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Research Article

Optimization of the Smoking Process of Pangasius Fish Fillet to Increase the Product Quality

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Abstract: The aim of this study is building the mathematical models to determine the effects of moisture in raw material, temperature of the smoking process and treatment time on quality of the product (smoking Pangasius fish fillet) by the experimental method. The results showed that the optimal conditions for the smoking process of Pangasius fish fillet were the moisture in raw material of 71.3%, smoking temperature of 34.4°C and smoking time of 8 h 55 min. At these conditions, the maximum value of total phenolic compounds, minimum value of total aerobic bacteria and sensory value were 38.6 ppm and 710 CFU/g and 16.33, respectively. The results were suitable with experimental conditions. The product not only met the microorganism require but also had good sensory value.

Keywords: Multi-objective optimization problems, optimization, phenolic compounds, sensory value, smoking, smoking process, total aerobic bacteria

INTRODUCTION

Pangasius fish (Pangasius hypophthalmus) is one of the most grown fish in Mekong Delta area of Vietnam. The production of Pangasius fish each year in this area increases rapidly. For instances, the quantity increased from 70 000 ton in the year 2000 to 400 000 ton in the year 2005 which then rose sharply to 1.5 mil ton in the year 2012 (Alasalvar *et al*., 2010; Can *et al*., 2001, 2002; Janes, 2001; Anh, 2005). Pangasius fish which belongs to Siluriformes group has ivory-white, tender, favorful meat incomparison with other freshwater fish. The composing of Pangasius fish fillet was: 19.6% protein, 2.1% lipid, 74.8% water and 3.5% minerals. Besides, Pangasius fish also contents significant amount of essential amino acid such as: valine, leucine, isoleucine, methionine, phenylanine, tryptophan, lysine, arginine, histidine and threonine (Can *et al*., 2001, 2002).

According to Alasalvar *et al*. (2010) and Janes (2001), when sawdust of wood is incompletely fired, the wood will release up to 480 different kinds of flavorings. In addition, fired wood also releases some antibacterial and antioxidant substances. The composition of these substances mainly depends on kind an characteristics of the wood. In food technology, the smoking is one of the earliest technological food process in 12th century in Europe. The intrinsic mocking process of Pangasius fish fillet consists of two parallel processes: Firstly, the separative water inside product under temperature gradient and moisture gradient from smoking process. Secondly, the diffusion and the osmosis of flavorings, antibacterial and antioxidant substances into the product under the mechanism of the complicated adsorption. These substances adsorbed into the surface product; consequently, they osmose into product because of differences of concentration gradient and temperature gradient. This process will make the Pangasius fish fillet ripen naturally and create product with special smell and taste, flavorous and that increase the product value (Anh, 2005).

Also, the product after smoking has the antibacterial property and the ability to prevent the product from oxidization during the preservation process (Dzung, 2011; Anh, 2005). Therefore, the shelf life of the product will be extended for a long time.

It could be said that moking is complicated physicochemical process. The amount of flavorings, antibacterial and antioxidant substances which absord into the product has not been determined exactly until now (Canh, 2004). The previous research about smoking mainly focused on the establishment of technical mode which was used to made product with high quality and long shelf-life. However, the problem related to the determination of amount of absorbed antibacterial and antioxidant substances, bacteria and sensory evaluation of the product especially smoking Pangasius fish fillet has not been clearly considered (Canh, 2004; Dzung *et al*., 2010a).

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Fig. 1: The smoking equipment

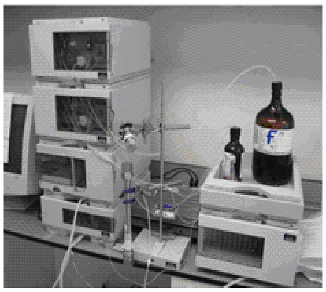

Fig. 2: The system of HPLC

To solve this problem, this study have built the mathematical models to describe the relationship between moisture inside the Pangasius fish fillet (Z_1, %), temperature of the smoking process (Z_2, °C) and smoking time (Z_3, h) with the amount of adsorbed phenolic compound (y_1, ppm), total amount of aerobic bacteria in the product (y_2, CFU/g) and the sensory value of the product (y_3).

