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Optimisation of Soaking Conditions to Improve the Quality of Frozen Fillets of Bocourti's Catfish (*Pangasius bocourti* Sauvage) using Response Surface Methodology (RSM)

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ABSTRACT

Bocourti's catfish (*Pangasius bocourti* Sauvage) is one of Asia's economic freshwater fish. The fish has high demand in Asian markets particularly as a frozen product due to its tasty meat and a size that makes it suitable for cooking as fish steak. However, there are few studies about its production and quality. For frozen products, soaking in appropriate chemicals and conditions is the key procedure that food producers use to improve the quality of the frozen fillet. Therefore, this research aims to establish the optimum conditions for soaking. Several phosphate compounds, sodium acid pyrophosphate (SAPP), tetra sodium pyrophosphate (TSPP), sodium tripolyphosphate (STPP) and sodium hexametaphosphate (SHMP), were investigated. It was found that the best phosphate compound was STPP that provided high L*, a*, gained weight, cooking yield and sensory acceptability with less drip loss and cooking loss. Consequently, the optimisation of the soaking condition was conducted. The three main factors, STPP (0.13-4.38% w/v), soaking time (3-37 min) and salt concentration (0.30-3.70% w/v), were optimised by response surface methodology (RSM). The results showed that the optimised condition was STPP of 2.56%, soaking time of 37 min and salt concentration of 3.70%. At this condition, the obtained frozen fillets showed a good result with gained weight of 11.45%, cooking yield of 73.11%, a* of 10.97 and ^{o}h of 9.94, respectively.

Keywords: phosphate, *Pangasius bocourti* Sauvage, frozen fillets, response surface methodology, soaking conditions

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INTRODUCTION

Bocourti's catfish (*Pangasius bocourti* Sauvage) is an important fish for aquaculture in Asian countries. Bocourti's catfish is a hybrid from the female striped catfish (Pangasiidae) and the male Snail eater Pangasius (Wiwat & Chaisiri, 1995). Nowadays, it has been promoted as a new commercial fish and supported for cage aquaculture in many countries along the Mekong River, such as Thailand, Cambodia and Vietnam (Cacot et al., 2002). Its estimated monetary value is 1.2 million tons in 2014 and it is exported to more than 151 countries (FAO, 2014). The striped catfish is produced as a fillet product for export to European, USA, Russia and Asian markets (Doungporn & Kriangsak, 2010; Chatchai et al., 2011).

Although frozen fillets of Bocourti's catfish has high demand in markets, there are few studies on its production and quality. The freshness, colour and weight of fillets are significant factors for customer's consideration. To improve the frozen products, soaking in appropriate chemicals and conditions is the key procedure that food producers use to improve the quality of the frozen fillet. Phosphates or related compounds and sodium chloride (NaCl) have been used to improve meat properties during frozen food processing and storage. Phosphates could improve water retention and reduce weight loss in the thawing process (Masniyom et al., 2005). The synergistic application of NaCl and phosphates provide good water holding capacity (WHC) and cooking yield (Rattanasatheirn et al., 2008). Therefore, several types and amounts of phosphates with addition of NaCl are used in the soaking process to improve the quality of fillets (Thorarinsdottir et al., 2004; Margrethe et al., 2005; Rattanasatheirn et al., 2008; Kin et al., 2010).

Response surface methodology (RSM) was introduced in 1951 (Box & Wilson, 1951). The concept of RSM is to use an experimental design with a sequence level such as the Mixture design, Box-Behnken design and Central composite design to obtain the optimal response. A second-degree polynomial model is recommended to create a mathematical model for response prediction. At present, RSM is recognised as an effective tool to improve the qualities and processes and is widely used in food industries (Wangtueai & Noomhorm, 2009; Koli et al., 2011; Bai et al., 2015; Murthy et al., 2015).

While the production of frozen Bocourti's catfish fillets is increasing due to market demand, proper research-based information about the product and its quality is lacking. Thus, the aim of this study was to determine the effect of soaking conditions on some key quality parameters of frozen Bocourti's catfish fillets.

