Meat Research
Vol 3, Issue 3 Article 60
ISSN: 2790-1971
https://doi.org/10.55002/mr.3.3.60 http://www.bmsa.info/meatresearch

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Keywords:
Freeze storage
Colour
Texture
Ice crystals
Triangle test

Article Info:
Received: 03 May 2023
Accepted: 15 June 2023
Published online: 30 June 2023

Research Article

Muscle histology and Sensory quality changes during freeze storage of North Atlantic shrimps (*Pandulus borealis*)

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Abstract

It is known that inappropriate transport or storage of shrimp can adversely affect different quality parameters. An experiment was designed to store North Atlantic Shrimp at two temperatures (-20ºC & -40ºC) for 2,4,6 months and analyze the quality changes during this period from these two groups at the seafood quality laboratory of Faculty of Biosciences and Aquaculture, Bodø University College, Norway. Texture was done with TA-XT2 Texture Analyzer and Color analysis was done with Minolta Chroma meter 300, shrimp muscle histology was studied and sensory analysis was done as triangle test. During the study texture was firmer and color was whiter at -40ºC storage than at –20ºC storage. Shear force increased during freeze storage at -40ºC and decreased during storage at -20ºC. In-20ºC stored samples larger ice crystals formed between the muscles. The sensory panel found difference between the -20ºC and -40ºC stored Atlantic shrimp samples after 2 months.

Introduction

Shrimps in international trade are regarded as one of the most valuable products from the sea. As like other seafood products shrimps serve as important sources of amino acids, peptides, protein and other useful nutrients in the human diet. Shrimp is found to be an excellent source of protein (Yanar and Celik, 2006). Shrimps can be served hot or cold and are extremely popular seafood in US and Europe due to its clean and crispy taste. Additionally, shrimp muscle consists of highly unsaturated fatty acids (HUFA) such as Eicosapentaenoic (20:5n3, EPA) and Docosahexaenoic (22:6n3, DHA) which are considered as essential and cardio-protective omega-3 fatty acid(Feliz et al., 2002). EPA and DHA are vital nutrients and may be taken to maintain healthy function of brain and retina (Simpson et al., 1998).

Freezing is most widely used method of food preservation and help to preserve taste, texture, and nutritional value in foods (Akhter et al., 2022 and 2009; Akter et al., 2009; Delgado and Sun, 2001; Sarker et al., 2021; Yasmin et al., 2022). Low temperatures during freezing inhibit growth of micro organisms, chemical reactions and cellular metabolic reactions (Delgado and Sun, 2001). Inappropriate transport or freeze storage of frozen shrimp can adversely affect the quality parameters. Experiments confirmed that the storage temperature is very important in storing of shrimps, and storing at a temperature of -25°C the quality was much better than at a temperature of -16°C (Karsti and Hakvaag, 1961). Lightness, redness and yellowness decrease and hardness and chewiness increase as result of freezing in seafood (Schubring, 2002). Shear force of cooked prawns decreased after three freeze-thaw cycles which coincided with accelerated lipid oxidation in raw prawns (Srinivasan et al., 1997). Temperature fluctuations resulted in very pronounced formation of frost in the packages. After 6 to 9 months of frozen storage, the amount of frost corresponded to the weight of the glazing layer applied before storage (Bak et al., 1999).

It is certain that during long period of storage different types of physiochemical changes occur inside and outside the shrimps and any deviation from the normal status of a food obviously lost some of its appeal to consumers than a fresh one. Studies on freeze storage revealed that long time storage of shrimps made the final products unacceptable to customers (Angel et al., 1981). Lower temperature can inhibit the growth of bacteria and extend the shelf life of shrimp , but the texture of shrimp becomes soft (Li et al., 2002), which is not a good attribute for consumer acceptance. Usually the sensory qualities of shrimp during storage changes due to biochemical changes (Antony et al., 2002) and it exaggerates due to the bacterial types and quality during storage (Anwar et al., 1988). Findings of research show that shrimp frozen after 10-day ice-storage are poorer in quality and result in an unacceptable product. Shrimp kept in ice for 0-3 days give a superior quality product on freezing and those kept for 4-10 days give inferior (medium) quality shrimp on freezing (Shamshad et al., 1990). Although ice stored shrimps start getting black discolouration but still it remain organoleptically acceptable for 15 days (Joseph et al., 1998). Changes in quality of farm produced prawn during ice storage were similar to the quality changes in wild prawns (Joseph et al., 1998). Little information regarding either the physical or sensory changes of shrimps has been reported on long term freeze storage at low temperatures like -20°C

and -40°C. It is important to know more about the freeze storage and how it affects the quality parameters of shrimps to produce more quality product to sustain the global business. Bearing all these practical conditions in mind the present study has designed to assess the quality of frozen shrimp in different periods of storage at low freezing temperatures.

Materials and methods

Experimental site

This experiment was conducted at Seafood quality Laboratory under the Faculty of Biosciences and Aquaculture, Bodo University College (Presently University of Nordland), Norway.

