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Effect of Phosphates and Salt on Yield and Quality of Cooked White Shrimp (*Penaeus vannamei*)

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ABSTRACT

The effects of phosphates; namely tetra sodium pyrophosphate (TSPP), sodium tripolyphosphate (STPP) and sodium hexametaphosphate (SHMP), on the quality of cooked white shrimp (*Penaeus vannamei*) were studied. Compared to the control, concentration of phosphates and immersion time significantly affected the weight gained of raw shrimp and cooking weight loss of cooked shrimp ($p \leq 0.05$). The results on the effects of immersing the shrimp in 2 % TSPP for 8 h were similar to those in 2 % STPP for 10 h; while the immersion in 3 % SHMP for 10 h was less effective. Apparently, the addition of 1-3 % sodium chloride increased the weight gained in all raw samples immersed in different phosphates solution. Nevertheless, STPP showed a synergistic effect with salt on reducing the cooking weight loss. The combined effect of 2 % salt and all types of phosphates yielded a good quality cooked shrimp with high acceptability.

Key words: white shrimp, *Penaeus vannamei*, phosphates, salt, weight gained, cooking weight loss

INTRODUCTION

Phosphates are legally permitted additives widely used to aid processing or to improve eating quality of many foods, particularly meat and fish products. Phosphates have been used in many types of meat products to improve water binding capacity of protein and to reduce the drip and cooking loss. Consequently the yield increased, the flavor is preserved, and the texture of the product is soft and juicy (Tiecher, 1990). Phosphates affect protein solubility, pH and ionic strength and increase the interactions between molecules of protein and water. Furthermore, the interactions between negative charges of phosphate molecules and myofibrillar proteins increase electrostatic repulsion of polypeptide chains, which resulted in the swelling of muscle (Lindsay, 1996). Liu and Xiong (1997) reported the effect of salt on water holding capacity and solubility of proteins. Xiong *et al.* (2000) showed that at the salt concentration of less than 0.4 M, an A-band of myofibrillar protein did not swell but at the concentration higher than 0.5 M, the myofibrillar protein started swelling and the protein extractability increased markedly at 0.6 M. Most processors now use proprietary mixtures containing appropriate polyphosphates. These mixtures may contain pyrophosphate, tripolyphosphate or compounds with more than three phosphate units, so that the supplier can offer concentrated solutions that can be readily diluted

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to the required strength by the processor. Mixtures based on tripolyphosphate often contain other phosphates to make the solution less alkaline and less likely to cause skin irritation (http://www.fao.org/wairdocs/tan/x5909E/x5909e01.htm).

Generally, the mixed commercial polyphosphates have been used in frozen shrimp industry. Therefore, the appropriate conditions for each phosphate should be investigated. The objectives of this work were to find an appropriate concentration and immersion time of each phosphate and the effect of phosphates and salt on the yield and qualities of cooked white shrimp (*Penaeus vannamei*).

MATERIALS AND METHODS

1. Raw material preparation for setting acceptability criteria

White shrimp (100-110 pieces/kg), purchased from a local fresh market, was washed, headed, peeled and deveined before determining freshness as total volatile basic nitrogen, TVB-N (MFRD, 1987). The limit of TVB-N was set at 30 mg/100 g shrimp (TISI, 1986). Fresh shrimp was immersed in 3 % (w/v) food grade sodium tripolyphosphate, STPP (F.A. Unity Co., Ltd., Thailand) for 1, 3, 6, 12 and 18 h at 4-5°C. The treated shrimp was then cooked in the boiling water until its center reached 70°C measured by a thermocouple (Delta Ohm, HD 9016, Padova, Italy). Quantitative Descriptive Analysis (QDA) of the cooked shrimp was carried out by 12 trained panelists on appearance, texture and flavor according to Meilgaard *et al.* (1999) on a scale of 1-5.

