



## A Comparative Study on the Quality Changes of Croaker (*Johnius dussumieri*) Fish Stored in Slurry Ice and Flake Ice

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### ABSTRACT

In the present study, the effect of storage in slurry ice compared to conventional flake ice (control) on the quality of croaker (*Johnius dussumieri*) fish was evaluated. Biochemical, microbiological, and sensory analyses were performed. Total volatile base nitrogen, trimethylamine nitrogen, and pH values were lower for fish stored in slurry ice than in control. Similarly, aerobic plate count and *Pseudomonas* sp. count were also found at lower population levels in fish stored in slurry ice. Texture profile analysis revealed that fish stored in slurry ice showed improved texture. Based on the microbiological and sensory analysis, the shelf life of croaker fish stored in slurry ice was 15 days.

### KEYWORDS

Croaker fish; slurry ice; flake ice; quality; shelf life

### Introduction

Fish is a highly perishable product, and the freshness of fish is an important factor that determines its commercial value and potential for export. Perishability depends on the fish species and handling and storage method (Olafsdottir et al., 1997). Among the various preservation methods, flake ice, refrigerated seawater, and chilled sea water are commonly used for seafood preservation. The use of slurry ice for preservation of aquatic products was first reported by Chapman (1990). It is a promising technique for the maintenance of fish quality compared to other chilling methods. Slurry ice consists of millions of micro-ice crystals surrounded by seawater at subzero temperature. Slurry ice is also known as liquid ice, flow ice, fluid ice, and slush ice. The major advantages of slurry ice include: (1) it provides a rapid chilling rate; (2) it reduces the physical damage and dehydration to seafood. In addition, slurry ice can be used with other additives such as ozone and melanosis inhibitors to improve the quality of fish and shell fish (Huidobro et al., 2002). Moreover, a huge quantity of normal ice has to be carried onboard – i.e., double the amount of the fish catch is needed due to melting of the ice. But, the slurry ice can be prepared whenever the requirement/catch is available, and also it can be pumped through a pipe into the fish box, which allows for more hygienic fish handling. Due to its advantages, the application of slurry ice systems for preservation of aquatic food products is receiving increasing attention (Pineiro et al., 2004). It has been reported that preserving fish using slurry ice maintains the quality of fish stored onboard as compared to other chilling methods (Mugica et al., 2008). Although slurry ice has potential application for preservation of fish and shell fish, very little scientific data has been reported (Huidobro et al., 2002; Mugica et al., 2008; Rodriquiz et al., 2006, 2004). In India, Sciaenids, commonly known as jewfishes or croakers, occur as by catch in shrimp trawls and contribute 10–12% of catch at Mumbai. Among this, *Johnius dussumieri* contributes 4–5% (Sushant Kumar, 1997). It is one of the major fish species used in India for surimi production and produces roughly 65,000 tons per year (Guenneugues, 2012). It is also used for the development of mince-based value-

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added products. These fishes are caught in multi-days fishing and single-day fishing gets equal treatment in terms of priority. Due to its low cost, most of the catches are not preserved properly onboard. Utilization of slurry ice for preservation of croaker fish will reduce these problems. However, there is a lack of scientific data on the quality of croaker fish stored in slurry ice. Hence, the present work was aimed to study the quality changes of croaker fish stored in slurry ice during storage and to compare its quality with fish stored in conventional flake ice.

## Materials and methods

### Preparation of slurry ice and flake ice

Slurry ice was prepared from filtered seawater (salinity: 3.5%) using ICEFLOW (Chirag, Navi Mumbai, India) machine, which is comprised of BOCK F4 compressor with 1800 RPM, wherein R-22 was used as a refrigerant. The capacity of the machine is 5–6 tons per day, and its efficiency is 2500 L/h. The temperature of the slurry ice mixture was  $-2^{\circ}\text{C}$ . Flake ice was prepared from lab scale flake ice machine (BANWAY-IRC, New Delhi, India).

### Sample preparation

Fresh croaker (*Johnius dussumieri*) were procured from the local fish market, Vashi, Navi Mumbai and brought to the laboratory in an iced condition. Average length and weight of fish were  $20 \pm 0.5$  cm and  $250 \pm 2.5$  g, respectively. After that, they were deiced and washed with potable water. Then, they were divided into two batches. The first batch of fish was kept under flake ice, and the second batch fish was kept under slurry ice in an insulated box. Hereafter, they were designated as FI and SI, respectively. Fish were kept in either flake ice or slurry ice at a ratio of 1:1. Melted ice was compensated with required flake ice/slurry ice at a regular interval. Samples were taken from each lot at two day intervals up to 15 days, and their biochemical, sensory, and microbiological qualities were evaluated. All the analyses were performed in triplicate.