MATERIALS AND METHOD

Raw Materials

Bocourti's catfish (*Pangasius bocourti* Sauvage) was collected from cage aquaculture in the Mekong River at Nakhon Phanom Province, Thailand (17.4108 in latitude and 104.779 in longitude of decimal degrees). The samples used were from the same crop (nine-month-old fish) with average body weight of 1 kg. The fish were caught and packed in iced and transported in plastic boxes to the Food Science Laboratory, Rajamangala University, Sakon Nakhon campus, within 2 h. The fish were slaughtered, manually eviscerated, filleted and de-skinned by hand. The fillets had an individual average weight of 150 g/piece.

Chemicals

Food grade sodium tripolyphosphate (STPP), tetrasodium pyrophosphate (TSPP), sodium hexametaphosphate (SHMP) and sodium acid pyrophosphate (SAPP) were purchased from Haifa Chemicals Ltd. (Bangkok, Thailand). Refined NaCl (99.99%) was obtained from Thai Refined Salt Co., Ltd. (Bangkok, Thailand).

Investigation of Suitable Phosphates

Four phosphate-related solutions (STPP, TSPP, SHMP and SAPP) were each prepared in tap water at 2.0% (w/v) with NaCl (2.5% w/v). Then, fish fillets were dipped in the phosphate solution at 4°C for 10 min and drained of excess water in a strainer for 1 min. The obtained fillets were individually packed into polyethylene bags and placed in a freezer (NFT-4258, Cleo Natural Group co. Ltd., Nonthaburi, Thailand) at -20°C for 24 h.

Physical Properties Determination

The physical parameters, gained weight, cooking loss and cooking yield, were analysed following the method of Rattanasatheirn et al. (2008). The gained weight was calculated using the following equation:

Gained weight (%) = [(weight after soaking – weight before soaking)/weight before soaking] × 100

Cooking loss and yield of the frozen fillets were thawed in the refrigerator at 4 ºC for 24 h. The weight of fillets were measured before and after cooking by steaming at 95±2ºC for 15 min to determine cooking loss and cooking yield as following:

Cooking loss (%) = [(weight after thawing – weight after steaming)/ weight after thawing] × 100

Cooking yield (%) = (weight after steaming/ weight after thawing) × 100

For drip loss, the frozen fillets were weighted and thawed in a refrigerator at 4ºC for 24 h and excessive water was removed from the fish surface using filter paper. Then, the weight of each fillet was measured and the drip loss calculated as per the following (Gonçalves & Ribeiro, 2009).

Drip loss (%) = [(weight before thawing – weight after thawing)/weight before thawing] × 100

Chemical Properties

The moisture content of frozen fillets were investigated according to the standard method of 934.01AOAC (2000). The colour of the fillets was determined using a colourimeter (Hunter Lab, Colorflex, USA).

Sensory Analysis

A frozen fillet was thawed in the refrigerator at 4ºC for 24 h. The sample was then cut into square cubes of 30×30×20 mm, wrapped in aluminum foil and cooked in a steaming pot at 95±2ºC for 15 min. A sensory test was conducted by 40 non-trained panelists for the fillet's appearance and texture using a 9-point hedonic scale.

Optimisation of Soaking Conditions

The phosphates giving the best results from the previous experiment were used for soaking optimisation. Three main factors, phosphate concentration (1-3.5% w/v), time (10-30 min) and NaCl concentration (1-3% w/v), were investigated for optimum conditions. The experimental design was created by central composite design (CCD) by Minitab (Trial version 16, Minitab Inc., State College, PA, USA). Twenty treatments could be observed. The code and real value of each factor is shown in Table 1.

Table 1
Experimental design range and values of the independent variables in the central composite design (CCD) of fish fillets in optimisation step

Independent Variables	Symbols	Levels				
		Code Value				
		-1.0	0.0	+1.0	+1.7	
		Real Value				
Phosphate Concentration (%)	X_1	0.13	1.00	2.25	3.50	4.38
Soaking Time (min)	X_2	3	10	20	30	37
NaCl Concentration (%)	X_3	0.3	1.0	2.0	3.0	3.7

Statistical Analysis

The response model was calculated by Minitab. The model proposed was $Y = \beta_0 + \Sigma\, \beta_i x_i + \Sigma\, \beta_{ii} x_2 + \Sigma\Sigma\, \beta_{ij} x_i x_j$, where x_i and x_j are the code independent variables, whereas β_0, β_i, β_{ii}, and β_{ij} are the coefficients for intercept, linear, quadratic and interaction. One-way ANOVA was performed for significant difference using SPSS statistical package 16.0 software (SPSS Inc., USA). Duncan's new multiple range test (DMRT) was used to test for the differences between means with a significance level of $p \leq 0.05$.