2. Appropriate concentration and immersion time of phosphates

Three kinds of food grade phosphates (F.A. Unity Co., Ltd., Thailand); namely, tetra sodium pyrophosphate (TSPP), sodium tripolyphosphate (STPP) and sodium hexametaphosphate (SHMP) were used. Ten white shrimps in each treatment were weighed (Shimadzu, Libror EB-3200D, Japan) then immersed in the phosphate solution at a ratio of shrimp: solution = 1:2 (w/v). The concentrations of phosphate solutions were 0, 2, 3, 4 and 5 % (w/v) and the immersion times were 2, 4, 6, 8 and 10 h at controlled temperature not higher than 5°C. The gained weight (%) was determined according to the method of Young and Lyon (1997). The shrimp was cooked until the center reached 70°C. The cooking weight loss was measured (Young and Lyon, 1997) and the samples were sensory evaluated according to the criteria obtained from Experiment 1. The experimental design was factorial (5×5) in completely randomized design (CRD) performed in three replicates. ANOVA and Duncan’s New Multiple Range test (DMRT) were employed.

3. Effect of salt concentration on phosphate treatment

The treatments with the level of each phosphate and immersion time that resulted in the lowest cooking weight loss and accepted sensory score (score ≥ 3) from Experiment 2 were selected. The combined effects of the selected phosphates and various concentrations of sodium chloride; i.e. 0, 1, 2, 3 and 4 % (w/v) were investigated. White shrimp were immersed in phosphate with salt solution and cooked. Weight gained, cooking weight loss and moisture content (AOAC, 2000) were determined. Texture was measured as shear force using a texture analyzer (Stable Micro System, TA-HD, Surrey, U.K.) by cutting the third tagmata crosswise with Warner-Blazler blade at a speed of 2 mm/second according to the method described by Bourne (1982). Sensory evaluation according to the set criteria was conducted. The panelists were asked to judge whether the saltiness was acceptable and the accepted numbers were calculated as percentage of the total number of judges.

RESULTS AND DISCUSSION

1. Raw material preparation for setting acceptability criteria

The criteria for attribute scoring of cooked shrimp set by 12 panelists are shown in Table 1. The panelists were able to differentiate the appearance and texture of samples treated with phosphates for different immersion times. The appearance, texture and flavor of sample immersed in STPP for 1 h before cooking were similar to those of control (no phosphate); therefore, the acceptability score was set as 5. Increasing immersion time to 3 and 6 h yielded products without off flavor but the appearance varied from slightly opaque to opaque meat; slightly glossy to glossy; slightly slippery to slippery skin; and very elastic to elastic meat. The scores were then set as 4 and 3, respectively. Sample immersed in phosphate solution for 12 h was slightly transparent, very glossy and slippery skin, medium crunchy, slightly elastic and slightly off-flavor. It was then scored as 2. Sample immersed in phosphate solution for 18 h was glass-like, very glossy and slippery skin, very crunchy which was much different from control with distinctive off-flavor and the acceptability score was set as 1.

2. Appropriate concentration and immersion time of phosphate solutions

Effects of concentration and immersion time of each phosphate solution on weight gained and cooking weight loss are shown in Figure 1. It was found that both concentration and immersion time affected weight gained and cooking weight loss of white shrimp and both factors had interaction effect. Immersing white shrimp in 2 % TSPP for 8–10 h yielded higher gained weight than those using higher concentrations of phosphate. This result was similar to the work reported by Xiong and Kupski (1999a) that 1.6 % phosphate solution had a higher rate of penetration into chicken piece than that of 3.2 %. It was also found that the longer the immersion time, the lower the cooking weight loss. The lowest cooking weight loss was also found in sample treated with 2 % TSPP for 10 h with an average acceptability score of 3.6±1.0. However, the sample treated with 2 % solution for 8 h received the score of 4.0±1.0. At higher concentration (3-5%), the acceptability scores were lower than 3. Thus, the appropriate conditions for using TSPP were 2 % for 8 h. It was found that using 4 and 5 % STPP for 8-10 h yielded the products with acceptability score less than 3. However, cooked shrimp immersed in 3 % STPP for 10 h had acceptability score of 3.2±0.8 with non significant cooking weight loss compared

Table 1 Criteria for attribute scoring of cooked shrimp immersing in phosphate solution.