### Biochemical analysis

Proximate composition of croaker fish flesh was determined by AOAC (2005) method. The pH of homogenate was determined using a glass electrode digital pH meter. Trimethylamine nitrogen (TMA-N) and total volatile base nitrogen (TVB-N) content were estimated by the Conway micro-diffusion method (1950). Free fatty acid (FFA) and peroxide values were evaluated according to AOAC (2005). Thiobarbituric acid (TBA) value was determined as described by Tarladgis et al. (1960). The nonprotein nitrogen (NPN) and alpha amino nitrogen (AAN) content were analyzed according to the method followed by George and Gopakumar (1987).

### Color and texture analysis

The color of croaker fish flesh was measured using a Hunter- Lab Scan XE – Spectrocolorimeter (Hunter Associates Laboratory, Reston, VA, USA.) at D-65 illuminant and  $10^{\circ}$  observer. Results were expressed by CIE (Commission Internationale de L'Éclairage's) color values [ $L^*$ (lightness),  $a^*$ (redness),  $b^*$ (yellowness)]. Texture profile analysis was measured using a texture analyzer (Perten Instrument, India) as described by Anderson et al. (1994). Tex Calc software was used for the tabulation of texture parameters.

### **Microbiological analysis**

Aerobic plate count (APC) was determined by pour plate technique using plate count agar (Hi-Media, M091). Plates were incubated at 35°C and the colonies, were enumerated after 48 h (USFDA, 2012). For enumeration of *Pseudomonas* species, *Pseudomonas* agar base (Hi-Media: M085) supplemented with CFC (Hi-Media: FD036) was used, and the plates were incubated at 20°C for 5 days. Oxidase positive colonies were counted as a *Pseudomonas* species (Mead and Adams, 1977).

### **Sensory analysis**

Sensory evaluation of croaker fish was performed by the six trained panelists. The samples were served after steam cooking for 10 min and cooling for 1–2 min. The panelists were asked to evaluate sensory attributes such as appearance, texture, color, odor, and overall acceptability and assign a score of 1–9, as prescribed by Meilgaard et al. (1999). A high score (7–9) was given to fish with no off-odors, and a score below 5 was considered as unacceptable quality.

### **Statistical analyses**

All the analyses were performed in triplicate ( $n = 3$ ). The data obtained were analyzed by one-way analysis of variance using Statistical Package for Social Science (SPSS) software version 16.0 (SPSS Inc., Chicago, IL, USA). All mean separations were carried out by Duncan multiple range test, using the significance level of 95% ( $P < 0.05$ ).

## **Results and discussion**

### **Proximate composition**

Fresh croaker fish flesh contained 79.87% moisture, 17.38% protein, 0.53% fat, and 1.20% ash. Nareshkumar et al. (2016) reported similar results for croaker mince. Proximate composition of fish flesh is influenced by different factors such as species, growth stage, feed, and season (Karakoltsidis et al., 1995). Fish can be classified into four categories based on their fat content: lean fish (<2%), low fat (2–4%), medium fat (4–8%), and high fat (>8%) (Ackman, 1989). Accordingly, croaker fish used in the present study falls under the lean fish variety.

### **Changes in biochemical quality**

#### **Moisture and pH**

The moisture content of croaker fish showed an increased trend in both FI (79.87–83.96%) and SI (78.99–82.50%). This may be due to loss of proteins and other soluble compounds during iced storage. On the day 3, there was a significant difference in moisture content (Figure 1a). The pH of fish flesh has an important role in determining the quality. The initial pH value of croaker flesh was 6.87 (Figure 1b), and it showed an increasing trend during storage. The increase in pH may be due to the accumulation of volatile bases such as ammonia and trimethylamine by the action of endogenous or microbial enzymes (Jeyakumari et al., 2016). Fish stored in slurry ice had lower pH value than FI. Lower pH indicates a better control of both endogenous and microbial activity in fish muscle under slurry ice during storage. Similar results were reported for mackerel, turbot, and hake (Rodriquiz et al., 2004; Ruiz-Capillas and Moras, 2001) stored in slurry ice.

#### **Total volatile base nitrogen and trimethylamine nitrogen**

In the present study, TVB-N content was found to be higher in FI (5.2–12.6 mg/100 g) than SI (5.2–7.25 mg/100 g) (Figure 1c). Chen et al. (2016) also found similar results for bighead croaker