RESULTS AND DISCUSSION

Investigation of Suitable Phosphates

The physical property results of the fillet dip in different phosphates (SAPP, TSPP, STPP and SHMP) is shown in Table 2. It was found that moisture content was at a similar level for all the treatments (80-82%). The highest moisture content was observed in STPP, implying that the least water loss occurred in the soaking step. The control (no phosphate) had a moisture content of 80%, which matched the results obtained in a similar study of lingcod fillet

(Duan et al., 2010). The gained weight ranged between 17 and 40%. STPP showed a highly significant difference compared to TSPP, SHMP, SAPP and the control. Xiong et al. (2000) studied the effects of different phosphate compounds on chicken meat and reported that triphosphate and pyrophosphate compounds showed similar levels but at higher levels than hexametaphosphate compounds. The mechanism of phosphate forming in the meat could be explained as follows: Phosphate attacks inside structures of myofribrilla protein, leading to pH change and increasing ionic bonds, resulting in higher water holding in muscle protein and increasing binding of water and protein (Thorarinsdottir et al., 2004).

Table 2
Gained weight and moisture content of fish fillets after soaking and drip loss, cooking loss and cooking yield of frozen fish fillets treated with different phosphates

Phosphates	Moisture (%)	Gained Weight (%)	Drip Loss (%)	Cooking Loss (%)	Cooking Yield (%)
SAPP	81.28±0.12^{b}	17.00±0.71^{c}	3.50±0.32^{b}	19.36±1.09^{b}	71.64±0.76^{b}
TSPP	82.19±0.53^{ab}	32.00±0.73^{b}	2.50±0.34^{b}	20.97±0.40^{b}	75.85±1.05^{a}
STPP	82.33±0.24^{a}	40.00± 0.32^{a}	1.18±0.10^{c}	18.28±0.11^{c}	75.85±0.39^{a}
SHMP	81.97±0.61^{b}	24.00±0.20^{c}	5.59±0.20^{a}	24.53±1.89^{a}	71.23±2.58^{b}
Control	80.16±0.26^{c}	13.00±0.44^{d}	5.60±0.32^{a}	25.26±1.09^{a}	67.64±0.76^{c}

Note: SAPP; Sodium acid pyrophosphate, TSPP; Tetra sodium pyrophosphate, STPP; Sodium tripolyphosphate, SHMP; Sodium hexametaphosphate, Control; no phosphate/-mean±SD and different letters (a, b, c) in the same column indicate significant ($p \leq 0.05$) differences among different phosphates

Drip loss is the weight loss owing to water leaking from frozen food products during the thawing process, causing cell membrane damage and distortion resulting in water leakage from cells (Xiong, 1997). Phosphates could increase binding between water and protein during freezing storage (Woyewoda & Bligh, 1986). In this study, drip loss ranged between 1.8 and 5.6%. STPP showed the lowest drip loss value with a significant difference comparing with other phosphates ($p \leq 0.05$). This implied that STPP could maintain the highest water holding capacity of protein in the freezing step. STPP showed the least cooking loss with significant difference ($p \leq 0.05$) at 18.28%. For cooking yield, TSPP and STPP provided the highest value of 75.85% ($p \leq 0.05$).

Colour

The results of fillet colour are shown in Table 3. A high L* value for STPP and SAPP was observed. The L* value showed the lightness of the sample due to associate expansion capacity (Altan et al., 2008) and lighter colour tended to customer preference (Huda et al., 2010). Fillets dipped in STPP had high a* value ($p \leq 0.05$) compared with those that used other treatments while c* (colour intensity) had the highest value for SAPP and the control. There was no significant difference of °h in all the treatments.

