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Research Article

Effect of Phosphate Compounds on Water Retention Capacity of Round Scad Surimi during Frozen Storage

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Abstract: This study reports a study of the influence of phosphate compounds on the cooking loss of round scad surimi during the frozen storage. Further more, water retention property of round scad surimi optimized by phosphate compounds through combination design of ternary quadratic form and center of rotation and the regression model was established to predict the cooking loss effect. Results show that the best water retention capacity when composite phosphate contains 50% sodium tripolyphosphate, 20% trisodium phosphate and 30% sodium hexametaphosphate. Under this operational condition, the cooking loss ratio of frozen surimi is only 24.60%, which is 10.24% less than that of frozen surimi without any phosphate compounds. These results generally indicate that the presence of phosphate compounds improve water retention capacity of round scad surimi during frozen storage obviously.

Keywords: Cooking loss, phosphate compounds, round scad surimi, water retention

INTRODUCTION

Round scad (*decapterus maruadsi*) is a kind of marine fish, belongs to the family of mackerel (Jiang *et al*., 2014). In China, the peak of production for round scad is during the hot season, but this kind of fish is limited in utilization because of their dark colour, susceptibility to oxidation and off-flavour. As a sequence, this species is usually regarded as a byproduct in fishery, discarded or processed into fish meal or fertilizer. Therefore, it is necessary to process low-valued pelagic fish into high market-value products, such as surimi production (Benjakul *et al*., 2008), which is stabilized with myofibrillar proteins and blended with cryoprotectant for long periods of frozen storage (Nopianti *et al*., 2013). Besides, the bioactive substance (Thiansilakul *et al*., 2007a) and biological functional ingredients were extracted and prepared from round scad (Artharn *et al*., 2009, 2007; Prodpran *et al*., 2007; Thiansilakul *et al*., 2007b).

It is well-known that phosphate compounds have been widely applied as additives in fish and seafood to improve the functional properties of those products by increasing water retention capacity in fresh fish and reducing the thaw loss in frozen fish (Chang and Regenstein, 1997; Park, 2005; Li *et al*., 2009; Sheard *et al*., 1999). Phosphate is normally added to surimi in combination with cryoprotectants such as sugar or sorbitol (Sultanbawa and Li-Chan, 2001; Auh *et al*., 1999; Wang and Xiong, 1998). This is because when the fish is dead with low pH, the addition of phosphate can raise pH to keep away from protein isoelectric point, so that mutual repulsion among charges can make more space among protein and make muscle keep more moisture. Besides, water retention of surimi is closely related to protein solubleness of myofibril. Phosphate can provide high ionic strength is helpful for the digestion of myofibrillar protein so as to improve water retention of the surimi.

Different polyphosphates play different water retention capacity and common phosphates used in meat product include sodium tripolyphosphate (Batista *et al*., 1999), pyrophosphate (Nakamura *et al*., 2013), metaphosphate and so on. However, information is scant about the effects of polyphosphates on the functionalities and storage stability of round scad surimi.

Thus, the study aimed to investigate the effect of phosphate compounds, including Sodium Tripolyphosphate (STPP), Trisodium Phosphate (TSPP) and Sodium Hexametaphosphate (SHMP) on the water retention of round scad surimi during frozen storage, expect to improve the cooking yield and textural palatability.

MATERIALS AND METHODS

Materials: Round scad was bought from local supermarket. Food grade salt is purchased from Fujian Zhongyan Co.. Phosphate compounds (STPP, TSPP

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and SHMP) are food grade; sodium bicarbonate is chemical pure.

Preparation of frozen round scad surimi: Frozen round scad with 12 cm to 16 cm was chosed and made into fish flakes with 4 mm to 6 mm, rinsed in water for 8 min and placed them for 2 min at the temperature of 3~10°C. Besides, fish flakes should contain about 78% of moisture (Sánchez-Alonso *et al*., 2007) and then are mixed evenly with cryoprotectant, using food processor with low speed. Then, those fish flakes are kept at-18°C for 6 weeks of frozen storage.