Sample collection and preservation

Frozen and peeled North Atlantic Shrimp (*Pandalus borealis)* samples were supplied from Nergård AS, Norway. Shrimp samples were divided into two equal groups in terms of quantity to make treatment groups of -20°C and -40°C and packed in airtight food grade poly bags. These bags were then stored in cryo boxes in the freezer at -20°C and -40 °C for 2, 4 and 6 months. Samples on the day of delivery were treated as control and went through lab analysis. During this experiment shrimp samples were collected from a single batch. Each time for laboratory analysis one bag has been taken from the freezer and analysis was done these were not true replicates during the study.

Thawing of samples

The samples were thawed overnight in a natural fabricated mesh to runoff the water through the bottom and the mesh was covered by aluminium foil to avoid drying out of the shrimps.

Colour analysis

The L, a*, b* values were analyzed to determine the colour of the samples with Minolta Chroma meter 300. North Atlantic Shrimps were blended in a food processor and placed in the lens plate 6 measurements of L, a*, b* values were taken by putting the measuring sensor on the lens in circulatory order and the average value was taken as final.

Texture analysis

Texture analysis of the shrimp muscles was conducted by TA-XT2 Texture Analyzer to measure the shear resistance (kg). Where Pre-test, Test and Post test speeds were 2, 1, 2 mm/sec respectively with 90% Distance, 100g Force and 10sec Time.

Histology of Shrimp muscle during freeze storage

Raw and cooked freshly caught North Atlantic Shrimp were analyzed to find out the change in muscle structure due to ice crystal formation during storage in 20ºC and -40ºC freezers. The shrimps were manually peeled and muscle was taken by cutting at approximately 70% of the length towards the tail. Thirty pieces of muscle (15 from each type) were removed from thirty random shrimps and the measurement of the pieces were roughly 0.3 × 0.3 × 0.3 cm. Half of these pieces were then placed on marked cork pieces, covered with Cryomatrix to prevent drying out and then frozen in cooled Isopentan (chilled with liquid nitrogen) for 45 seconds. After freezing each sample was rapped with aluminum foil and stored in liquid nitrogen until all samples has been frozen. The samples were divided into two metal boxes and kept in -20ºC and -40ºC freezers and 2 samples was kept in -70ºC freezers and analyzed within 24 hours to find out the muscle structure of freshly frozen shrimp muscle. The samples were cut after 1 month. Before cutting the samples were kept in Cryostat at -20ºC for 1 hour to acclimatize. Samples were cut at -20ºC and sections were placed on glass slides in pairs. These sections were dried and stained with Harris Hematoxilin Solution for 8 minutes, then washed in running tap water for 10 minutes and cover slips were placed on the sections using Glycerol Gelatin. Slides were kept in open place overnight to dry out before taking the picture of the muscle structures in the microscope. From the dried slides picture was taken by microscope (Axioskop 2 mot plus, Carl Zeiss A/S Norway, Oslo) using computer software (Axiovision Rel 4.2).

Results and Discussions

Colour and texture Changes during freeze storage

Table 1 shows the changes in colour and texture during freeze storage. There were no specific trend of change found in a* (redness) and b* (yellowness). There were, however, measured small changes in lightness.

Table 1. Chemical and physical parameter in Ready Peeled North Atlantic Shrimp

Particulars	Shear Force (kg)	L (Lightness)	a* (Redness)	b* (Yellowness)
RP, Control	0.88	61.10	-0.94	4.45
RP,2M-20	0.88	61.13	-0.65	4.29
RP,2M-40	0.92	61.16	-0.17	4.81
RP,4M-20	0.86	61.09	0.13	6.30
RP,4M-40	0.95	61.16	-0.37	5.51
RP,6M-20	0.84	61.10	-0.39	5.90
RP,6M-40	0.99	61.18	0.01	6.96

RP = Ready Peeled North Atlantic Shrimp

Shrimp muscle was darker during the course of six month storage at -20°C, whereas it was lighter at -40°C. Higher L-value observed at -40°C and lower for -20°C storage. There was a gradual increase in shear force from control at -40°C, whereas a decrease observed at -20°C during six month storage. Usually shrimp muscle gets tougher during frozen storage (Webb et al., 1975, Noomhorm and Vongsawasdi, 1998) and this relates with the present study values from -40°C but in case of -20°C storage shrimp muscle had lower shear force i.e., muscle structure got softer. This may be due to freezing damage due to larger ice crystal formation at -20°C.

Histology of Shrimp Muscle during freeze storage

Figure 1 shows ice crystal formation within the muscle cells of shrimp during freeze storage.