Table 3
Colour of frozen fish fillets treated with different phosphates

Treatment	Colour				
	L*	a*	b*ns	c*	°hns
SAPP	66.28±1.17a	4.01±0.85ab	9.25±0.35	56.28±1.17b	9.84±33.74
TSPP	62.57±5.20b	3.67±2.34ab	8.33±1.86	5.20±3.00b	9.18±2.63
STPP	67.63±3.64a	5.22±1.42a	8.74±0.71	3.64±2.10b	10.22±1.14
SHMP	63.37±2.71b	2.32±178ab	8.72±0.92	2.71±1.56a	9.07±1.31
Control	52.77±1.60c	1.14±0.54b	7.75±0.48	56.77±1.60b	7.90±0.56

Note: SAPP; Sodium acid pyrophosphate, TSPP; Tetra sodium pyrophosphate, STPP; Sodium tripolyphosphate, SHMP; Sodium hexametaphosphate, Control; no phosphate/-mean±SD and different letters (a, b, c) in the same column indicate significant ($p \leq 0.05$) differences among different phosphates, ns; non-significantly difference ($p > 0.05$)

Sensory Analysis

The sensory test (cooked fillets) was conducted by 40 non-trained panelists using a 9-point hedonic scale, where 1 = extremely dislike; 5 = neither like nor dislike; 9 = extremely like. The results of the sensory score are shown in Table 4. Fillets dipped in SHMP and STPP had high a appearance score at 7.16 and 7.05 ($p > 0.05$). There were no significant differences for colour and taste scores. STPP had the highest odour, texture and overall consistency score with 6.75, 7.20 and 7.75, respectively. Similarly, Goncalves and Riberio (2009) found that STPP showed high sensory scores for frozen shrimp, caused from increasing water holding capacity resulting in higher sensory evaluation scores (Goncalves et al., 2008).

Table 4
Sensory evaluation of cooked fillet using 9-point hedonic scale

	Sensory Analysis					
Treatment	Appearance	Colour	Odour	Tastens	Texture	Overall
SAPP	6.33±1.04b	6.37±1.37	5.87±1.36b	6.62±1.20	6.70±1.16ab	6.86±1.12b
TSPP	6.33±1.04b	6.50±1.14	6.75±1.56a	6.95±1.36	6.79±1.18ab	7.04±0.95ab
STPP	7.05±1.06a	6.55±1.28	6.75±1.35a	6.83±1.08	7.20±1.12a	7.75±0.94a
SHMP	7.16±1.04a	6.40±1.07	6.37±1.31ab	6.83±1.09	7.16±09.1a	7.12±0.99ab
Control	6.07±1.12ab	6.59±1.44	6.26±1.34ab	6.12±0.85	6.54±1.35b	7.04±0.99b

Note: SAPP; Sodium acid pyrophosphate, TSPP; Tetra sodium pyrophosphate, STPP; Sodium tripolyphosphate, SHMP; Sodium hexametaphosphate, Control; no phosphate/-mean±SD and different letters (a, b, c) in the same column indicate significant ($p \leq 0.05$) differences among different phosphates, ns; non-significantly difference ($p > 0.05$)

Compared with four phosphate compounds, STPP showed the best results, such as gained weight, drip loss, cooking loss and cooking yield and provided a high L* and a*; these significantly related to the customer's preference. Moreover, STPP is available in the market at low cost, is considered safe for consumption and handling, and is widely used in the food industry. Therefore, STPP was utilised and studied in the soaking process in the further optimisation step.