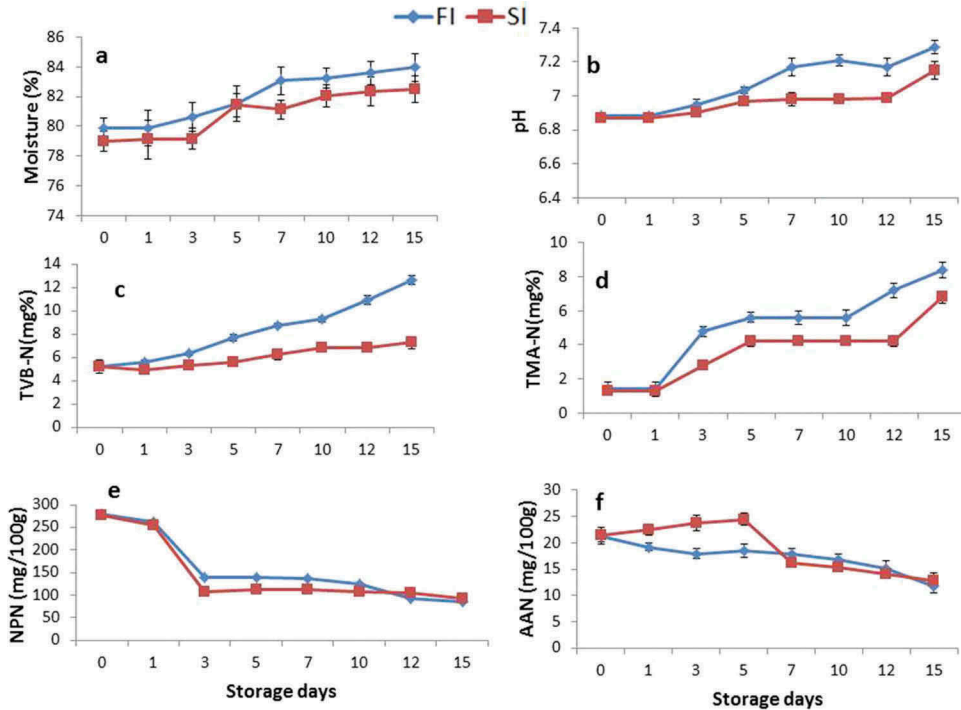


Figure 1. Changes in (a) moisture, (b) pH, (c) TVB-N, (d) TMA-N, (e) NPN, and (f) AAN values of croaker during ice storage.

stored in slurry ice. Increase in TVB-N content during ice storage is due to endogenous enzymes activity and spoilage bacteria. TVB-N content was found to be 12.6 mg/100 g and 7.25 mg/100 g for FI and SI samples, respectively, on day 15; TVB-N level of 30 mg/100 g is considered as the upper limit for consumption of fishery products (Harpaz et al., 2003). Accordingly, both the samples had an acceptable level of TVB-N values during storage. The present results are in agreement with previous reports for other fishes stored in flake ice (Ruiz-Capillas and Moras, 2001). TMA content of croaker fish showed increasing trend during storage (Figure 1d). It was observed that TVB-N and TMA-N content had a positive correlation ( $r = 0.95$ ) with APC during storage. TMA-N content was found to be 8.4 mg/100 g and 6.8 mg/100 g for FI and SI samples, respectively, on day 15. TMA content of fish and fishery products of about 10–15 mg/100 g is recommended for human consumption (Connell, 1995). Accordingly, both samples had TMA-N values within acceptable limit throughout the storage period.

**Non-protein nitrogen and alpha amino nitrogen**

In the present study, NPN values showed decreased trend during iced storage. Initial NPN content of 278.45 mg/100 g in fish flesh decreased to 85.4 mg/100 g and 91.70 mg/100 g in FI and SI samples, respectively (Figure 1e). This might be due to leaching of soluble compounds in the fish muscle during iced storage (Jeyakumari et al., 2015). The decrease in NPN content results in loss or deterioration of flavor. Results indicated that NPN had a positive correlation ( $r = 0.76$ ) with a sensory score of fish flesh. However, AAN values increased in the beginning and then showed a decreased trend during storage (Figure 1f). The initial increase in AAN content may be due to the bacterial activity. Further, a decrease in AAN in a later stage may be due to the ice melt water (Viji et al., 2015; Kumar et al., 1995).

