Reducing of weight variation in soaking step of shrimp processing: effects of iced storage time and soaking equipment

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Abstract. The aim of shrimp soaking is to improve functional properties and yield of a shrimp product. The weight variation in the soaking step in actual production is larger than that in the laboratory due to many uncontrollable factors that have not been identified. The objective of this work, therefore, was to investigate the causes that provoke the difference in yield calculation between the laboratory and the real production conditions to improve the soaking process of shrimp within the regulated time. First, the effect of storage time in ice (0 and 24 h) on soaking yield variation was studied. Then, the effect of soaking equipment, i.e. flat bottom tank with rod impeller and cone bottom tank with paddle blade impeller, on weight variation was determined. The result revealed that the iced storage time and the design of soaking equipment had no significant effect on the variations of yield and weight (p > 0.05). Nevertheless, water holding capacities after soaking and cooking were significantly influenced by the iced storage period (p < 0.05). The result revealed that the 24-h iced storage significantly reduced the yields of soaking, cooking, and freezing.

1. Introduction

Processed seafood is an important exporting product of Thailand. Shrimp is one of the popular seafood in the world because it has several applications in foods. Generally, soaking is the crucial step to improve the texture and the product yields, so the manufacturers can get more profits. Thai Fishery department, however, has urged the manufacturers to shorten the soaking time from 24 h to no longer than 6 h. From a preliminary study in a laboratory, soaking shrimp with phosphate treatment for 6 h was enough to achieve the desired yield of 116% on average. However, the actual average yield was much lower. It was hypothesized that differences between the laboratory and the actual processes used in a large scale production, such as the delayed time of raw material kept in ice storage and soaking equipment may cause this problem. The flat bottom tank with rod impellers is often used in the laboratory, while the cone bottom tank with paddle blades is used in the mass production. This probably leads to the variation of water absorption of the shrimp due to difference in shrimp movement during stirring. Another observation was the extended storage time in the actual production of which varied from 0 to 24 h. This could be a potential factor affecting the yield variation of the soaked shrimps. The difference in yield calculation impacts the production plan and cost estimation of the factory.
Shrimp is a very perishable product; it can easily be digested by microorganisms. Its post-mortem changes occur more rapid than that of fish. Zeng et al. [1] found that water holding capacity (WHC) of shrimp stored in ice rapidly decreased with time during day 1 and was slow down during the rest of 6 days.

Rielly et al. [2] found that very large dead zone was formed below the impeller of a dished bottom tank that installed baffles reaching the dish level. The diameter of the dead zone was almost one-fifth of the impeller diameter and it extended from the impeller to the bottom of the vessel. On the other hand, a flat bottom stirred tank has a minimum dead zone with a better mixing performance than the dish bottom tanks at the same operating condition. It is clear that the shape of a tank bottom has a significant effect on flow pattern and velocity profile under the impeller.

To minimize the weight variation in the soaking step, this study aimed to investigate the effects of iced storage time and design of the soaking equipment.

2. Materials and methods

2.1. Frozen shrimp processing procedure
Pacific white shrimp (Litopenaeus vannamei) was used. Peeled and deveined shrimps with the size of 90–110 shrimp/kg and soaking solution (mixed-phosphate, non-phosphate and salt – food grade) were obtained from a factory in Samut Sakhon province, Thailand. The shrimps were packed in a plastic bag and kept in an insulated polystyrene box containing crushed ice during transferred to the laboratory in Food Engineering department, KMUTT. Then, the shrimps were washed with cold water and soaked in the phosphate solution with the ratio of shrimp: soaking solution (by weight) of 1.0:1.3 for 6 h at 8±2 °C. The impeller was run at 9 rpm for 3 h and stopped for 3 h. After soaking, the shrimps were cooked in hot water at 86±2 °C for 127 s, cooled in cold water until the core temperature reached 9 °C, and finally frozen by an air blast freezer at below -18 °C.

2.2. Determination of the effect of soaking equipment on the soaking yield of shrimp
Two tanks with different designs were used in the soaking step: flat bottom tank with rod impellers (FBR) and cone bottom tank with paddle blade impellers (CBP) as shown in figure 1. Two thousand grams of shrimp was soaked in the phosphate solution for 6 h. Every hour, 5 shrimps per position were sampled from 5 locations represented by the green circles as shown in figure 1. After soaking, cooking, and freezing, the yields were determined.

![Figure 1. Soaking tank configurations: (a) flat bottom tank with rod impeller and (b) cone bottom tank with paddle blade impeller.](image)

2.3. Determination of the effect of iced storage time on the soaking yield of shrimp
Fresh shrimps were immediately soaked in the phosphate solution after arriving at the laboratory and treated as 0-h storage sample. The rest were covered and successively layered with ice in an insulated polystyrene box and kept in a cold storage (below 4 °C) for 24 h. In this experiment, the flat bottom tank with rod impeller was used. Two thousand grams of shrimp was soaked in the phosphate solution. After
that, the soaked shrimps were cooked and frozen. The soaking, cooking and freezing conditions were explained in section 2.1.