Optimisation of Soaking Conditions

The central composite design (CCD) was used to create treatments. The main factor was phosphate concentration (X_1), soaking time (X_2) and NaCl concentration (X_3). Twenty treatments were found and the results are shown in Table 5 and Table 6. Each response value was calculated using a regression model in terms of linear, intercept and quadratic model, which is expressed as the following equation:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{33} X_3^2 + \beta_{12} X_1X_2 + \beta_{13} X_1X_3 + \beta 2_3 X_2 X_3$$

Table 5
Treatments created by central composite design (CCD) and physical properties

Treatment	Code factor			Response									
	X_1	X_2	X_3	Moisture (%)	Gained weight	Cook loss	Cook yield	Drip loss	L*	a*	b*	C*	°h
1	0	0	1.7	79.50	19.99	19.99	69.68	2.40	60.81	11.00	76.64	2.49	10.53
2	1	1	1	80.90	19.01	32.80	81.08	4.67	58.12	11.87	74.21	3.25	11.39
3	-1	-1	1	78.00	20.41	19.41	78.57	1.20	64.05	13.35	75.73	3.35	12.87
4	0	1.7	0	80.60	21.25	36.30	80.4	3.95	50.23	15.28	61.00	7.36	13.38
5	0	0	-1.7	80.80	18.87	18.25	72.17	2.52	58.76	14.74	75.79	3.62	14.27
6	-1	1	1	78.20	15.80	18.63	75.56	5.44	55.22	15.64	63.75	6.91	14.02
7	0	0	0	80.70	22.68	22.90	72.21	4.28	57.14	15.01	68.27	5.57	13.94
8	0	0	0	78.05	23.91	22.90	83.45	4.28	59.70	15.89	73.09	4.63	15.20
9	0	-1.7	0	78.55	17.89	18.05	72.67	2.76	61.95	14.18	72.02	4.38	13.48
10	0	0	0	76.46	21.28	28.73	71.23	4.52	61.64	14.88	79.08	2.88	14.57
11	-1	1	-1	77.45	18.31	27.37	77.18	3.28	58.80	13.72	68.98	4.74	12.87
12	1	-1	1	80.45	21.95	13.20	86.9	2.40	62.28	12.57	78.08	2.61	12.26
13	1	1	-1	80.65	14.96	25.82	78.83	3.43	62.72	14.23	78.13	2.94	13.92
14	0	0	0	78.70	22.68	22.90	78.74	3.28	60.84	14.64	77.09	3.33	14.23
15	0	0	0	77.70	22.68	22.90	78.38	4.08	65.85	12.82	81.40	1.91	12.63
16	-1.7	0	0	79.65	22.79	19.41	82.4	1.20	64.08	14.36	72.48	4.34	13.69
17	0	0	0	80.10	19.88	26.79	87.9	3.68	56.35	15.23	67.19	5.94	14.01
18	1.7	0	0	75.40	20.13	29.12	72.17	4.58	54.98	14.74	62.37	6.89	12.97
19	1	-1	-1	80.90	11.32	18.63	78.94	1.20	60.82	14.43	71.34	4.63	13.67
20	-1	-1	-1	78.20	13.84	19.41	78.38	2.40	59.90	11.08	58.30	3.09	14.22

Note: X_1: Phosphate concentration, X_2: Soaking time, X_3: NaCl concentration

Table 6
Treatments created by central composite design (CCD) and sensory evaluation

Treatment	Code factor			Response					
	X_1	X_2	X_3	Appearance	Colour	Odour	Taste	Texture	Overall
1	0	0	1.7	79.50	19.99	19.99	69.68	2.40	60.81
2	1	1	1	80.90	19.01	32.80	81.08	4.67	58.12
3	-1	-1	1	78.00	20.41	19.41	78.57	1.20	64.05
4	0	1.7	0	80.60	21.25	36.30	80.4	3.95	50.23
5	0	0	-1.7	80.80	18.87	18.25	72.17	2.52	58.76
6	-1	1	1	78.20	15.80	18.63	75.56	5.44	55.22
7	0	0	0	80.70	22.68	22.90	72.21	4.28	57.14
8	0	0	0	78.05	23.91	22.90	83.45	4.28	59.70
9	0	-1.7	0	78.55	17.89	18.05	72.67	2.76	61.95
10	0	0	0	76.46	21.28	28.73	71.23	4.52	61.64
11	-1	1	-1	77.45	18.31	27.37	77.18	3.28	58.80
12	1	-1	1	80.45	21.95	13.20	86.9	2.40	62.28
13	1	1	-1	80.65	14.96	25.82	78.83	3.43	62.72
14	0	0	0	78.70	22.68	22.90	78.74	3.28	60.84
15	0	0	0	77.70	22.68	22.90	78.38	4.08	65.85
16	-1.7	0	0	79.65	22.79	19.41	82.4	1.20	64.08
17	0	0	0	80.10	19.88	26.79	87.9	3.68	56.35
18	1.7	0	0	75.40	20.13	29.12	72.17	4.58	54.98
19	1	-1	-1	80.90	11.32	18.63	78.94	1.20	60.82
20	-1	-1	-1	78.20	13.84	19.41	78.38	2.40	59.90