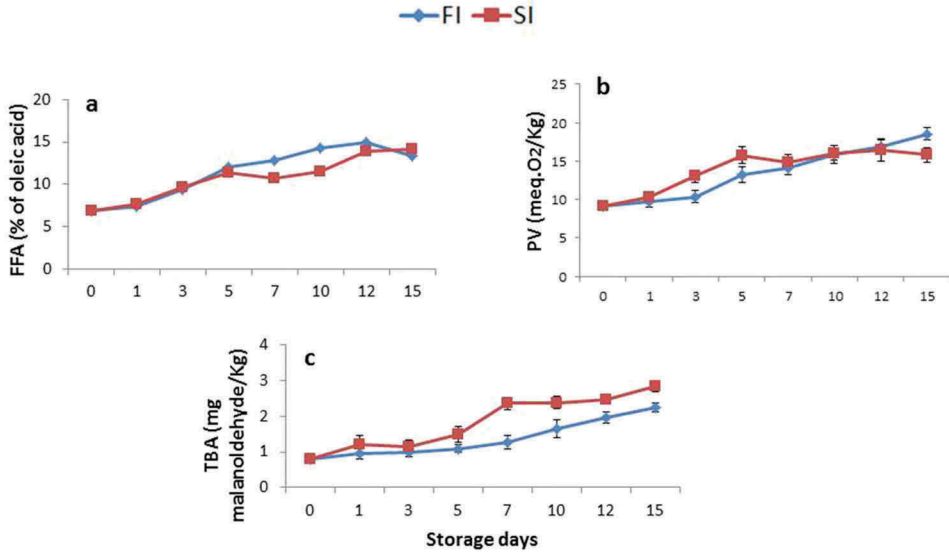


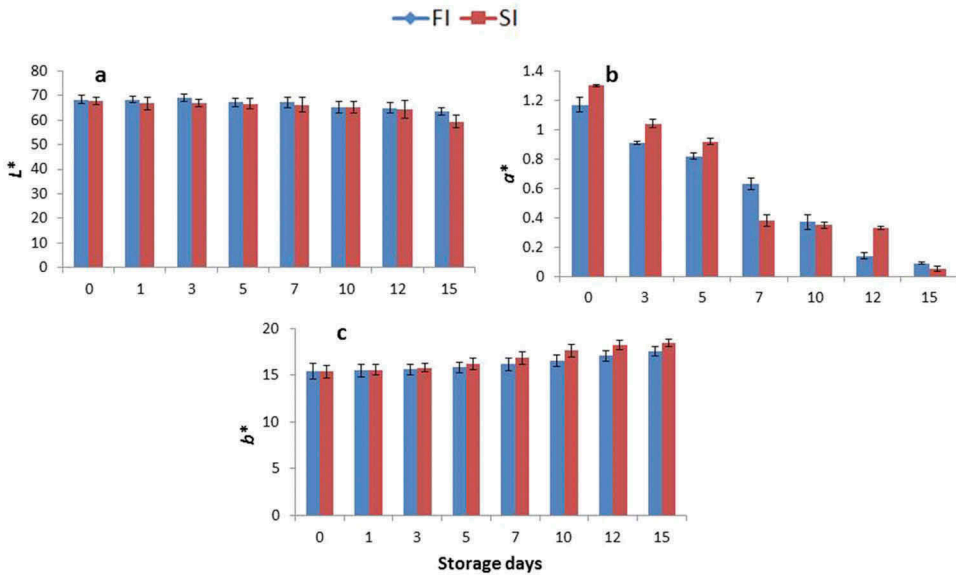
Figure 2. Changes in (a) FFA, (b) PV, and (c) TBA values of croaker during ice storage.

### Free fatty acid, peroxide value, and thiobarbituric acid value

During storage, the fat or fatty material may be hydrolyzed by lipases to liberate the FFAs that are responsible for enhanced lipid oxidation and development of off-flavors in the muscle (Jeyakumari et al., 2016). In the present study, FFA showed an increasing trend from 6.85% to 14.92% oleic acid in FI sample on day 12, and after that, it decreased to 13.38% oleic acid (Figure 2a). Fish stored in slurry ice did not show any significant change in lipid hydrolysis as compared to flake ice. Rodriquiz et al. (2006) observed similar results for farmed turbot stored in slurry ice. The unsaturated fatty acid present in fish fat undergoes oxidation during storage to form peroxides. Peroxides are the primary lipid oxidation products and play a major role in auto-oxidation of lipids, which results in decomposition of peroxide into aldehydes, ketones, etc. Initial peroxide value of 9.20 meq.O<sub>2</sub>/kg in fish meat increased to 18.51 meq.O<sub>2</sub>/kg on day 15 for FI samples (Figure 2b). TBA value has been widely used to determine the level of rancidity. A significant increase in TBA value in both SI and FI samples was observed throughout the storage. Initial TBA value of 0.81 mg MDA/kg increased to 2.25 mg MDA/kg on day 15 for FI sample. However, SI sample had a little higher TBA value of 2.84 mg MDA/kg on day 15 (Figure 2c). The TBA values of 5 mg of MDA/kg indicate the good quality of chilled or ice-stored fish. However, fish can be consumed up to 8 mg MDA/kg of TBA content (Adenike, 2014). Accordingly, both the sample had a TBA content well below the acceptable limit.