Based on that foundation, the multi-objective optimization problem was established. By the utopian method, the optimization problem was solved to find root to determine technological mode for the moking process of Pangasius fish fillet.

MATERIALS AND METHODS

Materials: Pangasius fish of approximately (1.0÷1.2) kg/body grown in the MeKong delta area of Vietnam was cut off head, viscera and filleted.

The Pangasius fish was filleted into small pieces (0.15÷0.2) kg/piece before smoking. The nutrition composition of the Pangasius fish fillet was: 19.6% protein, 2.1% lipid, 74.8% water and 3.5% mineral (Can *et al*., 2001, 2002).

According to Can *et al*. (2001, 2002), the pretreatment of Pangasius fish fillet was done before smoking process. Firstly, the fillet was sunk into salt solution (12÷15) % for 17 h at (4÷6) °C. The process insured that structure of the fillet was tender. Subsequently, the fillet was desalinated until the amount of salt inside Pangasius fish fillet was (2.5÷3) %. Finally, the Pangasius fish fillet was dried to evaporate water on the surface.

The sawdust of *Artocarpus heterophyllus* wood has a moisture of 28% was used to create smoke.

Tools and equipments:

- Smoking creator equipment (Fig. 1)
- HPLC equipment was used to determine the amount of total phenolic compounds (Fig. 2)
- Tools for determination of total amount of aerobic bacteria: tubes, pipetes, petri disks and Wilson Blair media
- Sensory value of the product was evaluated by a group of experiential testers. The mark scale was 20
- Besides, other equipments and machines were also used in this study such as: quantity scale, infrared scale to determine moisture content, salt concentration equipment, thermometer and timer

Methods:

- Total phenolic compounds (y_1, ppm) were examined by HPLC, 1994 (Dzung *et al*., 2010b)
- The total amount of aerobic bacteria in the product (y_2, CFU/g) was examined by the method in Vietnamese standard methods (TCVN 4884: 2005), (Dzung, 2011) according to the equation below:

$$y_2 = \frac{\sum C}{(n_1 + 0.1\, n_2)d}, \text{ CFU/g} \quad (1)$$

where,

$\sum C$ = Total amount of CFU in two petri disks which have sequent concentrations of media
n_1 = Number of disk counted at first concentration
n_2 = Number of disk counted at second concentration
d = First concentration of media in petri disk.
y_2 (CFU/g) = Total amount of CFU in 1 g of sample

- Sensory value of the product was determined by scaling method (Harry and Hildegarde, 2010) with range scale of 20, according to the equation below:

$$y_3 = \frac{1}{n}\sum_{i=1}^{n} H_i \quad (2)$$

where,

n = The amound of tester
H_i = Point that the tester evaluated

- The experimental method and secondary orthogonal experimental method of Box-Hunter were used to establish the mathematical model to describe the smoking process of Pangasius fish fillet (Dzung, 2012)
- Mathematical tools, Microsoft Excel and MATLAB V.7.0.1 software were used to solve the mathematical model to find out the optimal roots (Dzung, 2012)

RESULTS AND DISCUSSION

Buiding the mathematical model to describe the smoking process of Pangasius fish fillet: On the basis of the system analysis and approach, it can be seen that the smoking process of Pangasius fish fillet mainly depend on the technological parameters of the smoking process such as: moisture inside the Pangasius fish fillet (Z_1, %), temperature of the smoking process (Z_2, °C) and smoking time (Z_3, h). These technological parameters affect objective functions: the total amount of phenolic compounds (y_1, ppm), total amount of aerobic bacteria (y_2, CFU/g) and the sensory value of the product (y_3).