Note: X_1: Phosphate concentration, X_2: Soaking time, X_3: NaCl concentration

In this study, the significant models (p≤0.05) were cooking yield, gained weight and °h. Moreover, a* also showed a fine model with high R^2 as well as this factor was the important response for consumer acceptability (Huda et al., 2010). In addition, the a* value cloud showed accumulation of brown-coloured methemoglobin from the indication of hemoglobin oxidation in flesh fish (Kachele et al., 2017). Therefore, the models of cooking yield, °h, a* and gained weight were applied in the process of response optimisation step. The parameters, regression coefficient and full models are shown in Table 7 and Table 8. Gained weight, cooking yield, a* and °h showed good performances with R^2 of 0.7545, 0.6851, 0.7192 and 0.7138, respectively. These responses were used to create the response surface plots as shown in Figure 1. To find the optimum condition for the soaking process, the multi-response optimiser function in Minitab software was used for calculation. The response of gained weight and cooking yield were set at the maximum while the a* and °h values were set at the minimum together with weight and important of all response equal one. It was found the optimum point was 2.56% of phosphate concentration (code value = 0.25), soaking time was 37 min (code value = 1.68) and 3.7% of NaCl concentration (code value = 1.68). The fillets soaking in this condition had 11.45% of gained weight, 73.11% of cooking yield, 10.97 of a* and 9.94 of °h, respectively. Thorarinsdottir et al. (2001) reported that addition of NaCl (0.5-5%) could increase space in myofibrillar protein and reduce repulsive charges, resulting in increasing water holding capacity. However, the limitation of the current work for model development and optimisation was that important parameters could not be developed to predict the models. Further optimisation should be focused on some parameters involving economic factors and consumer preference in fish fillet processing such as gained weight and drip loss.