### Changes in color

Color is an important quality attribute for any product because it is associated with freshness and flavor and influences consumer acceptance (Wu and Sun, 2013). Myoglobin present in the fish is responsible for the color of fish flesh. During storage, myoglobin present in the fish undergoes chemical changes, which result in the formation of brown color (Jeyakumari et al., 2015). In the present study, *L*\* (lightness) value of fresh fish was 68.55. During storage, it showed a decreasing trend (Figure 3a). However, SI sample had lower *L*\* value than FI sample. A similar trend was observed for *a*\* (redness) values for both the samples (Figure 3b). However, *b*\* (yellowness) values showed a gradual increase (Figure 3c) and was a little higher in SI sample due to salt content present



**Figure 3.** Changes in (a)  $L^*$ , (b)  $a^*$ , and (c)  $b^*$  values of croaker during ice storage.

in the slurry ice absorbed by fish muscle. It was observed that decreasing  $L^*$  values showed positive correlation ( $r = 0.96$ ) with sensory quality. Moreover, increase in TBA values resulted in the decrease in  $L^*$  values of fish meat during storage.

### Changes in textural properties

The texture of fish muscle is related to the muscle fiber density and depends on some of the intrinsic biological factors such as species, age, size, feeding habit, proximate composition, and collagen content (Zhao et al., 2012). Textural properties include hardness, springiness, chewiness, juiciness, and adhesiveness (Szczeniak, 1963). Hardness is an important attribute because it decides the commercial value. In the present study, hardness showed decreased trend during storage (Figure 4a). This may be due to the weakening of connective tissue of fish muscle by proteolysis. Nareshkumar et al. (2016) observed similar results for croaker fish stored under flake ice. Moreover, SI sample had improved hardness compared to FI sample. Chen et al. (2016) observed similar results for bighead croaker stored in slurry ice. Roy et al. (2012) reported that changes in hardness of fish muscle during chilled storage might be due to loss of myofibers to myofiber adhesion, detachment of the sarcolemma, and increase of intermyofibrillar spaces.

Springiness measures the elasticity or recovering property of fish muscle during compression. Chewiness relates to the number of chews necessary for food to be swallowed. In the present study, springiness and chewiness showed decreased trend during storage (Figure 4b and 4c). In general, the SI sample had lower values of springiness and chewiness than the FI sample. Cohesiveness measures the extent to which a material could be deformed before it ruptures. It was observed that cohesiveness did not follow the definite trend in both the samples during storage (Figure 4d). This indicates that there were not many internal changes in the fish muscle during storage. Viji et al. (2015) observed similar results for fish stored under ice.

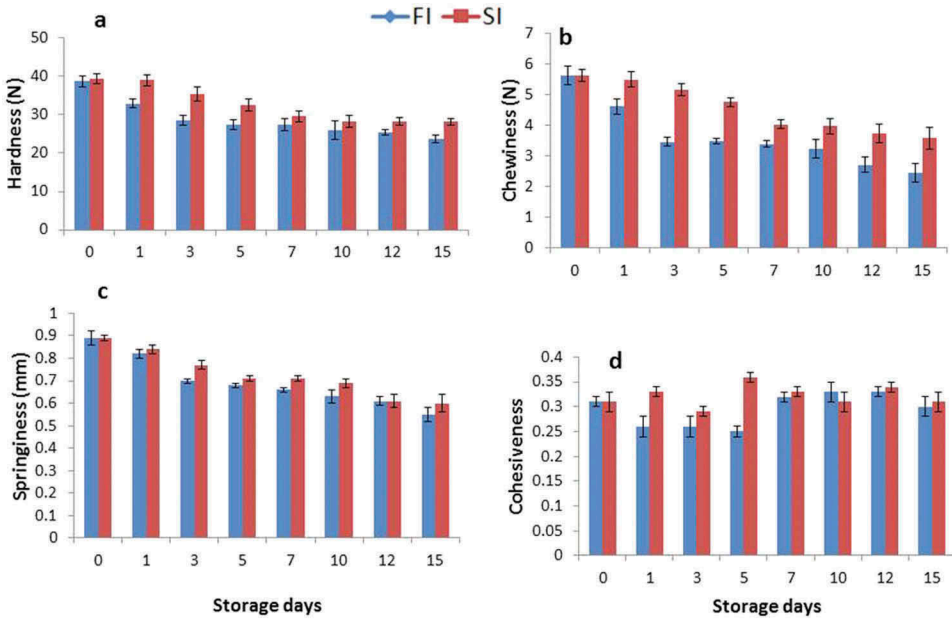


Figure 4. Changes in (a) hardness, (b) chewiness, (c) springiness, and (d) cohesiveness values of croaker during ice storage.