Therefore, the technological mode for the smoking process of Pangasius fish fillet need to be determined in order to produce high quality product and extend the shelf-life. At the high quality, the product has maximum level of phenolic compounds, minimum total value of bacteria and maximum level of sensory value. As a consequences, in this study, the mathematical model was built by Box-Hunter (Canh, 2004) with $k = 3$, $n_0 = 6$ about the relations between y_1, y_2, y_3 with Z_1, Z_2, Z_3, (Heldman and Lund, 1992; Haugvalstad *et al*., 2005; Hai and Lan, 2008a; Dzung, 2011, 2012) according to the equation bellow:

$$y = b_0 + \sum_{j=1}^{k} b_j x_j + \sum_{j \neq i; j=1}^{k} b_{ji} x_j x_i + \sum_{j=1}^{k} b_{jj} x_j^2 \tag{3}$$

- Number of experiment in this method was determined as the equation follow:

$$N = 2^k + 2k + n_0 = 2^3 + 2x3 + 6 = 20 \tag{4}$$

- In order to the experimental matrix is orthogonal, α was determined as follow:

$$\alpha = 2^{k/4} = 1.682 \tag{5}$$

- x_1, x_2, x_3 are variables that were coded with Z_1, Z_2, Z_3 and were calculated as the equation described below:

$$x_i = \frac{Z_i - Z_i^0}{\Delta Z_i}, \quad i = \overline{1,3} \tag{6}$$

where, $Z_i^{min} \le Z_i \le Z_i^{max}$

$$Z_i^0 = \frac{Z_i^{max} + Z_i^{min}}{2}; \quad \Delta Z_i = \frac{Z_i^{max} - Z_i^{min}}{2} \tag{7}$$

From the conditions of technology, experimental process as well as production process, the range of technological parameters used in this research was presented in the Table 1:

The experiment was carried out with the level of technological parameters in Table 1 and experimental plans in Table 2. The results of objectives at different levels were also presented in Table 2.

The results in Table 2 was calculated by using Microsoft Excel 2010 to determine coefficiences of the

Table 1: Level of technological parameters in the experimental design

Parameters	Levels					Deviation ΔZ_i
	$-\alpha$ (-1.682)	Low -1	Central 0	High +1	$+\alpha$ (1.682)	
Z_1 (%)	64.590	68	73	78	81.410	5
Z_2 (°C)	30.636	32	34	36	37.364	2
Z_3 (h)	4.6360	6	8	10	11.364	2

Table 2: Matrix of Box-Hunter's secondary orthogonal experimental method with $k = 3$, $n_0 = 6$

N		x_0	x_1	x_2	x_3	x_1x_2	x_1x_3	x_2x_3	x_1^2	x_2^2	x_3^2	y_1	y_2	y_3
	1	1	+1	+1	+1	+1	+1	+1	+1	+1	+1	36.5	970	15.2
	2	1	-1	+1	+1	-1	+1	+1	+1	+1	+1	34.1	775	12.5
	3	1	+1	-1	+1	-1	+1	-1	+1	+1	+1	36.8	890	14.6
2^k	4	1	-1	-1	+1	+1	-1	-1	+1	+1	+1	34.6	754	12.8
	5	1	+1	+1	-1	+1	-1	-1	+1	+1	+1	25.3	960	12.0
	6	1	-1	+1	-1	-1	+1	-1	+1	+1	+1	21.6	820	10.4
	7	1	+1	-1	-1	-1	-1	+1	+1	+1	+1	30.2	1055	11.2
	8	1	-1	-1	-1	+	+1	+1	+1	+1	+1	28.6	1033	9.30
	9	1	+1.682	0	0	0	0	0	2.829	0	0	35.6	910	15.6
	10	1	-1.682	0	0	0	0	0	2.829	0	0	28.2	893	10.1
2k	11	1	0	+1.682	0	0	0	0	0	2.829	0	30.8	780	14.1
	12	1	0	-1.682	0	0	0	0	0	2.829	0	35.8	1028	11.3
	13	1	0	0	+1.682	0	0	0	0	0	2.829	36.5	788	15.0
	14	1	0	0	-1.682	0	0	0	0	0	2.829	22.7	1080	8.30
	15	1	0	0	0	0	0	0	0	0	0	37.1	724	16.6
	16	1	0	0	0	0	0	0	0	0	0	38.8	750	17.8
n_0	17	1	0	0	0	0	0	0	0	0	0	38.2	704	16.1
	18	1	0	0	0	0	0	0	0	0	0	37.3	757	16.6
	19	1	0	0	0	0	0	0	0	0	0	39.7	762	15.8
	20	1	0	0	0	0	0	0	0	0	0	38.2	714	16.5