Qualities of the shrimps were determined in terms of total volatile base nitrogen (TVB-N), moisture content (MC), water holding capacity (WHC). The yields of storage, soaking, cooking and freeing steps were also determined. TVB-N was analyzed according to Conway and Byrne [3]. Moisture content was determined by drying at 105 °C for 24 h [4]. WHC was determined by centrifugation according to the procedure of Wongngam [5], and calculated by the following equation:

\[
\text{Water holding capacity} \% = \frac{w_2}{w_1} \times 100
\]  

where \(w_1\) is the initial weight (g), and \(w_2\) is the weight after centrifuging (g).

Step yield is defined as the yield of each processing step, and can be calculated by the following equations:

\[
\text{Storage yield} \% = \frac{w_{st}}{w_i} \times 100
\]

\[
\text{Soaking yield} \% = \frac{w_{as}}{w_{bs}} \times 100
\]

\[
\text{Cooking yield} \% = \frac{w_{bc}}{w_{ac}} \times 100
\]

\[
\text{Freezing yield} \% = \frac{w_{bf}}{w_{af}} \times 100
\]

where \(w\) is weight (g); subscripts \(i\) represents initial, \(st\) after iced storage, \(bs\) before soaking, as after soaking, \(bc\) before cooking, \(ac\) weight after cooking, \(bf\) before freezing, and \(af\) after freezing.

2.4. Statistical Analysis
ANOVA (one-way) was used to analyze the significance of the treatments (i.e. iced storage time, and soaking equipment), using Minitab® software version 17. The experiments were carried out in duplicate. Tukey comparison test at the significant level of 5% was used to analyze the difference of mean values of the responses. To confirm the quality of the data for ANOVA analysis, the test of equal variances was performed.

3. Results and discussion

3.1. Effect of soaking equipment on weight variation
Weight variations were calculated in terms of average standard deviation (avg. S.D.) in weight from different locations. After soaking, the step yields of soaking, cooking, and freezing were determined.

| Soaking time (h)NS | Weight variation (Avg. S.D.) (g)  |
|-------------------|---------------------------------|
|                   | FBR    | CBP     |
| 1                 | 1.14±0.07 | 1.30±0.04 |
| 2                 | 1.30±0.06 | 1.17±0.06 |
| 3                 | 1.14±0.14 | 1.42±0.05 |
| 4                 | 1.47±0.12 | 1.25±0.12 |
| 5                 | 1.38±0.05 | 1.15±0.13 |
| 6                 | 1.38±0.08 | 1.18±0.10 |

NS not significantly different (\(p > 0.05\)) in the same row
Table 1 presents the weight variations throughout 6 h of soaking from different designs of soaking equipment. The standard deviations ranged from 1.14 to 1.47 g. At a given time, no significant difference between the weight variations obtained from the two designs was detected ($p > 0.05$). It implies that there were no dead zones in both designs and well mixed conditions were obtained. Figure 2 shows the soaking, cooking and freezing yields of shrimps soaked in soaking equipment with different designs. It was obvious that different designs of soaking equipment did not significantly affect the yields ($p > 0.05$). Both designs provide the same degree of mixing with high soaking yields (>116%).

![Figure 2. Step yields of soaking, cooking, and freezing.](image)

3.2. Effect of iced storage time on soaking yield variation

To study the effect of delayed time during ice storage on soaking yield, TVB-N, moisture content, WHC, and soaking yield were determined. TVB-N is one of the most widely used methods to evaluate the degree of seafood decomposition. It was found that the average TVB-N values of shrimp stored for 0 h and 24 h before soaking were 5.33±0.17 and 5.70±0.18 mg N/100 g of sample, respectively (figure 3). The iced storage period of shrimp within 24 h did not significantly increase the TVB-N value ($p > 0.05$). In general, the critical limits of TVB-N (25–40 mg N/100 g of sample) have been established for different groups of seafood. For shrimp, the critical TVB-N of 30 mg N/100 g has been reported [6]. Thus, during the storage period of 24 h in ice, the shrimp freshness was still preserved.

![Figure 3. Total volatile basic nitrogen (TVB-N) of shrimp before soaking.](image)

In general, the water content in seafood is not only important for economical quality but also the sensory properties (e.g. juiciness, tenderness and mouthfeel) of the final products. Moisture of 75–80% in fresh shrimp is typically reported [7]. In this study, the initial moisture content of the shrimp is
78.82±0.35% (w.b.). Table 2 shows the changes of moisture content after iced storage, soaking, and cooking.

**Table 2.** Moisture content of shrimps from different iced storage periods after each step of processing.

| Iced storage period (h) | Moisture content (%) (w.b.) | After iced storage | After soaking | After cooking |
|-------------------------|----------------------------|--------------------|---------------|--------------|
|                         |                            | 78.82±0.35         | 82.73±0.16a    | 82.24±0.14a  |
| 0 h                     |                            | 82.39±0.34         | 84.01±0.26b    | 82.93±0.17a  |

Different letters in the same column are significantly different (p < 0.05).

