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Efficiency of Dry Ice and Ice Combination on Improving the Quality and Shelflife of Seerfish (*Scomberomorus commersonii*) Steaks

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Abstract

Seerfish (*Scomberomorus commersonii*) steaks stored in a combination of dry ice and ice at a ratio of 1:0.2:0.5 (fish:dry ice:ice) and in dry ice at a ratio of 1:1 (fish:dry ice) were found to be in good quality and sensorially suitable for consumption when they were stored for 24 h and 30 h, respectively, without reicing. When fish steaks were stored in ice at a ratio of 1:1 (fish:ice) as control, they were in good condition only up to 18 h. Total bacterial load ranged from 10^5 to 10^8 cfu/g, while total psychrophiles was from 10^2 to 10^5 cfu/g. Total lactics and H_2S producers were found to be 10^1 to 10^4 cfu/g. Total histamine formers were from 10^2 to 10^4 cfu/g. Total coliforms were 1600 MPN/g at the end of the storage period. The TMA-N contents were within the limit of acceptability. Histamine contents varied from 0 to 20 ppm. A lowest temperature (-11.9°C) was observed in steaks stored in dry ice. Highest level of CO_2 was recorded in steaks stored in both the dry ice and combination of dry ice and ice. *Staphylococcus* constituted 37% of the flora in fresh fish followed by *Proteus*, *Pseudomonas*, *Aeromonas*, *Bacillus*, *Alcaligenes*, *Micrococcus*, *Acinetobacter* and *Flavobacterium*. *Pseudomonas* was the dominant flora in both the dry ice-stored and combination of dry ice and ice-stored steaks while in control pack, *Proteus* was dominant. Thus, a combination of dry ice and ice improved the quality and increased the shelf life of fish steaks by about 6 h compared to ice alone.

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Introduction

Immediately after harvesting, fish is completely fresh but while in storage, it loses its freshness. The prevalent method of retarding spoilage of fish in India, as well as in other tropical countries, is storage in ice (Surendran et al. 1989). The most common chilling medium for preserving fresh fish is ice. However, the quantity of crushed ice required for chilling fresh fish is quite substantial which is at least 1:1 ratio (fish:ice) (wt/wt) and is sometimes even higher under tropical conditions (Lima dos Santos et al. 1981). The other disadvantages of using ice are more drip loss, textural toughness, nutrient loss, and protein extractability (Putro 1989).

Modified atmosphere with an enhanced carbon dioxide level or reduced oxygen concentration extends the shelf life considerably (Stiles, 1991). Dry ice has recently gained popularity in India for the rapid transportation of fresh fish by air by reducing the temperature rapidly as well as modifying the packing environment with CO₂. Dry ice acts as coolant in the present trends of shipping of fresh seafoods (Schoemaker 1990) and it has certain advantages such as its bacteriostatic effect; it also acts as an insulant enveloping the fish upon evaporation (Putro 1989). Several exporters blindly use dry ice in combination with ice, without any scientific knowledge in fresh fish transportation. Hence, initial studies conducted by our laboratory showed that a combination of dry ice and ice at a ratio of 1:0.2:0.5 (fish:dry ice: ice) yielded a good quality product with better shelf life (Sasi et al. 2000). It has also been reported that the fish, Emperor breams stored in said dry ice and ice combination was superior when compared to storage in ice only (Jeyasekaran et al. 2004a). Information on specific spoilage organisms of different fish from various aquatic environments and under different packaging condition is still limited (Sivertsvik et al. 2002). Seerfish is a highly valuable fish in India as it always commands a higher price and it is also exported from India in chilled condition. Hence, the present study was carried out to find out the quantitative and qualitative changes in the bacteriological and biochemical qualities of seerfish (*Scomberomorus commersonii*) steaks in relation to their sensorial quality and shelf life, when they were chilled in dry ice as well as in ice.