**Changes in microbiological quality**

APC is one of the useful quality parameters for determining potential spoilage of perishable food products. The initial total APC in croaker fish meat was 3.50 log<sub>10</sub>, which indicates that the fish used in the present study had a good quality (Viji et al., 2016). According to ICMSF (1998), the maximum prescribed microbial limit for total APC in food products for human consumption is 7 log<sub>10</sub>. In the present study, the FI sample reached APC of 7.2 log<sub>10</sub> on day 15. However, the SI sample reached 6.45 log<sub>10</sub> on day 12 (Figure 5a). Results confirmed lower microbial growth in the slurry ice and are in agreement with previous reports (Mugica et al., 2008; Rodriguez et al., 2006). Further, the SI sample exhibited off-flavor with an APC of 6.57 log<sub>10</sub> on day 15, and it was rejected. *Pseudomonas* sp. is considered one of the specific spoilage bacteria associated with spoilage of chilled or iced fish (Jeyasekaran et al., 2006; Viji et al., 2016). Results showed a gradual increase in *Pseudomonas* sp. growth pattern during storage and reached higher count (7.05 log<sub>10</sub>) on day 10 for the FI sample (Figure 5b). Results coincided with the generation of off-

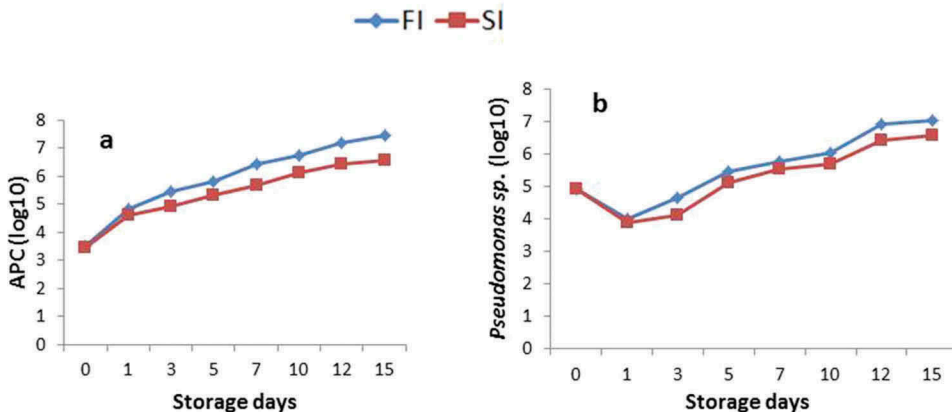
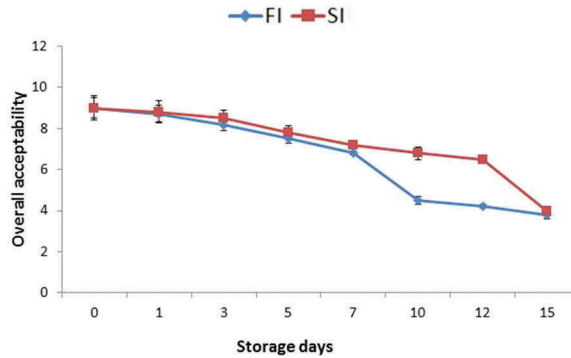


Figure 5. Changes in (a) APC and (b) *Pseudomonas* sp. count of croaker during ice storage.



**Figure 6.** Changes in overall acceptability of croaker during ice storage.

flavor in FI samples as confirmed by sensory evaluation. Moreover, results indicated that *Pseudomonas* sp. served as a good spoilage index in ice-stored fish. Jeyasekaran et al. (2006) observed similar results for fish stored in ice.

### Acceptability

Sensory evaluation revealed that the SI sample had a better score for appearance, odor, texture, and acceptability (Figure 6). Similarly, biochemical and microbiological results also showed a lower pH, TVB-N, TMA-N content, mesophilic, and *Pseudomonas* sp. count. It has been reported that formation of some volatile low molecular weight compounds from protein hydrolysis and lipid oxidation during storage contribute significantly to undesirable changes in seafood products. The changes in odor, texture, and appearance lead to spoilage of seafood products (Rodríguez et al., 2004). In the present study, FI samples were rejected on day 10 due to off-odor and higher aerobic count ( $7.05 \log_{10}$ ). However, the SI samples were rejected on day 15. It has been reported that the use of slurry ice maintains better quality and extends the shelf life of non-fat fish species (Chen et al., 2016; Huidobro et al., 2002).

### Conclusion

From the study, it can be concluded that croaker fish stored in slurry ice had lower pH, TVB-N, TMA-N content, total aerobes, and *Pseudomonas* sp. count. Results indicated that slurry ice controlled the biochemical and microbial activity of fish during storage. Moreover, acceptability and texture attributes were scored higher for the SI sample. Based on the microbial and sensory analysis, the shelf life of croaker fish stored in slurry ice was found to be 15 days. Results suggested that the use of slurry ice for the storage of croaker fish can be encouraged.