Attribute		Score
Appearance	Texture and flavor	
Meat is opaque, skin is slightly glossy but not slippery	Firm, slightly crunchy, very elastic, no off-flavor	5
Meat is opaque, skin is slightly glossy and slightly slippery	Medium crunchy, very elastic, no off-flavor	4
Meat is slightly opaque, skin is glossy and slippery	Medium crunchy and elastic, no off-flavor	3
Meat is slightly transparent, skin is very glossy and slippery	Medium crunchy and slightly elastic, slightly astringent	2
Meat is glass-like, skin is very glossy and very slippery	Very crunchy, not elastic, distinctive astringent	1

to that immersed in 2 % STPP for 10 h (P>0.05) with a higher acceptability score of 3.6±1.0. Thus, treated with 2 % STPP for 10 h was considered suitable. However, raw white shrimp treated with 2-5 % SHMP for 2 -8 h gained more weight than that treated for 10 h (P≤0.05). Cooking weight loss was also decreased when the immersion time increased but panelists did not accept the samples treated with 4-5 % SHMP for 10 h; while sample treated with 3 % SHMP for 10 h was still acceptable with no significant difference in cooking weight loss compared to those treated with the higher concentrations of phosphate for the same duration. Therefore, immersion of white shrimp with 3 % SHMP for 10 h was appropriate conditions.

