained, it is found that it is impossible to meat brining in conditions of high temperature of 26 - 30°C, even though the time is shorter because the development of the microflora cannot be controlled, leading to bad changes to the properties of the meat, such as sour taste and product safety. Both sample 2 and sample 3 brined meat at low temperature showed that the microorganism was quite low within the allowable limit, but the sensory evaluation showed that sample 3 had a not very thorough salting process. The penetration of the brine into the meat after 24 hours has not reached the maximum, so the color and taste are worse than that of sample 2, and at the same time, when salting at low temperature will have a higher cost, so choose the meat brining mode optimal is 8 - 10°C for 24 hours.

Figure 2. *Slice surface of meat samples brined in different conditions*

3.2.2 Study on heat treatment process

3.2.2.1. Evaluation of heating regimes at different drying temperatures

The product heating process is preceded through 3 stages: three samples were dried for 4 hours at different temperatures of 60°C (sample 1), 70°C (sample 2), and 80°C (sample 3). After being smoked at 75 - 80°C/15 minutes, these samples were steamed at 95 - 100°C/30 minutes. Measure the temperature at the center of the product during the heating process, and the results were shown in Figure 3.

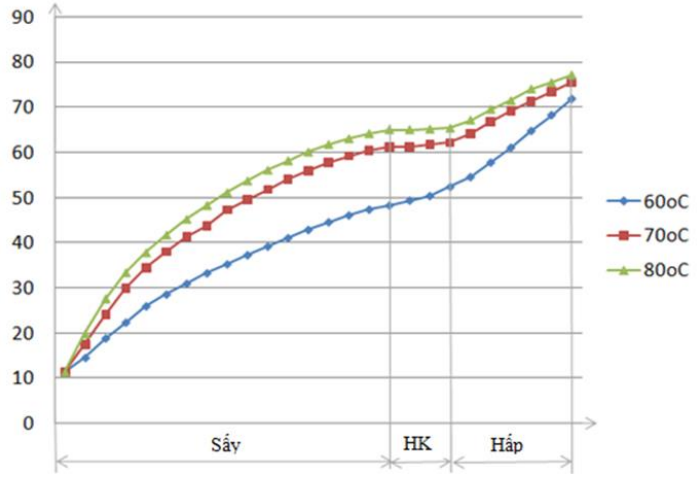

Figure 3*. Temperature at the center of the product during heating process*

According to the standards to ensure food hygiene and safety for this product group, center temperature must be maintained at ≥ 68°C for at least 20 minutes (TCVN 5542:2008). The results showed that the samples dried at 60°C did not meet the above requirements due to the low drying temperature. Samples dried at 70°C and 80°C meet the requirements for the temperature at the product center of 68 - 75°C/20 minutes. However, in order to choose the right drying temperature, it is necessary to fully consider especially the organoleptic quality, the mass loss, and the specific microbiological criteria. Therefore, select the appropriate drying mode through the level 2 orthogonal experimental matrix

3.2.2.2. Level 2 orthogonal experimental matrix optimize drying mode

Factors affecting product quality were investigated according to level 2 orthogonal experimental with Hadamard matrix, results processed by Design Expert 7.0 software. The equation of the objective function of product quality found as Total aerobic microorganisms (Y_1), Weight loss (Y_2), and sensory quality score (Y_3) depend on two variables of drying temperature (X_1) and (X_2) as follows:

Regression equation of Total aerobic microorganisms function

$$\mathbf{Y_1 = + 3.91 - 0{,}99 \times X_1 - 0.57 \times X_2 - 0.023 \times X_1 \times X_2 + 0{,}38 \times X_1^2 + 0.16 \times X_2^2}$$

$$\mathbf{R^2 = 0.9958}$$

Through the regression equation showing the relationships of the function Y_1 with the factors, we can see that both temperature and drying time have a dominant influence on Y_1 at level 2. Furthermore, both factors exert influence on the number of microorganisms through the regression coefficient $X_1 \times X_2$. The results are shown in Figure 4.