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### References

- Ackman, R. G. 1989. Nutritional composition of fats in seafood. *Prog. Food Nutr. Sci.* 13: 161–289.
- Adenike, O. M. 2014. The effect of different processing methods on the nutritional quality and microbiological status of cat fish (*Clarias lezera*). *J. Food Process. Technol.* doi:10.4172/2157-7110.1000333

- Anderson, U. B., Stomsnes, A. N., Thomassen, M. S., and Steinsholt, K. 1994. Fillet gaping in farmed Atlantic salmon. *Nor. J. Agric. Sci.* 8: 165–179.
- AOAC. 2005. *Official Methods of Analysis of AOAC International*. 17th ed. Washington, DC: Association of Official and Analytical Chemists International.
- Chapman, L. 1990. Making the grade. Ice slurries get top marks for quality products. *Aust. Fish.* 7: 16–19.
- Chen, J., Huang, J., Deng, S., and Huang, Y. 2016. Combining ozone and slurry ice to maximize shelf-life and quality of bighead croaker (*Collichthys niveatus*). *J. Food Sci. Technol.* 53(10): 3651–3660. doi:10.1007/s13197-016-2331-8
- Connell, J. J. 1995. Quality deterioration and extrinsic quality defects in raw material. In *Control of Fish Quality*. 4th ed., Surrey, UK: Fishing News Books Ltd. Pp. 31–35.
- Conway, E. J. 1950. *Micro-Diffusion Analysis and Volumetric Error*. 5th ed. London: Lockwood and Son Ltd. Pp. 467–472.
- George, C., and Gopakumar, K. 1987. Biochemical studies on crab *Scylla serrata*. *Fish.Tech.* 24: 57–61.
- Guenneugues, P. 2012. Surimi market updates: future seafood group. <http://www.groundfishforum.com/2012/chapters/Pascal%20Guenneugues%20presentation.pdf>
- Harpaz, S., Glatman, L., Drabkin, V., and Gelman, A. 2003. Effects of herbal essential oils used to extend the shelf life of freshwater-reared Asian sea bass fish (*Lates calcarifer*). *J. Food Prot.* 66(3): 410–417. doi:10.4315/0362-028X-66.3.410
- Huidobro, A., Lopez-Caballero, M., and Mendes, R. 2002. Onboard processing of deepwater pink shrimp (*Parapenaeus longirostris*) with liquid ice: effect on quality. *Eur. Food Res. Technol.* 214: 469–475. doi:10.1007/s00217-002-0490-5
- International Commission on Microbiological Specifications for Foods (ICMSF). 1998. *Microorganisms in Foods*, Vol. 6. Baltimore, MD: Microbial Ecology of Food Commodities, Blackie Academic & Professional.
- Jeyakumari, A., Ninan, G., Joshy, G., Parvathy, U., Zynudheen, A. A., and Lalitha, K. V. 2016. Effect of chitosan on shelf life of restructured fish products from pangasius (*Pangasianodon hypophthalmus*) surimi during chilled storage. *J. Food Sci. Technol.* 53(4): 2099–3077. doi:10.1007/s13197-016-2174-3
- Jeyakumari, A., Remya, S., Debbarma, J., Ravishankar, C. N., Zynudheen, A. A., Ninan, G., Ronda, V., and Lalitha, K. V. 2015. Effect of delayed icing on the quality of white shrimp (*Litopenaeus vannamei*) during chilled storage. *J. Food Process. Preserv.* doi:10.1111/jfpp.12539
- Jeyasekaran, G., Ganesan, P., Anandaraj, R., Jeya Shakila, R., and Sukumar, D. 2006. Quantitative and qualitative studies on the bacteriological quality of Indian white shrimp (*Penaeus indicus*) stored in dry ice. *J. Food Microbiol.* 23(6): 526–533. doi:10.1016/j.fm.2005.09.009
- Karakoltsidis, P. A., Zotos, A., and Constantinides, S. M. 1995. Composition of the commercially important Mediterranean finfish, crustaceans and molluscs. *J. Food Compos. Anal.* 8: 258–273. doi:10.1006/jfca.1995.1019
- Kumar, M., Basu, S., and Hazra, A. 1995. Ice storage characteristics of cultured silver carp. *J. Ind. Fish. Assoc.* 25: 123–129.
- Mead, G. C., and Adams, B. W. 1977. A selective medium for the rapid isolation of pseudomonads associated with poultry meat spoilage. *Brit. Poultry Sci.* 18(6): 661–670. doi:10.1080/00071667708416418
- Meilgaard, M., Civille, G. V., and Carr, B. T. 1999. *Sensory Evaluation Techniques*. 3rd ed. Boca Raton, Fla: CRC Press. Pp. 387.
- Mugica, B., Barros-Velazquez, J., Miranda, J. M., and Aubourg, S. P. 2008. Evaluation of a slurry ice system for the commercialization of ray (*Raja clavata*): effects on spoilage mechanism directly affecting quality loss and shelf life. *LWT - Food Sci. Technol.* 41(6): 974–981. doi:10.1016/j.lwt.2007.06.017
- Nareshkumar, M., Chouksey, M. K., Balangae, A. K., Tripathi, G., and Nayak, B. B. 2016. Physico-chemical and gel properties of myofibrillar protein from sin croaker (*Johnius dussumieri*) fish during ice storage. *J. Aquatic. Food Prod. Technol.* doi:10.1080/10498850.2015.1092485
- Olafsdottir, G., Martinsdottir, E., Oehlenschbger, J., Dalgaard, P., Jensen, B., Undeland, I., Mackie, I. M., Henehan, G., Nielsen, J., and Nilsen, H. 1997. Methods to evaluate fish freshness in research and industry - a review. *Trends Food Sci. Technol.* 8: 258–265. doi:10.1016/S0924-2244(97)01049-2
- Pineiro, C., Barros-Velazquez, J., and Aubourg, S. P. 2004. Effects of newer slurry ice systems on the quality of aquatic food products: a comparative review versus flake-ice chilling methods. *Trends Food Sci. Technol.* 15: 575–582. doi:10.1016/j.tifs.2004.09.005
- Rodriquiz, O., Barros-Velazquez, J., Piñeiro, C., Gallardo, J. M., and Aubourg, S. 2006. Effects of storage in slurry ice on the microbial, chemical and sensory quality on the shelf life of farmed turbot (*Psetta maxima*). *Food Chem.* 95: 270–278. doi:10.1016/j.foodchem.2004.11.054
- Rodriquiz, O., Losada, V., Aubourg, S., and Barros-Velazquez, J. 2004. Enhanced shelf life of chilled European hake (*Merluccius merluccius*) stored in stored in slurry ice as determined by sensory analysis and assessment of microbiological activity. *Food Res. Int.* 37: 749–757. doi:10.1016/j.foodres.2004.03.008
- Roy, B. C., Ando, M., Itoh, T., and Tsukamasa, Y. 2012. Structural and ultrastructural changes of full-cycle cultured Pacific bluefin tuna (*Thunnus orientalis*) muscle slices during chilled storage. *J. Sci. Food Agric.* 92(8): 1755–1764. doi:10.1002/jsfa.v92.8
- Ruiz-Capillas, C., and Moras, A. 2001. Correlation between biochemical and sensory quality indices in hake stored in ice. *Food Res. Int.* 34: 441–447. doi:10.1016/S0963-9969(00)00189-7