Determination of cooking loss: Frozen surimi sample (10.0 g) was weighted accurately and vacuum sealed in a retort pouch, were cooked on an open electric broiler, with the temperature of 72°C for 30 min when the center temperature reaches 70°C (Peña-Ramos and Xiong, 2003), After cooling down to room temperature,. The surimi sample was taken out and placed in styrene foam trays and water on surface was soaked up by filter paper. Then weighed it and calculated the cooking loss as follows. "m_1"stands for the quantity of surimi sample before cooking, "m_2" is the weight of surimi sample after cooking and the unit of weight is gram:

$$X(\%) = \frac{m_1 - m_2}{m_1} \times 100\% \quad (1)$$

Determination of the additive amount of STPP: Frozen and fresh surimi samples were made according to the above mentioned. After these surimi samples were added the TSPP content at 0.15% and SHMP content at 0.15%, they were respectively added the STPP content at 0.0, 0.05, 0.10, 0.15, 0.20, 0.25 and 0.30%, respectively kept at -18°C for six weeks of frozen storage. Then tested their cooking loss.

Determination of the additive amount of TSPP: Frozen and fresh surimi samples were made according to the above method 2.1. After these surimi samples were added the STPP content at 0.25% and SHMP content at 0.15%, they were respectively added the TSPP content at 0.0, 0.05, 0.10, 0.15, 0.20, 0.25 and 0.30%, respectively kept at -18°C for six weeks of frozen storage. Then tested their cooking loss.

Determination of the additive amount of SHMP: Frozen and fresh surimi samples were made according to the above mentioned. After these surimi samples were added the STPP content at 0.25% and TSPP at 0.25%, they were respectively added the SHMP content at 0.0, 0.05, 0.10, 0.15, 0.20, 0.25 and 0.30%, respectively kept at -18°C for six weeks of frozen storage. Then tested their cooking loss.

Table 1: Factors and coded levels for the experimental design

	Factors		
Coded levels	STPP (%)/X_1	TSPP (%)/X_2	SHMP (%)/X_3
-1	0.15	0.10	0.05
0	0.20	0.15	0.10
+1	0.25	0.20	0.15

Optimized composite phosphate proportion: Based on single factor experiments, the optimal proportion of composite phosphate was confirmed under the condition of 3 levels from 3 factors. The experimental design as follows (Table 1).

Data analysis: The experimental data was carried out and analyzed by the software of Excel and Design-Expert 8.05b.

RESULTS AND DISCUSSION

Effect of the additive amount of STPP: The effect of STPP on the cooking loss of round scad surimi was show in Fig. 1. From the Fig. 1, it was found clearly that the cooking loss gradually declines as the increasing addition of STPP. Compared with the surimi sample without any addition, the cooking loss of surimi samples respectively decline 3.16, 6.61, 13.22, 20.11 and 23.56%, after being respectively added STPP content of 0.05, 0.10, 0.15, 0.20 and 0.25%, respectively. Thus it could be seen that STPP has an obvious influence on the cooking loss; besides, we could see an obvious downward curve when the additive amount of STPP was limited during 0.00 to 0.20% and a relatively flat curve when the additive amount of STPP was limited during 0.20 to 0.25%. The reason why STPP can decline the cooking loss of round scad surimi is that STPP makes myofibril lateral expansion by electrostatic repulsion, improves the inner space of myofibril and protein solubility by enhancing ion strength so as to improve the water retention of round scad surimi and decline the cooking loss (Matsunaga *et al*., 1990).

Confirmation of the additive amount of TSPP: Fig. 2 shows the effect of TSPP on the cooking loss of round scad surimi. It could be seen that the cooking loss of round scad surimi reduces at first and then increase. When the additive amount of TSPP was 0.10%, the cooking loss reached the minimum of 25.8%, which was 10.10% lower than that of the sample without any addition.

As the same as STPP, TSPP also makes myofibril lateral expansion by electrostatic repulsion, improves the inner space of myofibril and protein solubility by enhancing ion strength (Xiong *et al*., 2000) so as to improve the water retention of round scad surimi and