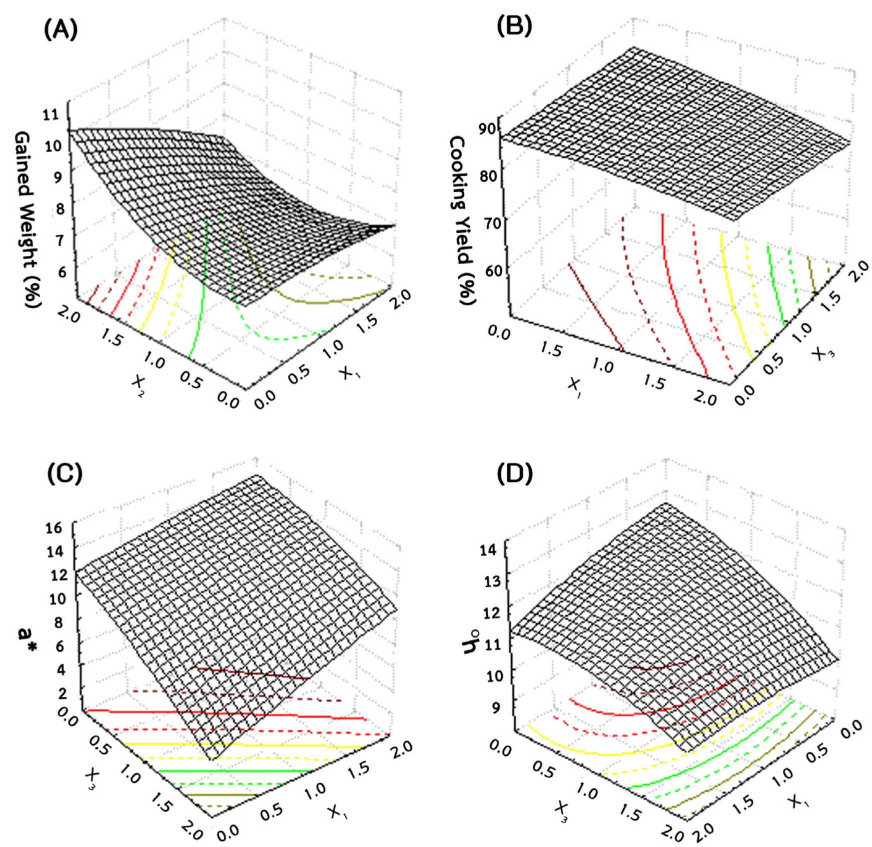

Figure 1. Response graphs of gained weight (A), cooking yield (B), a* (C) and °h (D)

Table 7
Parameters, regression coefficient and p-value of used responses

Parameter	Term	Gained weight		Cooking yield		a*		°h	
		Coef.	p-Value	Coef.	p-Value	Coef.	p-Value	Coef.	p-Value
β_0	Intercept	6.717	0.000	80.042	0.000	14.766	0.000	14.093	0.000
β_1	X_1	0.352	0.377	3.299	0.031	-0.003	0.000	-0.288	0.219
β_2	X_2	0.769	0.071	0.800	0.556	0.430	0.16	-0.724	0.749
β_3	X_3	0.030	0.938	-0.741	0.570	-0.463	0.133	-0.764	0.006
β_{11}	X_{12}	-0.181	0.635	-1.064	0.424	-0.205	0.473	-0.236	0.296
β_{22}	X_{22}	0.976	0.078	1.385	0.483	-0.141	0.621	-0.203	0.366
β_{33}	X_{32}	0.083	0.870	-0.045	0.980	-0.799	0.016	-0.566	0.025
β_{12}	X_1X_2	-0.708	0.085	-1.899	0.168	-0.729	0.078	-0.054	0.854
β_{13}	X_1X_3	-0.213	0.677	-1.415	0.980	-1.051	0.018	0.466	0.136
β_{23}	X_2X_3	-0.672	0.100	-0.258	0.844	-0.105	0.781	0.173	0.56

Table 8
The full quadratic polynomial models of each response

Response	Quadratic Polynomial Model	R^2	p-Value
Gained weight	$Y_1 = 6.71+0.35X_1+0.76X_2+0.03X_3 -0.18X_1^2+0.97 X_2^2+ 0.08 X_3^2 - 0.7X_1X_2 - 0.21 X_1X_3 - 0.67X_2X_3$	0.7545	0.051
Cooking yield	$Y_2 = 80.04+3.29X_1 +0.8X_2-0.74X_3 -1.06X_1^2+1.38 X_2^2 – 0.04 X_3^2 -1.89X_1X_2 -1.41 X_1X_3 - 0.25X_2X_3$	0.6851	0.015
a*	$Y_3 = 14.76-0.003X_1 +0.43X_2-0.46X_3 -0.2X_1^2-0.41X_2^2 – 0.79X_3^2 -0.72X_1X_2 -1.05X_1X_3-0.1X_2X_3$	0.7192	0.059
°h	$Y_4 = 14.09-0.28X_1 -0.72X_2-0.76X_3 -0.23X_1^2-0.2X_2^2 – 0.56X_3^2 -0.05X_1X_2 +0.46X_1X_3+0.17X_2X_3$	0.7138	0.050

Note: X_1: Phosphate concentration, X_2: Soaking time, X_3: NaCl concentration

CONCLUSION

Four phosphate compounds were compared on their effect on physical appearance, colour analysis and sensory analysis of frozen fillets of Bocourti's catfish. STPP showed the best results in gained weight, drip loss, cooking loss and cooking yield and provided a high L* and a* colour. Soaking conditions were optimised using the response surface methodology. The optimum conditions were 2.56% of STPP concentration, 3.7% of NaCl concentration and a soaking time of 37 min for improvement of the quality of frozen fillets, showing gained weight of 11.45%, cooking yield of 73.11%, a* of 10.97 and °h of 9.94.

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