After iced storage for 24 h, the moisture content increased from 78.82% to 82.39% which is almost similar to that of the fresh sample after soaking (82.73%). After soaking, the 24-h sample had 1.28% higher moisture content than the fresh sample. An increase in immersion time in melted ice resulted in the more water penetration in the shrimp muscle [8-9]. After cooking, the moisture content in the soaked shrimp decreased due to heat-induced protein denaturation and consequently shrinkage of myofibrillar protein [10]. However, the final moisture contents of both treatments were not significantly different (p > 0.05). Overall, the moisture content in 0-h and 24-h samples increased about 3.43±0.49% and 4.12±0.52%, respectively, after cooking. The observed results indicate that during storage in ice only free water can penetrate in the shrimp, whereas during soaking in the phosphate solution, most of the water was trapped in muscle fibers and myolemma of the shrimp and became intermediate and bound water.

Water holding capacity (WHC) is a quality parameter indicating the ability of meat to retain moisture. The WHC affects the yield and other quality of meat during production and storage. From table 3, after soaking, the WHC of both samples increased because of water binding capacity of phosphate. The phosphate influences muscle protein structure and breaks bonds between proteins. The interactions between negative charges of phosphate molecules and myofibrillar proteins increase electrostatic repulsion of polypeptide chains, which resulted in the swelling of muscle [14]. Thus, water can be held in the muscle structure. When heat was applied, denaturation and coagulation of protein take place and in turn lower water holding capacity and enhance protein-protein interaction leading to less water entrapped within the protein structure [10].

**Table 3.** WHC of shrimps from different iced storage periods after each step of processing.

| Iced storage period (h) | Water holding capacity (%) | After iced storage | After soaking | After cooking |
|-------------------------|----------------------------|--------------------|---------------|--------------|
|                         |                            | 73.42±0.73         | 79.60±0.96a    | 72.58±0.46a  |
| 0 h                     |                            | 68.93±0.45         | 73.05±0.60b    | 68.20±0.51b  |

Different letters in the same column are significantly different (p < 0.05).

The WHC after soaking and cooking of 0-h and 24-h samples was significantly different. It was obvious that the 24-h sample had lower WHC than the 0-h sample, indicating lower ability of protein to bind water. This result is consistent with the previous study [1]. Sriket et al. [12] also reported that the muscle softening of freshwater prawn during iced storage resulted from the degradation of collagen caused by trypsin released from cephalothorax during the extended iced storage. Since iced storage affects the quality of the raw material [13], the WHC of the fresh shrimp was significantly higher than that of the 24-h sample (p < 0.05). However, the cooking yields were not significantly different. Statistical analysis result also indicated that two populations have an equal variance (p ≥ 0.05).

From table 4, there were significant differences in step yields between the shrimps from different iced storage periods (p < 0.05). Although the 24-h sample had higher soaking yield, the yields of cooking and freezing were significantly lower than those of the 0-h sample. Although phosphate can help
increase water retention by increasing interactions between molecules of protein and water, it seemed like the quality of the muscle protein to hold water is more important; cooking and freezing yields of fresh shrimp (0-h sample) were significantly higher than those of 24-h sample. These results well corresponded to the WHC presented in table 3. The higher WHC resulted in the higher cooking and freezing yields due to the superior quality of protein. During storage, the structure of muscle protein is deteriorated by endogenous and bacterial enzymes [15]; consequently, water cannot be entrapped in the protein structure. The results indicated that the processor will get a large variation (high S.D.) of the calculated yields, if the data from differently treated shrimp are merged due to the difference in their inherent quality.

| Iced storage period (h) | Step yield (%) | Based on the initial weight of R.M. | After soaking | After cooking | After freezing |
|------------------------|----------------|------------------------------------|---------------|--------------|---------------|
| 0 h                    | 118.23±0.42b   | 112.33±0.50a                       |               |              | 109.27±0.53a  |
| 24 h                   | 120.80±0.56a   | 110.11±0.49b                       | 105.53±0.62b  |

Different letters in the same column are significantly different (p<0.05).

4. Conclusion
Two designs of equipment used in soaking step, namely flat bottom tank with rod impeller and cone bottom tank with paddle blade impeller, had no significant effect on weight variation at a given soaking time up to 6 h. Moreover, the moisture content of shrimp increased with an increase in iced storage time and soaking time. Although the 24-h iced-storage shrimp had higher moisture content than the fresh shrimp after cooking, the moisture lost was higher. The quality of protein was confirmed by WHC analysis, indicating that the shrimp with shorter period of iced storage had high-quality muscle protein, leading to significantly higher cooking and freezing yields, compared with the sample that was kept in ice for 24 h before processing.

In summary, although phosphate solution can help water absorption, the inherent quality of shrimp during iced storage is a relevant factor of variations in every step of processing. When the data of different raw material qualities are merged together to calculate an average yield during soaking, a low average value with large variation can be possibly observed. To minimize the variation of step yields, the iced storage time that can still maintain the protein quality of shrimp should be further studied.

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