experimental models (the regression equations). Subsequently, these coefficients were checked about the significance by Student standard and about the compatible of the regression equation by Fisher standard (Alasalvar *et al*., 2010; Can *et al*., 2001, 2002; Dzung and Dzung, 2011; Janes, 2001; Anh, 2005). Final mathematical models were presented below:

Mathematical model described the total amount of phenolic compounds absorbed in smoking fillet:

$$y_1 = 38.18 + 1.63x_1 - 1.54x_2 + 4.35x_3 - 2.27x_1^2 - 1.77x_2^2 - 3.08x_3^2 \quad (8)$$

- Mathematical model described the total amount of aerobic bacteria in smoking fillet:

$$y_2 = 734.5 + 38.18x_1 - 45.68x_2 - 71.01x_3 + 51.12x_2x_3 + 5.59x_1^2 + 56.47x^2_2 + 66.08x_3^2 \quad (9)$$

- Mathematical model described sensory value of smoking fillet:

$$y_3 = 16.54 + 1.26x_1 + 1.71x_3 - 1.28x_1^2 - 1.34x^2_2 - 1.71x_3^2 \quad (10)$$

The single objective optimization problems in the technological smoking of Pangasius fish fillet:

- **Building the single objective optimization problem :** Effects of x_1, x_2, x_3 on objective functions y_1, y_2 and y_3 individually were determined by Eq. (8), (9) and (10). It can be clearly seen that the single objective optimization problem was formed. Therein, the objective functions y_1, y_3 found maxium level whereas the objective function y_2 found minimum level (y_1, y_2, $y_3>0$). Therefore, in order to solve the multi-objective optimization problem afterward, the all mathematical equations were changed into the same form, that is to find the minimun level. By that, the new functions were formed from functions of y_1, y_2 and y_3 (Mercier *et al*., 1998; Harry and Hildegarde, 2010) :

$$I_1(x) = I_1(x_1, x_2, x_3) = 1/y_1(x) = 1/f_1(x_1, x_2, x_3) \quad (11)$$

$$I_2(x) = I_2(x_1, x_2, x_3) = y_2(x) = f_2(x_1, x_2, x_3) \quad (12)$$

$$I_3(x) = I_3(x_1, x_2, x_3) = 1/y_3(x) = 1/f_3(x_1, x_2, x_3) \quad (13)$$

It can be clearly seen that when $I_1(x) \to I_{1min}$, $y_1(x) \to y_{1max}$; when $I_3(x) \to I_{3min}$, $y_3(x) \to y_{3max}$

Therefore, the single objective optimization problem was written as follow: finding $x = (x_1^{jopt}, x_2^{jopt}, x_3^{jopt}) = \{-1.682 \le x_1, x_2, x_3 \le 1.682\} \in \Omega_x$ with $j = 1 \div 3$ in order to:

Table 3: Roots of the single objective optimization problems

j	y_j	I_{jmin}	$x_1^{j\,opt}$	$x_2^{j\,opt}$	$x_3^{j\,opt}$
1	40.343	0.025	0.359	-0.435	0.706
2	707.00	707.0	-0.343	0.195	0.462
3	17.278	0.058	0.492	0.000	0.500

$$\begin{cases} I_{jmin} = I_j\left(x_1^{jopt}, x_2^{jopt}, x_3^{jopt}\right) \\ \quad = \text{Min}\left\{I_j\left(x_1, x_2, x_3\right)\right\} \\ \forall x = (x_1, x_2, x_3) \in \Omega_x;\ j = 1 \div 3 \end{cases} \quad (14)$$

