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Effects of sodium bicarbonate containing traces of citric acid in combination with sodium chloride on yield and some properties of white shrimp (*Penaeus vannamei*) frozen by shelf freezing, air-blast and cryogenic freezing

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ABSTRACT

Effects of sodium bicarbonate with traces of citric acid in combination with sodium chloride on yield, freezing time, freezing rate, freezing loss and cutting force of white shrimp frozen by shelf, air-blast and cryogenic freezing with/without precooking were investigated. Shelf freezing was done at $-40\,^{\circ}C \pm 2\,^{\circ}C$ while air-blast freezing was carried out at $-35\,^{\circ}C \pm 2\,^{\circ}C$, and cryogenic freezing was done at $-35\,^{\circ}C$, $-40\,^{\circ}C$ and $-60\,^{\circ}C$. The freezing loss in the non-treated samples was 8.25, 4.6–5.84 and 1.92–3.48 g/100 g fresh shrimp for peeled samples frozen without precooking and increased to 21.85, 17.54–26.97, 17.92–20.31 g/100 g fresh shrimp in the precooked samples frozen by shelf, air-blast and cryogenic freezing, respectively. The treatment of sodium bicarbonate containing traces of citric acid at 4 g/100 ml with sodium chloride at 3 g/100 ml lead to the increase of yield thus reduced the freezing loss by about 6.83–10.28 and 6.41–12.4 g/100 g fresh shrimp for the frozen–thawed samples frozen as uncooked and cooked products, respectively. The toughening of shrimp was observed while sodium bicarbonate containing traces of citric acid treatment with sodium chloride could reduce the texture change occurred during the freezing.

1. Introduction

White shrimps (*Panaeus vannamei*) are generally processed as fresh, cooked or as value-added products before they are frozen and exported. Frozen storage is an important preservation method for seafood product. However, quality deterioration such as texture, flavor, and color still occurs during the storage (Sriket, Benjakul, Visessanguan, & Kijroongrojana, 2007). Many factors including freezing method and conditions, rate of freezing and thawing, storage temperature, temperature fluctuation and transportation affect the degree of quality loss (Boonsumrej, Chaiwanichsiri, Tantratian, Suzuki, & Takai, 2007; Giddings & Hill, 1978; Sebranek, 1982; Srinivasan, Xiong, & Blanchard, 1997). Textural changes of marine meat are due to protein denaturation and aggregation results in loss of water-holding capacity (WHC). The yield or loss after freezing and thawing is of important economic consequence. Freezing loss of peeled uncooked black tiger shrimp frozen by air-blast and cryogenic freezing ranged from 1.75 to 3.43 g/100 g shrimp (Boonsumrej et al., 2007) while yield losses for three sizes of frozen cooked white shrimp, *P. vannamei*, ranged from 1 to 40 g/100 g shrimp with moisture losses to 10 g/100 g shrimp (Erdogdu, 1996; Erdogdu, Luzuriaga, Balaban, & Chau, 2001).

Phosphate is widely used to promote water-binding capacity and reduce cooking loss on meat, fish and seafood products (Kijowski & Mast, 1988; Tehnet, Fihne, Nickelson, & Toloday, 1981; Thorarinsdottir, Gudmundsdottir, Arason, Thorkelsson, & Kristbergsson, 2004). The effectiveness of phosphates on water-holding properties of meat products depends on the type and quantity of phosphate on the specific food product. The role of phosphate may be due to the effects on pH and ionic strength and the interaction of phosphate ions with divalent cations and myofibrillar proteins (Thorarinsdottir et al., 2004). In spite of this, the non-phosphate additive, sodium bicarbonate was reported to be effective in improving the water-holding capacity, color, and organoleptic properties of fresh meats, beef, pork and poultry (Ahn, Patience, Fortin, & McCurdy, 1992; Boles, Shand, Patience, McCurdy, & Schaefer, 1993; Kauffman, Greaser, Pospiech, & Russell, 2000; Kauffman et al., 1998). Sodium bicarbonate from commercial source, which contains traces of citric acid, is currently used instead

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of phosphate in some factories that do freezing of shrimp in Thailand. Phosphate in term of P_2O_5 residue is limited to 0.5 g/100 g sample according to EU regulations for seafood products (Thorarinsdottir et al., 2004). Therefore, the use of non-phosphate ingredient such as sodium bicarbonate will have advantage over using phosphate. Use of Sodium bicarbonate has GRAS (generally recognized as safe) status according to FDA (Food and Drug Administration) and shows no P_2O_5 residue. However, no references were found about the effects of sodium bicarbonate on yield and quality of frozen white shrimps.

The objectives of this research were to study the effects of sodium bicarbonate containing traces of citric acid treatment in combination with sodium chloride, freezing methods carried out by shelf, air-blast and cryogenic freezing on yield and texture of white shrimps frozen with/without precooking.