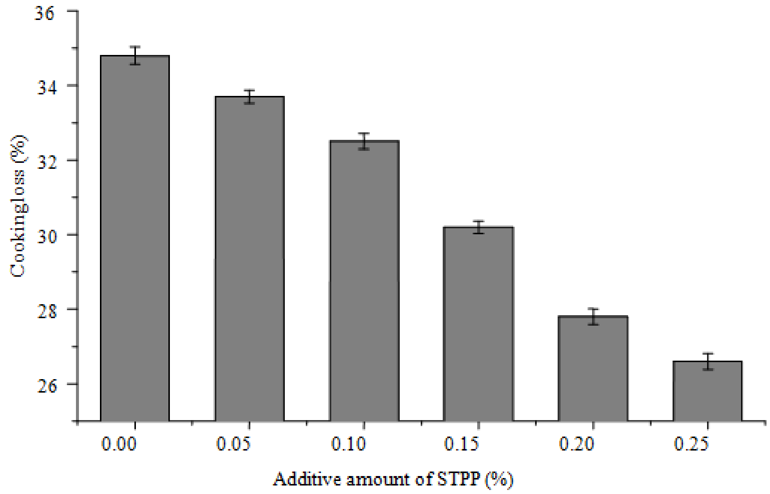

Fig. 1: Effect of STPP on the cooking loss of round scad surimi

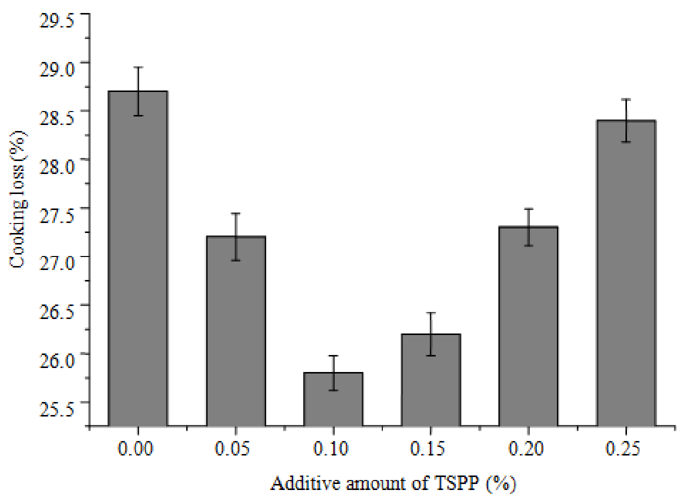

Fig. 2: Effect of TSPP on the cooking loss of round scad surimi

decline the cooking loss. What's more, TSPP could increase the inner space by destroying the internal connection of myofibrillar proteins to reduce the cooking loss of round scad surimi. When the additive amount of TSPP was more than 0.10%, the cooking loss of round scad surimi increased perhaps due to that hydrolysis of energy-rich chemical bond of TSPP dissociates actomyosin and then affects myofibril.

Effect of SHMP on the cooking loss: The effect of the additive amount of SHMP on the cooking loss of round scad surimi was studied and show in Fig. 3. It was clearly to see that the cooking loss rate was declined first but then elevated with the additive amount of SHMP and the cooking loss rate was lowest (25.4%) when the the additive amount of SHMP was 0.10%. As a result of additive SHMP should weaken the capacity of increasing whiteness of fish meat at the range of 0.00~0.10%. Meantime, the water retention capacity of round scad surimi was improved. Further more, the cooking loss rate was decreased at last. The contraction of myofibril become to diminution and interior space was greatly depleted. The hydrolyzation of SHMP reached equilibrium under the additive amount of SHMP was 0.15%. The effect of additive amount of SHMP increased, it was not obvious on the cooking loss of round scad surimi and the same tested results were obtained, that STPP and TSPP had greater water retention, compared to SHMP (Baublits *et al*., 2005).

Optimal proportion of phosphate compounds: With the index of cooking loss rate, the ternary quadratic regression equation was designed and optimized for improving water retention of round scad surimi by phosphate compounds and the factors to consider included the additive amount of STPP, TSPP and SHMP. The experimental results were as follows in Table 2.

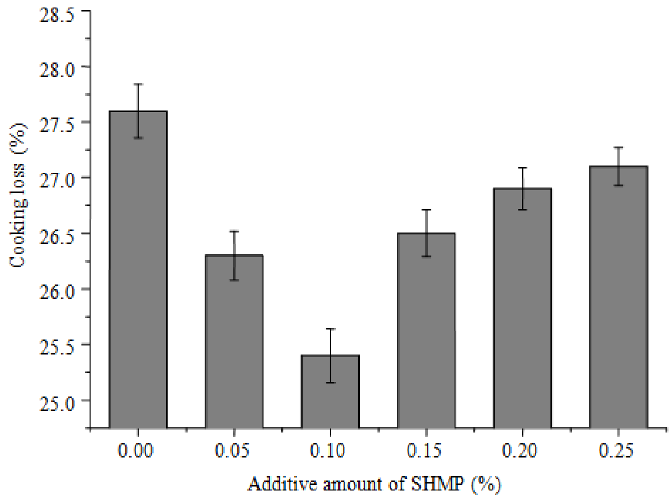

Fig. 3: Effect of SHMP on the cooking loss of round scad surimi

Table 2: Design and results of quadratic rotation-regression-orthogonal combination