- **Solving the single objective optimization problem:** According to Harry and Hildegarde (2010), solving the single objective optimization problem means to find the root $x = (x_1^{jopt}, x_2^{jopt}, x_3^{jopt}) \in \Omega_x$ with $j = 1 \div 3$ to $I_{1min} = I_1(x_1^{1opt}, x_2^{1opt}, x_3^{1opt})$; $I_{2min} = I_2(x_1^{2opt}, x_2^{2opt}, x_3^{2opt})$; $I_{3min} = I_3(x_1^{3opt}, x_2^{3opt}, x_3^{3opt})$. By using meshing method (Hai and Nguyen, 2008b) programmed in MATLAB 7.0 software, the single objective optimization problem were solved. The results were presented in Table 3.

Comments: Results of single objective optimization problem (14) have showed that maximum level of y_1, y_3 was $y_{1max} = 40.343$; $y_{3max} = 17.278$, respectively and minimum level of y_2 was $y_{2min} = 707.0$, the results were completely compatilbe with experimental data in Table 2. However, single objective optimization problems (14) did not exist the same roots $y_1 = y_{1max}$; $y_2 = y_{2min}$; $y_3 = y_{3max}$ because $(x_1^{jopt}, x_2^{jopt}, x_3^{jopt}) \neq (x_1^{kopt}, x_2^{kopt}, x_3^{kopt})$ with $j, k = 1 \div 3$, $j \neq k$. Therefore, the utopian root and the utopian plan did not exist, but the utopian point could be determined as follow: $y^{UT} = (y_{1max}, y_{2min}, y_{3max}) = (40.343, 707.0, 17.278)$ or $I^{UT} = (I_{1min}, I_{2min}, I_{3min}) = (0.025, 707.0, 0.058)$.

Building and solving the multi-objective optimization problem in the technological smoking of Pangasius fish fillet:

- **Building the multi-objective optimization problem:** Due to the parameters affected the objective functions in the same technological subject; therefore, the effects of x_1, x_2, x_3 on all objective functions were determined simultaneously. As a consequence, it could be seen that in the research of technological somking process of Pangasius fish fillet, the multi-objective optimization problem had appeared. Thus, the multi-objective optimization problem was written as follow: finding the root $x = (x_1^{opt}, x_2^{opt}, x_3^{opt}) = \{-1.682 \le x_1, x_2, x_3 \le 1.682\} \in \Omega_x$ with $j = 1 \div 3$ in order to:

$$\begin{cases} I_{jmin} = I_j\left(x_1^{opt}, x_2^{opt}, x_3^{opt}\right) \\ \quad = \text{Min}\left\{I_j\left(x_1, x_2, x_3\right)\right\} \\ \forall x = (x_1, x_2, x_3) \in \Omega_x;\ j = 1 \div 3 \end{cases} \quad (15)$$

- **Solving the multi-objective optimization problem:** The results of solving the single objective optimization problems showed that the utopian roots and the utopian plan did not exist, but the utopian point could be was also determined I^{UT} = (0.025, 707.0, 0.058). Therefore, the multi-objective optimization problem (15) need to be solved to find optimal Pareto root (x_1S, x_2S, x_3S) so that the distance between optimal Pareto efficiency IPS and utopian point $I^{UT} = (I_{1min}, I_{2min}, I_{3min})$ was the closest. The results obtained were used to set up technological mode of the smoking process of Pangasius fish fillet to apply for industrial production process.

According to Hai and Lan (2008a), to find root of multi-objective optimization problem, the utopian method should be applied. This method proposed S-optimal combination criterion, it is distance between the point in optimal Pareto efficiency set and the utopian point and can be written as follow:

$$S(I_1, I_2, I_3) = S(y_1, y_2, y_3) = S(x_1, x_2, x_3) = S(x) = \left\{\sum_{j=1}^{3}\left(I_j - I_{j\min}\right)^2\right\}^{1/2} \qquad (16)$$