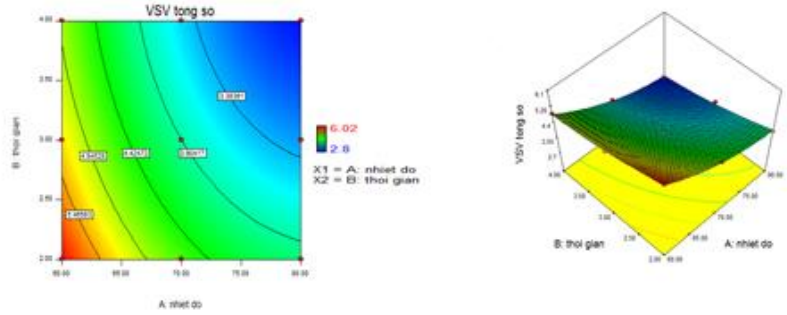

Figure 4. *Response surface of Total aerobic microorganisms depends on drying temperature and drying time*

Regression equation of mass loss function

$$Y_2 = + 10.94 + 1.11 \times X_1 + 0.86 \times X_2 + 0.47 \times X_1 \times X_2$$

$$R^2 = 0.9587$$

Regression equation of the sensory function

$$Y_3 = + 17.60 + 1.80 \times X_1 + 0.57 \times X_2 - 1.15 \times X_1 \times X_2 - 2.20 \times X_1^2 - 0.70 \times X_2^2$$

$$R^2 = 0.9598$$

The correlation coefficient R^2 of the objective functions which is in the range of 0.9587 - 0.9958 shows that the found regression equation shows relatively accurately the correlation or the obvious influence of the variables on the functions according to certain rules.

For smoked meat to have the best quality, the following criteria must be met:

- The total aerobic microbiological value should be as low as possible and should not exceed 105 (logCFU/g ≤ 5).
- The lower the mass loss, the better.
- The higher the sensory score, the better.

Using Design expert 7.1 mathematical software to analyze and process data, find the objective convolution for the optimal solution shown in Figures 5 and Table 6.

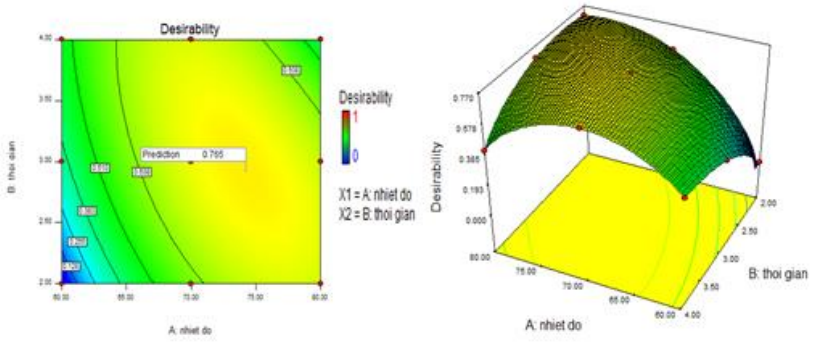

Figure 5. *Response surface of the objective convolution function*

The yellow area on the graph is the limit area which the best results, the optimal value is the point at the center of the region, and the significance level is 0.765.

Variable values and objective functions of the optimal results are shown in Table 6.

Table 6. *Values of variables, functions of the optimal solution*

Values of optimal variables	***Teperature (°C)***	***Time (h)***	***The objective convolution function***
	74.22	2.92	0.765
Values of optimal functions	***Total aerobic microorganisms (logCFU/g)***	***Weight loss (%)***	***Sensory quality score***
	3.60531	11.3186	17.9564

3.2.3. Evaluation of product quality under optimal conditions and during storage

The production of smoked-dried salted pork leg meat is preceded according to the optimal parameters found above drying at 74.22°C/2.92h rounded up to 75°C/3h, then vacuum packed and stored at 0 - 4°C, the results of the analysis of the quality criteria of the product. At storage time, the average result after three times is shown in Table 7.