No.	STPP/% X_1	TSPP/% X_2	SHMP/% X_3	Cooking loss rate/% Y
1	-1	-1	0	32.5
2	1	-1	0	25.4
3	-1	1	0	29.5
4	1	1	0	24.8
5	-1	0	-1	32.2
6	1	0	-1	27.1
7	-1	0	1	30.6
8	1	0	1	26.2
9	0	-1	-1	30.2
10	0	1	-1	27.4
11	0	-1	1	27.1
12	0	1	1	26.4
13	0	0	0	28.3
14	0	0	0	28.5
15	0	0	0	29.0
16	0	0	0	28.5
17	0	0	0	28.3

Analysis of variance: The analysis of variance result was shown in Table 3. From Table 3, it was clearly to see that the value of F was 44.38 and $p<0.0001$. This phenomenon explained that the regression model and practical situation were fitted well and the value of lack of fit p is 0.1071($p>0.05$). In consequence, the regression model could be considered meaningful and the model could be applied to predict the effect of STPP, TSPP and SHMP on the cooking loss of round scad surimi. Table 3 show that the affecting order on cooking loss was STPP, TSPP and SHMP, with observably interaction between STPP and TSPP, TSPP and SHMP, except STPP and SHMP.

Establishment of regression model and validation: The regression model was established between STPP, TSPP, SHMP and cooking loss by the software of Design Expert 8.05b. The model equation was expressed as:

$$Y = 28.52-2.66X_1-0.89X_2-0.83X_3+0.60X_1X_2+0.17X_1X_3+0.52X_2X_3+0.39X_1^2-0.86X_2^2+0.12X_3^2$$

And then excluded non-obvious item ($\alpha>0.05$) after significance testing. The simplified equation was described as:

$$Y = 28.52-2.66X_1-0.89X_2-0.83X_3+0.60X_1X_2+0.52X_2X_3+0.39X_1^2-0.86X_2^2.$$

The optimal ratio of compound phosphates were obtained, the additive amount of STPP, TSPP and SHMP were 0.25, 0.10 and 0.15% respectively and the proportion of compound phosphates were 5:2:3. Under this operation condition, the cooking loss of round scad surimi was lowest and the value was 24.60%.

On the basis of the optimal result, the cooking loss rate of round scad surimi was experimented in parallel for three times and compared with control group (without any sodium phosphate additives). Experiment results were 24.71, 24.48, 24.61%, respectively the average value was 24.60% and the cooking loss rate was decreased about 10.24%, compared with control group.

Table 3: Variance analysis of compound sodium phosphate

Variation sources	*SS*	*df*	*MS*	*F*	*p*
X_1	56.71	1	56.71	302.92	<0.0001
X_2	6.30	1	6.30	33.66	0.0007
X_3	5.44	1	5.44	29.08	0.0010
X_1X_2	1.44	1	1.44	7.69	0.0276
X_1X_3	0.12	1	0.12	0.65	0.4452
X_2X_3	1.10	1	1.10	5.89	0.0456
X_1^2	0.64	1	0.64	3.42	0.1068
X_2^2	3.11	1	3.11	16.63	0.0047
X_3^2	0.056	1	0.056	0.30	0.6024
Regression	74.77	9	8.31	44.38	< 0.0001
Residual	1.31	7	0.19		
Lack of fit	0.98	3	0.33	3.99	0.1071
Deviation	0.33	4	0.082		
Sum of squares for total	76.08	16			

$p<0.05$ is significant, $p<0.01$ is highly significant

CONCLUSION

In this study, the effect of different levels of complex phosphate on the cooking loss of round scad surimi was investigated successfully for the first time. In addition, we have established and tested the regression model for prediction their adaptable proportion. Eventually, it was confirmed that phosphate compounds have performed the best water conservation effect.

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Conflict of interest: The authors declare no conflict of interest.

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