The Eq. (16) can be written as follow:

$$S(x) = \{(I_1 - I_{1min})^2 + (I_2 - I_{2min})^2 + (I_3 - I_{3min})^2\}^{1/2} \qquad (17)$$

$$\forall x = (x_1, x_2, x_3) = \{-1.682 \le x_1, x_2, x_3 \le 1.682\} \in \Omega_x$$

If S(x) was chosen as objective function, the multi-objective optimization problem (17) would be present as follow: to find optimal Pareto root xS = (x_1S, x_2S, x_3S) = $\{-1.682 \le x_1, x_2, x_3 \le 1.682\} \in \Omega$ in order to:

$$\begin{cases} S_{\min} = S\left(x_1S, x_2S, x_3S\right) = \text{Min}\ \left\{S\left(x_1, x_2, x_3\right)\right\} \\ \qquad = \text{Min}\left\{\sum_{j=1}^{3}\left(I_j - I_{j\min}\right)^2\right\}^{1/2} \\ \forall x \in \Omega_x = \{-1.682 \le x_1, x_2, x_3 \le 1.682\} \end{cases} \qquad (18)$$

The multi-objective optimization problem were solved by mesh method programed in MATLAB 7.0 software Hai and Nguyen (2008b). The result had found roots as follow:

$$S_{min} = 0.012$$

at:

$$x_1S = -0.342;\ x_2S = 0.209;\ x_3S = 0.462 \qquad (19)$$

Subtitute (19) into (11), (12) and (13) to find the optimal Pareto root as follow:

$$I_1PS = 0.026;\ I_2PS = 707.099;\ I_3PS = 0.061 \qquad (20)$$

Corresponding to (20):

$$y_1PS = 38.31;\ y_2PS = 707.099 \text{ and } y_3PS = 16.33$$

Change (19) into real root:

$$Z_1 = 71.3\ \%;\ Z_2 = 34.4°C;\ Z_3 = 8\text{ h }55\text{ min} \qquad (21)$$

Commets:

- With optimal Pareto roots x_1S = -0.342; x_2S = 0.209; x_3S = 0.462 (the real roots were Z_1 = 71.3%; Z_2 = 34.4°C; Z_3 = 8 h 55 min, respectively) of the multi-objective optimization problem (15) or (18), the mathematical model about the smoking process of Pangasius fish fillet was built with optimal Pareto efficiency IPS = (I_1PS, I_2PS, I_3PS) = (0.026, 707.099, 0.061). In this case, the distance between IPS = (I_1PS, I_2PS, I_3PS) = (0.026, 707.099, 0.061) and utopian point $I^{UT} = (I_{1min}, I_{2min}, I_{3min})$ = (0.025, 707.0, 0.058) or yPS = (y_1PS, y_2PS, y_3PS) = (38.31, 707.099, 16.33) and $y^{UT} = (y_{1max}, y_{2min}, y_{3max})$ = (40.343, 707.0, 17.278) was the nearest. It could be seen in (15) or (18) that when one objective increased, the other objective decreased. Therefore, the effects of parameters on objective functions in (15) or (18) should be carried out simultaneously. The results showed that optimal Pareto roots did not reduce value of any objective functions. Therefore, it could be used to establish technological mode for the smoking process of Pangasius fish fillet.
- From the results, it could be said that optimal Pareto roots and optimal Pareto efficiency were completely compatible with results in Table 2.

Experiment confirm optimal pareto root: When the smoking process of Pangasius fish fillet was carried out at optimal Pareto root with moisture inside the fillet of Z_1 = 71.3%, tempturature the smoking process of Z_2 = 34.4°C and smoking time of Z_3 = 8 h 55 min, the total amount of phenolic compounds, the total amount of aerobic bacteria and the sensory value of the product were 38.6 ppm, 710 CFU/g, 16.5, respectively. In comparision with optimal Pareto efficiency (y_1PS = 38.31; y_2PS = 707.099; y_3PS = 16.33), the optimal Pareto roots were completely compatible with the experimental data.

Comments: The simulation of the mathematical models of the objective functions (11), (12), (13) and (17) in 3D were performed in Fig. 3, 4, 5 and 6.