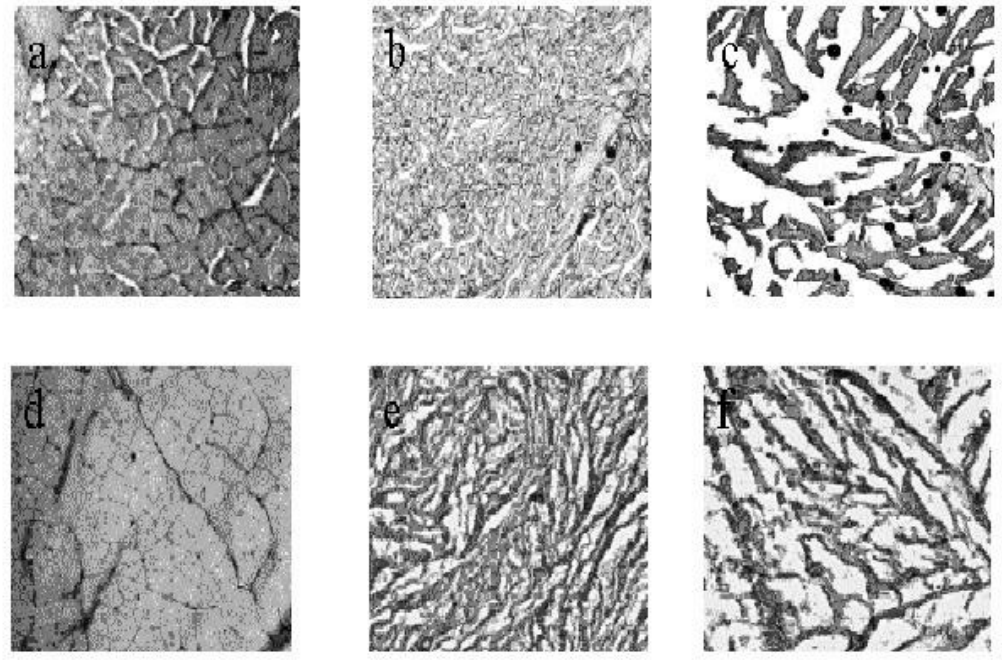

Figure 1. Change in Muscle structure during freeze storage of Cooked and Raw North Atlantic Shrimp.

[a]Cooked shrimp cryogenic frozen, at day 1, [b]Cooked shrimp at -40°C after 1 month, [d]Raw shrimp cryogenic frozen, at day 1 , [e]Raw shrimp at -40°C after 1 month, [f]Raw shrimp at -20°C after 1 month, [c]Cooked shrimp at -20°C after 1 month.

Initially there was some shrinkage occurring in the cooked shrimp (a) compared with the raw one (d). There was larger ice crystal formation in the muscles after 1 month and it was more at -20°C (c & f) than at -40°C (b & e). This means as the storage period progressed ice crystal damage increased more. After 24 hours of cryogenic freezing and storage at -80 °C there was almost no ice crystal formation in the raw shrimp because quick freezing prevented damage in muscle tissue. Cooking the shrimp resulted in some shrinkage of the muscle fibre (fig I). After 1 month of storage at -20°C resulted in larger ice crystal damage than shrimps stored at -40°C There is no study on histology of shrimp during different storage temperature and period, but Boonsumreja et al., (2007) found increased space between muscle fibres due to ice crystal formation during cryogenic freezing.

Sensory Analysis

After 2 months of storage sensory panel was able to differentiate between the shrimps from -20°C and -40°C, but they could not describe the differences. After 4 and 6 months of storage panel found difference in colour, texture and smell between the two samples. The details from the triangle test are presented in Table 2.

Table 2. Results from the Triangle test during sensory analysis of Peeled North Atlantic Shrimp

Judge	Difference between samples at 2 months storage	Comments	Difference between samples at 4 months storage	Comments	Difference between samples at 6 months storage	Comments
1	++	-40°C sample tasted fresh	++	-40°C sample juicier	++	-40°C sample more tasty and juicy
2	++	-40°C sample juicier	+		++	-20°C sample tasted drier and smell fishy
3	++	Very little difference, unidentified	++	-40°C sample tasted fresh and lighter in colour	++	-40°C sample tasted sweet and firmer texture
4	+		++	-40°C sample tasted fresh	++	-40°C sample smells fresh
5	++	-40 °C sample tasted sweet	++	-20°C sample have more fishy smell	++	Texture is juicier in -40°C sample and no rancid smell in any sample
6	+		++	-40°C sample was lighter in colour	++	-40°C sample had Firmer texture, smelt fresh

++ Differentiated confidently, +Differentiated on guess

Sensory analysis was done for the North Atlantic Shrimp samples up to 6 months. Sensory panel was able to differentiate the sample from -20°C and -40°C after 2 months, but there was a bit of guess from some of the judges. But after 4 and 6 months judges clearly differentiated samples from 2 storage temperatures and also commented on some sensory characteristics about the samples. Previous studies also found deterioration of sensory characteristics as the storage time increased and differences in low and high temperatures.

Conclusions

To get a longer shelf life it is better to store shrimps at -40°C but for domestic consumption -20°C may be useful. Freezing at -40 °C preserves the quality of peeled frozen shrimp. During this study it was found that freeze storage at -20°C results in larger ice crystals between the muscle cells than at -40°C and it gets larger and more in numbers as the storage period proceeds further. Larger ice crystal increases the intracellular spaces and after thawing this causes softer texture and at -40°C storage smaller ice crystal results in a firmer shrimp.

Acknowledgements

We are grateful to Faculty of Biosciences and Aquaculture, Bodo University College (Presently University of Nordland), Noway for funding this research.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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