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Optimization of the freezing process of red shrimp (*Pleoticus muelleri*) previously treated with phosphates

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ABSTRACT

The objective of this paper is the optimization of shrimp freezing process and evaluation of the influence of phosphate addition on product yield and quality. A systematic experiment was conducted to obtain data on yield and quality after the following process steps: immersion in phosphate solutions, freezing, defrosting, and cooking. The best results were obtained using phosphate and freezing the shrimps (*Pleoticus muelleri*) with liquid N_2. The use of phosphate was efficient in retaining water during thawing and after cooking. These results were confirmed with the diminishing of drip loss during thawing and after cooking, and with the increasing of moisture content after immersion.

Optimisation du processus de congélation des crevettes rouges (*Pleoticus muelleri*) traité auparavant à l'aide de phosphates

Mots clés : Crevettes ; Phosphate ; Qualité ; Optimisation ; Congélation ; Azote liquide

1. Introduction

One essential preoccupation, particularly in the seafood industry, is to improve conservation technologies of perishable foods to reach final products with best possible quality. Among the various methods currently used, the most accepted are those based on the action of low temperatures, which preserve taste and nutritional value (Chevalier et al., 2000a,b; Delgado and Sun, 2001; Campañone et al., 2002).

Different equipments have become available for freezing foodstuffs. Freezer systems can be classified considering how they extract heat from the product being frozen, i.e., *air*

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blast freezing, *contact freezing*, *immersion freezing*, *cryogenic freezing* and *cryomechanical freezing* (where the food first undergoes a cryogenic treatment, then is completely frozen by a mechanical process) (Tanikawa et al., 1985; Sikorski and Kotakowska, 1990; Garthwaite, 1992; Ogawa and Maia, 1999; Agnelli and Mascheroni, 2001, 2002; Bevilacqua et al., 2004).

Usually, two types of freezing systems are applied to assist the needs of cold chain in seafood industry: mechanical freezing (air blast freezing) and cryogenic freezing that uses the direct contact of gases (nitrogen or carbonic gas) and, sometimes, a cryomechanical freezing. These systems are accomplished through freezing tunnels and are not necessarily in the same production line, although sometime they exist side by side.

In food processing technology, the freezing process affects not only frozen food quality but also energy saving performance of the freezing equipment (Huan et al., 2003). The quality of frozen food is closely related to freezing and thawing processes. The rate of freezing and formation of small ice crystals are critical to minimize tissue damage and drip loss in thawing (Li and Sun, 2002). It was found that slow freezing produces intercellular ice crystals with large diameters. An increase in freezing rate is followed by a change on ice crystal location. The number of crystals increased while their size decreased. The most intensive fiber damage was found in samples frozen at slow rate and the least in samples frozen at fast rate with freezing temperature of −50 °C (Sikorski and Kotakowska, 1990; Bevilacqua et al., 2004; Li and Sun, 2002; Grujic et al., 1993; Anon., 1998; Molina-Garcia et al., 2004).

Factors that influence the quality of drip losses are numerous and opinions of investigators are partly contradictory. However, most of the investigators agree that the quantity of drip losses during meat thawing is lower if the meat was frozen at a faster rate (Agnelli and Mascheroni, 2002; Petrovic et al., 1993; Ngapo et al., 1999a,b).

In animal products, the signs of damage are seen when the product is defrosted, with an exudate drained from the tissues or collected in pockets inside the product. This is composed of water where various quantities of crystalline or colloidal substances are dissolved. The formation of exudate is influenced by various factors: (a) storage time and temperature prior to freezing; (b) freezing rate (slower freezing rates increase exudation); (c) storage time and temperature after freezing; (d) defrosting rate (slower defrosting rates increase exudation); (d) the conservation method after defrosting (Bevilacqua et al., 2004).

Phosphates help to restore water binding properties of seafood. Due to phosphate treatment, natural juices are bound and almost no drip losses occur during thawing and further processing. Treated seafood can be juicier, tender and maintain the expected nutritional value (Teicher, 1999; Schnee, 2004). However, few studies have been conducted to find optimum phosphate type and concentration, as well as optimum exposure time considering yield and quality of the final product (Applewhite et al., 1993; Aitken, 2001; Neto and Nakamura, 2003).

Based on these considerations, the aim of this paper is to compare two freezing systems used in seafood industry (individually quick frozen in spiral freezer and cryogenic freezer), considering weight loss after freezing, thawing and cooking, and verifying the yield obtained with the use of phosphate.

2. Materials and methods

2.1. *Experimental design*

In industrial research and development, usually it is necessary to cope with several factors or variables that affect final product quality. Without the use of an appropriate method, optimization can be time consuming and costly. In this work, the methodology of experimental design was used, which is considered an effective alternative for product and process development, mainly when a large number of variables is involved (Montgomery, 2001; Rodrigues and Iemma, 2005).

This methodology demands time investment in understanding the process, defining important variables to be studied (solution type, solution concentration, immersion time, freezing type, freezing time), and desirable responses (weight loss, residual phosphate, sensorial attributes).

As supported by literature, a correct freezing system choice and phosphate application before freezing can avoid losses during production and, consequently, contribute for final product yield and quality.

The first step of the experimental work was the identification of all experimental parameters of the shrimp freezing process. Next, the dominant parameters, which could produce larger effects on freezing process and the application of phosphate, were assigned. Considering those parameters, an experimental design was elaborated and real data for yield calculations in each studied stage (immersion in phosphate solutions, freezing, thawing, and cooking) was obtained.

Table 1 – Process parameters and response variables

Process parameters	Response variables
X1: shrimp specie	Y1: weight after immersion (before shelling)
X2: % STP (before shelled)	Y2: weight after shelling
X3: immersion time (before shelled)	Y3: shelling yield
X4: type of phosphate (STP and Blend)	Y4: % moisture, % P_2O_5 (before shelling)
X5: % STP (before freezing)	Y5: yields
X6: % blend (before freezing)	Y6: weight after immersion (before freezing)
X7: Immersion time (before freezing)	Y7: % moisture, % P_2O_5 (after immersion, before freezing)
X8: freezing temperature (N_2 liquid)	Y8: weight after freezing
X9: freezing temperature (spiral freezer)	Y9: weight after glazing
X10: freezing time	Y10: % of ice after glazing
X11: product temperature (before glazing)	Y11: % moisture, % P_2O_5 (after freezing/glazing)
X12: immersion time (glazing)	Y12: weight after thawing
X13: thawing temperature	Y13: % moisture, % P_2O_5 (after thawing)
X14: thawing time	Y14: weight after cooking
X15: cooking temperature	Y15: % moisture, % P_2O_5 (after cooking)
X16: cooking time	Y16: sensorial analysis after cooking