When the smoking process was carried out at high temperature for a long time, the dehydration of moisture on the surface of Pangasius fish fillet will made the surface dry rapidly. As a result, a film on the surface of Pangasius fish fillet would be formed and this film will prevent absorption process of odour from smoking on the surface of product. This much, it will

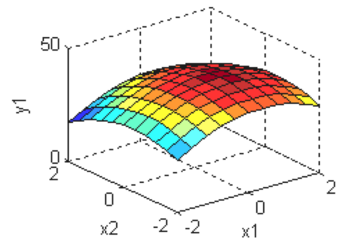

Fig. 3: The concentration of phenol, x3 = 0.462

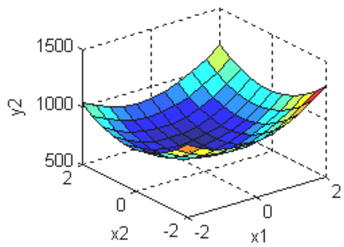

Fig. 4: The concentration of microorganism, x3 = 0.462

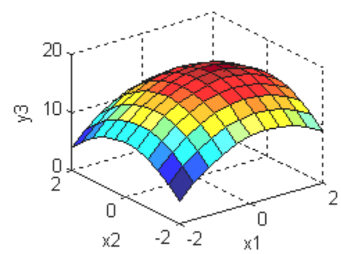

Fig. 5: The mark of sensory value, x3 = 0.462

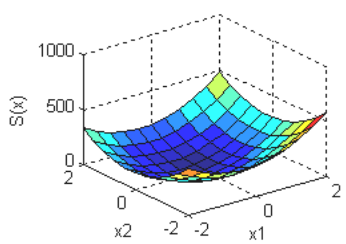

Fig. 6: The function S(x), x3 = 0.462

Fig. 7: The final product of technological smoking fillet Pangasius hypophthalmus

prevent the endosmosis and diffusibility process of odour from smoke into product and hinder diffusibility process of moisture from inside to outside simultaneously. Therefore, if the moking process was prolonged, the surface film would formed stably. In this case, the suface was ripen while the inside was not. As a result, the nutritious value and sensory value of the product would affected. In additon, the shelf-life of the product was also decreased.

It could be seen that when moisture inside the Pangasius fish fillet of Z_1 = 71.3%, tempturature of the smoking process of Z_2 = 34.4°C and smoking time of Z_3 = 8 h 55 min, the total amount of phenolic compounds reached maxium level (38.6 ppm), the total amount of aerobic bacteria decreased to the minimum level (710 CFU/g) and the sensory value of the product was the highest level 16.5. The results also showed that the film did not formed on the surface of the product, the antioxidants and odours were detected on the surface and even inside the product. The smoking fillet has brown yellow in color, tender and touch in structure, and special smell in sensory value (Fig. 7).

The preservation of smoking fillet has also done to research the effects of smoking process at optimal condition on quality of smoking Pangasius fish fillet. The results showed that nutritious and sensory value of the Pangasius fish fillet did not significantly change after 2 months preserving.

CONCLUSION

- From the results obtained, it could be concluded that mathematical models were built by the experimental method had well described the smoking process of Pangasius fish fillet. For this reason, they were used to set up the multi-objective optimization problem to determine the technological mode of smoking process of Pangasius fish fillet.
- Solving the multi-objective optimization problem to describe the smoking process of Pangasius fish fillet had found the optimal condtions for the smoking process of Pangasius fish fillet: moisture inside the fillet of Z_1 = 71.3%, tempturature of the smoking process of Z_2 = 34.4°C and smoking time of Z_3 = 8 h 55 min. At these conditions, the total amount of phenolic compounds reached maxium level of 38.6 ppm, the total amount of aerobic bacteria decreased to the minumum level of 710 CFU/g and the sensory value of the product were the highest level 16.5. The fillet has brown yellow color, sweet taste, special smell and long shelf-life. This was the scientific standard to choose the technological mode for the smoking process of Pangasius fish fillet to reach the maximum value.

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