- Sushant Kumar, C. 1997. Growth, mortality and yield per recruit of bearded croaker *Johnius dussumieri* (Val.) from Mumbai waters. Iranian J. Fish. Sci. 44(1): 45–49.
- Szczesniak, A. 1963. Classification of textural characteristics. J. Food Sci. 28: 385–389. doi:10.1111/j.1365-2621.1963.tb00215.x
- Tarladgis, G. B., Watts, M. B., and Younathan, M. 1960. TMA. Distillation method for the quantitative determination of malonaldehyde in rancid foods. J. Amer. Oil Chem. Soc. 37: 44–50. doi:10.1007/BF02630824
- United States Food and Drug Administration (USFDA). 2012. Aerobic plate count. Bacteriological analytical manual. <http://www.fda.gov/Food/FoodScienceResearch/LaboratoryMethods/ucm063346.htm>
- Viji, P., Panda, S. K., Mohan, C. O., Bindu, J., Ravishankar, C. N., and Srinivasa Gopal, T. K. 2016. Combined effects of vacuum packaging and mint extract treatment on the biochemical, sensory and microbial changes of chill stored Indian mackerel. J. Food Sci. Technol. 53(12): 4289–4297. doi:10.1007/s13197-016-2425-3
- Viji, P., Tanuja, S., Ninan, G., Lalitha, K. V., Zynudheen, A. A., Binsi, P. K., and Srinivasa Gopal, T. K. 2015. Biochemical, textural, microbiological and sensory attributes of gutted and ungutted sutchi catfish (*Pangasianodon hypophthalmus*) stored in ice. J. Food Sci. Technol. 52(6): 3312–3321.
- Wu, D., and Sun, D. W. 2013. Colour measurements by computer vision for food quality control. A review. Trend Food Sci. Technol. 29: 5–20. doi:10.1016/j.tifs.2012.08.004
- Zhao, J., Li, J. R., Wang, J. L., and Lu, W. J. 2012. Applying different methods to evaluate the freshness of large yellow croaker (*Pseudosciaena crocea*) fillets during chilled storage. J. Agric. Food Chem. 60: 11387–11394. doi:10.1021/jf303439p