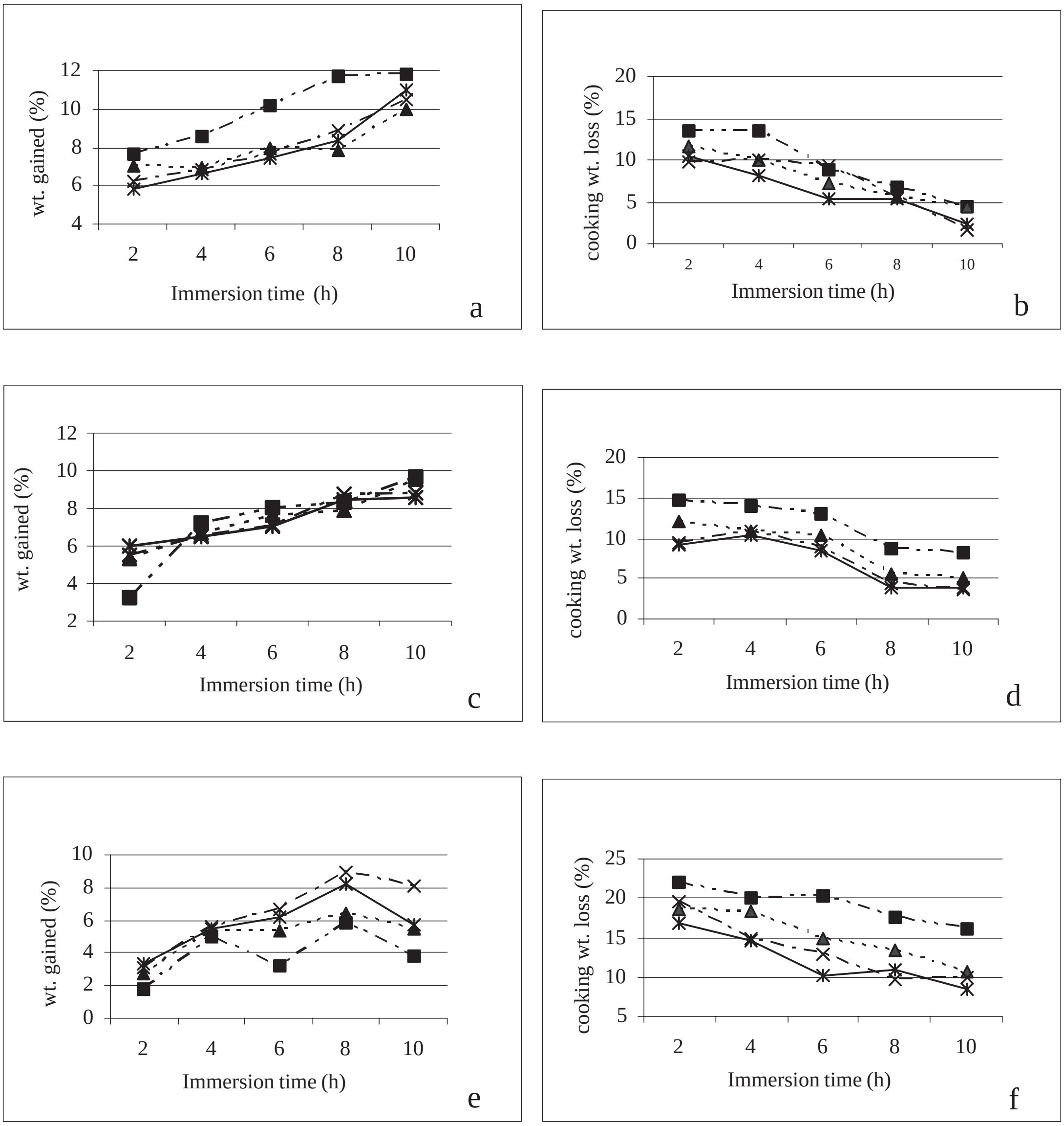

Figure 1 Relationship between immersion time and phosphates level on % weight gained and % cooking weight loss (a) and (b) TSPP (c) and (d) STPP (e) and (f) SHMP.
2 %: _..■.._ , 3 %: · ·▲· · , 4 %: _·_¥_·_· , 5 %: ——✱——

3. Effect of salt concentration on phosphate treatment

The effects of 1-3 % salt in combination with the appropriate concentration and immersion time of phosphate from Experiment 2; i.e. 2 % TSPP (immersed for 8 h), 2 % STPP (immersed for 10 h) and 3 % SHMP (immersed for 10 h) on weight gained, cooking weight loss, moisture content, sensory evaluation score, saltiness acceptance, and shear force are shown in Table 2.

3.1 Effects of phosphates type

Without salt, it was found that weight gained after immersion in 2 % TSPP for 8 h was not significantly different from that of 2 % STPP immersed for 10 h (P>0.05). However, TSPP was more effective in reducing cooking weight loss of shrimp. TSPP required a shorter immersion time due to its higher absorption rate as reported by Shults and Wierbicki (1973) and Xiong and Kupski (1999 b). For SHMP, it was found that the weight gained was only 3.84±0.29 %; while those immersed in TSPP and STPP were 8.20±1.48 and 9.23±0.57 %, respectively. When cooking weight loss was compared, the ones immersed in SHMP showed the highest weight loss of 11.07±0.33 %; while those immersed in TSPP and STPP were lower; i.e., 4.89±0.17 and 6.26±0.22 %, respectively (P≤0.05). Baublits *et al.* (2005) also reported that SHMP was less effective in reducing cooking weight loss of beef biceps femoris compared to TSPP and STPP. Trout and Schmidt (1984), Liu and Xiong (1997) and Xiong and Kupski (1999b) reported similar results and explained that the effect was due to the molecular structure of phosphates and pH of the solution; i.e., the effectiveness of phosphates decreased when the chain length increased and pH decreased (Trout and Schmidt, 1984). Therefore, the effectiveness of phosphates from high to low was TSPP>STPP>SHMP.

3.2 Effect of phosphates and salt on weight gained

Sodium chloride at 1-3 % in combination with TSPP, STPP and SHMP, significantly increased the weight gained of treated shrimp more than phosphate alone (P≤0.05). Shults and Wierbicki (1973) reported the higher water holding capacity of chicken muscle when 1 % salt was added to TSPP, STPP and SHMP compared to the control without salt. This was due to the increased ionic strength which caused the swelling of muscle fiber and increased extractability and solubility of myofibrillar protein, thus increased the water holding capacity (Liu and Xiong, 1997). An increase in protein solubility with the addition of 0.4 – 0.5 M salt up to an ionic strength of 1.0 was reported. Phosphate compounds act the same way as adenosine triphosphate (ATP) in cutting chain of proteins and increase solubility as well as enhancing swelling of muscle fiber. At the same time, salt increases water holding capacity of proteins (Xiong *et al.*, 2000). Baublits *et al.* (2005) found that the injection of 0.2 – 0.4 % TSPP, STPP and SHMP with 2 % salt (w/w of meat) to beef biceps femoris increased the phosphate-protein interactions thus increased negative charges of protein and water holding capacity of muscle.