2. Materials and methods

2.1. Raw materials and chemicals

White shrimps (*P. vannamei*), size 68–72 shrimps per kilogram, were cleaned with cooled water (about 5 °C), washed with chlorine water at 100 mg/l and soaked in sodium meta-bisulfite solution at 0.1 g/100 ml for 15 min before soaking in the solution of sodium chloride and sodium bicarbonate containing traces of citric acid which is the product of Bornnet Corporation Co., Ltd. (Bangkok, Thailand). STPP (sodium tri-polyphosphate) was kindly obtained from World Agro Tech Co., Ltd. (Bangkok, Thailand).

2.2. Effects of sodium chloride, sodium bicarbonate, sodium bicarbonate containing traces of citric acid and STPP on yield and texture of white shrimp

White shrimps were deheaded and peeled. Fifteen shrimps per treatment were soaked in the solution of sodium chloride at 3 g/100 ml, sodium bicarbonate at 2, 4 g/100 ml, sodium bicarbonate containing traces of citric acid at 2, 4 g/100 ml and STPP at 2, 4 g/100 ml and combination of sodium chloride at 3 g/100 ml with other salts at 2 and 4 g/100 ml for 3 h at about 5 °C. The sample soaked in the water without any salts was set as control. The samples were then frozen without precooking in the shelf freezer (Siam Patkol Ltd., Bangkok, Thailand) at $-40\,°C \pm 2\,°C$. Yield after the salt treatment and a freeze–thaw cycle was determined. The frozen–thawed samples were precooked by steaming in the laboratory cooker for 2 min and measured for cutting force.

2.3. Effects of sodium bicarbonate containing traces of citric acid in combination with sodium chloride, freezing methods on yield and texture of peeled white shrimps frozen without precooking

The experiments were carried out using a 7×3 factorial design (freezing method × sodium bicarbonate containing traces of citric acid concentration). White shrimps were deheaded and peeled. Fifteen shrimps per treatment were soaked in the solution of sodium chloride at 3 g/100 ml and sodium bicarbonate containing traces of citric acid at 2, 4 g/100 ml, respectively, for 3 h at about 5 °C. The sample soaked in the water without both salts was set as control. The samples were then frozen without precooking by three freezing methods, shelf freezing, air-blast freezing and cryogenic freezing with liquid nitrogen. The shelf freezer (Siam Patkol Ltd., Bangkok, Thailand) was set at $-40\,°C \pm 2\,°C$ whereas air-blast freezing was done at $-35\,°C \pm 2\,°C$ with the air-velocity of 4, 5.5, and 6.5 m/s in an air-blast freezer (Patkol Public Company Ltd., Bangkok, Thailand). The cryogenic freezing was carried out at −35, −40 and −60 °C in a Cryo-test Chamber (Air Products and Chemicals model F831059E; Allentown, Penn., USA) by exposing samples with the liquid N_2 vapor supplied by Liquid N_2 tank (Taylor-Wharton model XL-55HP, USA). The freezing of cooked shrimps was done following the same procedure except that the samples after sodium bicarbonate containing traces of citric acid treatment were precooked by steaming in the laboratory cooker for 2 min and immediately cooled in water (4–7 °C) for 3 min before laying on a sieve for 2 min and frozen.

The temperature of the samples during freezing for each condition was monitored by using a type T thermocouple inserted at the second abdominal segment of a shrimp (Boonsumrej et al., 2007) and connected to a data logger (DATA TAKER 605 Series 2). Freezing time was time (s) needed for the temperature change of shrimp from 10 °C to −18 °C. The freezing rate (Boonsumrej et al., 2007; Pan & Yeh, 1993) was calculated from

$$\text{Freezing rate} = \frac{\text{Maximum distance from the surface to the thermal center of shrimp (cm)}}{\text{Thermal arrest time (h) to reach } -18\,°\text{C}}$$

Freezing time, freezing rate, and yield of the shell-on or unpeeled white shrimps after soaking in sodium chloride at 3 g/100 ml and sodium bicarbonate containing traces of citric acid solution at 4 g/100 ml were also investigated following the described procedure.

2.4. Determination of yield, freezing loss and moisture content

Total weight of shrimps after sodium chloride and sodium bicarbonate containing traces of citric acid treatment, precooking and a freeze–thaw cycle (thawing at room temperature for 45 min) was determined and compared to the weight of raw materials (calculated at 100) used (AOAC, 1995) and shown as yield. Values less than 100 indicated that shrimps had lost weight while values over 100 showed that shrimps had gained weight during processing

$$\text{Yield} = \frac{\text{Weight of shrimps after treatment, precooking or freeze-thawing}}{\text{Weight of raw shrimps}} \times 100$$

The freezing loss of shrimps after a freeze–thaw cycle was determined from the known weight of raw shrimps before and after a freeze–thaw cycle (thawing at room temperature for 45 min) by following AOAC (1995).