Table 7. *Evaluating of product quality in the optimal solution*

Storage time (days)	0	10	20	30		40
				Optimal sample	***Market sample****	
Total aerobic microorganisms (CFU/g)	5×10^3	1×10^3	2×10^3	9×10^3	$4{,}2 \times 10^6$	$1{,}5 \times 10^4$
Sensory quality score	18	18	18	17	14	17

* Market samples bought at supermarkets were analyzed on the 30th day after production and had a shelf life of 35 days.

After the vacuum storage at 0 - 4°C, the product quality after 10, 20 days did not change compared to the recently manufactured sample in terms of all indicators, firmer texture and quantity of aerobic microorganisms decreased (possibly due to low storage temperature inhibiting growth).

After the storage period of 30, 40 days, the smoke flavor has decreased slightly but not significantly, while the color and other flavors have not changed much. Microbiological criteria are still within the allowable limits ($\leq 3 \times 10^5$ CFU/g) according to QCVN 8-2:2011 and TCVN 7049:2020 [5].

Comparative assessment with samples of salted, dried, and smoked pork leg products on the market after 30 days of production showed that the market products have much worse quality, wet slice surface, and begin to have viscosity, light pinkish red. Regarding the microbiological criteria, the market sample has a high total number of microorganisms, exceeding the allowed standard.

4. CONCLUSION

The study has obtained some valuable results: Main ingredients of the brine solution have been optimized: NaCl 8%, gelatin 0.5%, modified starch 3%. The condition of brining process for salted and smoked pork leg products was determined at a temperature of 8 - 10^{o}C for 24 hours. A suitable heat treatment regime has been found for salted and smoked pork leg products: dried at 75^{o}C for 3 hours, smoked for 15 minutes at 75 - 85^{o}C, steamed for 30 minutes. Evaluated product quality right after production and within 40 days of storage at 0 - 4°C, vacuum packed show that the product meets all the criteria, ensuring hygiene and safety according to Vietnamese standard TCVN 7049-2020, the taste is harmonious and delicious and is much higher than that of the same type on the market.

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Nghiên cứu công nghệ sản xuất thịt chân giò muối sấy, hun khói đảm bảo vệ sinh an toàn thực phẩm

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Tóm tắt

Sản phẩm thịt chân giò muối sấy hun khói *(Ham)* được xuất hiện từ rất lâu trên thế giới, tuy nhiên ở Việt Nam mới chỉ được có mặt từ vài năm trở lại đây, nhưng đã được người tiêu dùng đón nhận rất nồng nhiệt bởi hương vị thơm ngon đặc trưng của nó. Chất lượng của nhóm sản phẩm này bị ảnh hưởng nhiều bởi các yếu tố công nghệ như: Thành phần dung dịch muối với các phụ gia an toàn, kỹ thuật muối thịt cũng như quá trình xử lý nhiệt (sấy, hun khói, hấp), quá trình bảo quản,... Việc nghiên cứu đầy đủ công nghệ sản xuất sản phẩm này nhằm đảm bảo chất lượng vệ sinh an toàn thực phẩm (VSATTP) là rất cần thiết. Bài toán qui hoạch thực nghiệm trực giao cấp 2 và tối ưu các yếu tố công nghệ cho chất lượng sản phẩm tốt nhất đã được áp dụng. Tất cả điều này giúp hoàn thiện công nghệ sản xuất sản phẩm thịt muối hun khói đảm bảo VSATTP cho người tiêu dùng, góp phần thúc đẩy ngành chế biến thịt trong nước phát triển theo hướng công nghiệp hóa, an toàn và hội nhập.

***Từ khóa**: Thịt muối hun khói, chất lượng sản phẩm, chỉ tiêu hóa lý, chỉ tiêu vi sinh vật.*