3.3 Effect of phosphates and salt on cooking weight loss

Increasing salt concentration or ionic strength affected the cooking weight loss. Apparently, increased salt concentration from 1-3 % (ionic strength 0.17-0.52) decreased cooking weight loss when treated with 2 % STPP. Nevertheless, with TSPP and SHMP, the reduction of cooking weight loss was not depended on salt concentration. The result indicated that at the same ionic strength, the effect of each phosphate compound on cooking weight loss was not in the same direction. Therefore, it might be concluded that this effect was due to the type of phosphate. Liu and Xiong (1997) reported that the difference in the effect of phosphates on protein solubility

Table 2 Effect of phosphates and salt on weight gained, cooking weight loss, moisture content, sensory evaluation score, saltiness acceptance and shear force of cooked white shrimp.

Concentration and immersion time	Salt (%)	Weight gain (%)	Cooking wt. loss (%)	Moisture content (%)	Sensory score	Saltiness acceptance (%)	Shear force (N)
TSPP	0	8.20±1.48 ^{g}	4.89±0.17 ^{ef}	82.21±0.48 ^{a}	4.0±1.0 ^{a}	100	8.55±0.65 ^{f}
2 %	1	9.87±0.33 ^{def}	5.04±0.17 ^{ef}	82.08±0.16 ^{ab}	2.2±0.9 ^{d}	92	9.34±0.57 ^{e}
8 h	2	10.20±0.46 ^{de}	3.99±0.74 ^{fg}	81.21±0.12 ^{bc}	4.0±0.7 ^{a}	79	10.63±0.61 ^{c}
	3	11.02±0.44 ^{cd}	4.82±0.54 ^{ef}	80.19±0.14 ^{c}	3.4±1.2 ^{ab}	42	10.00±0.44 ^{d}
STPP	0	9.23±0.57 ^{efg}	6.26±0.22 ^{c}	82.64±0.34 ^{a}	3.5±1.0 ^{ab}	100	9.93±0.60 ^{de}
2 %	1	11.99±0.66 ^{bc}	5.12±0.66 ^{de}	81.14±0.12 ^{bc}	2.5±1.0 ^{cd}	83	10.89±0.64 ^{bc}
10 h	2	12.30±0.23 ^{ab}	4.51±0.65 ^{fg}	80.52±0.59 ^{c}	3.2±1.0 ^{abc}	75	11.02±0.60 ^{bc}
	3	13.17±1.00 ^{ab}	3.74±0.64 ^{g}	80.82±0.50 ^{c}	2.7±1.1 ^{bcd}	42	11.15±0.64 ^{bc}
SHMP 3 %	0	3.84±0.29 ^{i}	11.07±0.33 ^{b}	81.05±0.38 ^{c}	3.7±1.2 ^{a}	100	12.09±0.95 ^{a}
10 h	1	6.87±0.08 ^{h}	12.46±0.64 ^{a}	80.22±0.15 ^{c}	3.8±1.1 ^{a}	100	11.25±1.16 ^{bc}
	2	8.62±0.22 ^{fg}	12.91±0.12 ^{a}	79.03±0.23 ^{d}	3.6±0.8 ^{a}	71	11.55±0.62 ^{ab}
	3	9.02±0.42 ^{efg}	10.77±0.73 ^{b}	78.92±0.43 ^{d}	3.8±0.8 ^{a}	7	11.45±0.80 ^{b}

Values in the same column with the same superscript are not significantly different ($p > 0.05$)

was due to the different numbers of negative charges and the chain lengths. Xiong and Kupski (1999a) also reported that a larger phosphate molecule has a lower penetration rate into the muscle.

Phosphates and salt was found to have a synergistic effect on reducing cooking weight loss. The result was similar to those reported by Shults and Wierbicki (1973) that the addition of 1 % salt to TSPP, STPP and SHMP increased water holding capacity of chicken breast and reduced shrinkage after cooking compared to sample containing only phosphates. However, in our study, only samples treated with STPP and salt showed a significant difference in cooking weight loss compared to sample treated with only phosphate. It is apparent that the higher salt content, the lower cooking weight loss. The samples treated with TSPP and SHMP, together with salt, showed a trend in reducing weight loss but it was not significantly different from those without salt. Thus, it might be concluded that 1-3 % salt did not have a synergistic effect with TSPP or SHMP in reducing cooking weight loss. This result was coincided with the reports of Xiong and Kupski (1999b) that the treatment of chicken fillet with 1.6 % TSPP, with or without salt, yielded the same result of cooking weight loss reduction. Shults and Wierbicki (1973) also reported that SHMP, with or without salt, had the same effect on reduction of shrinkage of chicken muscle.

3.4 Effects of phosphate and salt on moisture content and shear force

Apparently, moisture content decreased when salt concentration increased. Moisture content of samples treated with STPP and 1-3 % salt was significantly lower than that of control (without salt). However, moisture contents of the shrimp treated with TSPP or SHMP, with or without 1 % salt, were not significantly different ($P>0.05$); while those with 2 and 3 % salt, moisture content significantly decreased ($P\leq0.05$). Damodaran and Kinsella (1982) reported the effect of salt on functional properties of protein was due to the hydrophobic interactions and electrostatic interactions which resulted in thermal-stability of proteins. Effect of salt on shear force was found to be depended on salt concentration. Samples with salt in all treatments had higher shear force than those of control. The shrimp immersed in a higher salt concentration resulted in higher shear force. Shear force also increased when pH of the solution and moisture content decreased. Consequently, shrimp meat was crunchier; yet the sensory evaluation score decreased. Datienne and Wicker (1999) also found that 0.45 % STPP with 0.5-1.0 % salt increased shear force of pork loin. Sheard and Tali (2004) reported the use of 5 % salt, together with 5 % STPP injection in pork loin, increased shear force more than using phosphates alone.

3.5 Effect of phosphates and salt on sensory evaluation score

Table 2 shows that immersion of shrimp in TSPP and STPP, in combination with 1 % salt, increased shear force of shrimp compared to those using only phosphates with significantly different sensory scores ($P\leq0.05$). However, at 2 and 3 % salt, sensory scores were not significantly different from the samples without salt. Only shear force of samples treated with TSPP significantly increased with higher salt concentration. For STPP, with 1-3 % salt, shear forces were not significantly different. For SHMP, it was found that salt concentration did not affect sensory scores. It might be concluded that more than 80 and 70 % of the panelists accepted the saltiness of shrimp samples treated with 1 and 2 % salt, respectively; while at 3 % salt there were less than 42 % of the panelists accepted the treated samples. When cooking weight loss was accounted for, it was found that 2 % salt combined with phosphates increased weight gained of raw shrimp and decreased cooking weight loss with acceptable texture and taste (score >3.0).

CONCLUSIONS

Effects of TSPP, STPP and SHMP on raw weight gained and cooking weight loss of white shrimp depended on the concentration and immersion time. Effectiveness of TSPP and STPP was similar and better than SHMP. Use of TSPP (2%, 8 h), STPP (2 %, 10 h) and SHMP (3%, 10 h) in combination with 1-3 % salt increased raw weight gained in accordance with increased salt concentration but only STPP decreased cooking weight loss as the salt concentration increased. However, less than 50 % of the panelists accepted samples treated with 3 % salt. Therefore, it was concluded that immersing the white shrimp in phosphates solution with 2 % salt for 8-10 h was the most appropriate treatment.

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