Materials and Methods

Seerfish (*Scomberomorus commersonii*) were procured from a fish landing center of Tuticorin, one kilometer away from our laboratory. Time interval between harvesting and the arrival of fish at the landing center was about 7 h and during this period they were iced. Fish were immediately brought to the laboratory in insulated containers and washed with tap water. Whole fish were beheaded, washed, and made into steaks. Steaks had an average weight of 160 g. They were divided into three lots and each lot weighed 16 kg. There were eight packs in each lot. The first lot was packed with dry ice (Thermosafe Dry Ice Machine, USA) at a ratio of 1:1 (fish:dry ice) (wt/wt), the second lot with a combination of dry ice and ice at a ratio of 1:0.2:0.5 (fish:dry ice:ice) (Sasi et al., 2000) and the third lot with ice (Ziegra Flake Ice Maker, Germany) at a ratio of 1:1 (fish:ice), which served as control. They were designated as packages I, II and III. Gloves were worn during handling of ice and fish. Utmost care was taken to avoid direct contact of fish with ice and dry ice. Packages were wrapped in polythene bags, placed in styrofoam boxes and sealed airtight with cellophane tape. The boxes were stored at room temperature ($28 \pm 2^\circ\text{C}$). The packs were not opened and re-iced during the entire process of study. One pack from each lot was periodically analyzed in triplicate for sensory, bacteriological, biochemical and physical qualities until they were organoleptically unacceptable.

Sensory characteristics and overall acceptability of seerfish (*S. commersonii*) steaks were assessed by a panel of six experienced members of the Faculty of Fisheries College and Research Institute based on a ten point scale in each sampling. Sensory characteristics studied included general appearance, odor and texture of fish. The scale employed in evaluating the sensory quality of chilled seerfish steaks is given in table 1, which was developed based on the guidelines given by Lima dos Santos et al. (1981). The scores were given in decreasing order with 10-9 for excellent, 8-7 for good, 6-5 for fair and acceptable, 4-3 for poor and 2-1 for very poor. The mean of the scores given by the panel represented the overall sensory quality (Huss 1988). A score of 3 to 4 constituted unacceptability and shelf life failure.

Table 1. Scale employed for sensory evaluation of seerfish (*Scomberomorus commersonii*) steaks preserved in dry ice and ice

General appearance of meat	Texture	Odor	Score
Very fresh, shiny appearance, reddish	Very firm, elastic to finger touch, muscle not yet in rigor	Fresh seaweedy odor	10
Fresh, shiny, red	Moderately firm, elastic, muscle in pre-rigor	Loss of fresh seaweedy odor, shellfish odor	9
Fresh, slight loss in shiny appearance	Firm, moderately elastic, muscle in rigor	No odors, neutral odor	8
Slight loss in freshness, slight change in color from red to dark brown	Slightly firm, slightly elastic, muscle in rigor	Slightly musty, mousy, milky, garlic or peppery odor	7
Loss in freshness, pale brown	Slight soft	Bready, malty, beery, yeasty odor	6
Pale white, slightly bleached	Moderately soft	Lactic acid, sour milk or oily odor	5
Complete loss in freshness, milky white, slightly bleached	Soft, slightly loose flesh	Acetic or butyric acid, grassy, old boot, slightly sweet, sweet or chloroform odor	4
Completely bleached, yellowish white	Very soft, loosened flesh	Stale cabbage water, wet matches, phosphine like odor	3
Discolored, pale yellowish	Very soft and flabby, slight retaining of finger indentation, flesh easily torn	Ammonia odor	2
Completely discolored, yellowish	Extremely soft and flabby, strong retention of marks, flesh very easily torn	Indole, fecal, H ₂ S, strong ammonia and putrid odors	1

Bacteriological analysis carried out in this study included total bacterial load (TPC), total psychrophiles, total lactics, total H₂S producers, total histamine formers, total coliforms and total anaerobic sulphite reducers. Media used in this study were obtained from Hi-Media Laboratories, Mumbai, India and chemicals from S.D. Fine Chemicals Limited, Mumbai, India. Fish muscle was cut into very small pieces using sterile knife and forceps and pooled together. Then, 25 g was taken from this pool and homogenized using 225 ml sterile physiological saline (0.85%) and serial decimal dilutions of each homogenate were carried out using the same diluent for the respective bacteriological analysis (APHA 2001). Appropriate dilutions were spread plated onto Trypticase Soya Agar (TSA) for the enumeration of total bacterial load and total psychrophilic count. The plates were incubated at 37°C for 24 h for the enumeration of total bacterial load, whereas they were incubated under refrigerated condition (5°C) for 7 days for the enumeration of psychrophiles. The bacterial flora isolated from packages I, II and III were identified by various biochemical tests (LeChevallier et al. 1980; Balows et al. 1992). Double-layer pour plate technique was performed for the enumeration of total lactics and H₂S producers using Lactobacillus MRS Agar and Peptone Iron Agar (USFDA 2001), respectively. Inoculated plates were incubated at room temperature for 72 h. Pour plate technique was employed for the enumeration of total histamine formers using Modified Niven's Medium (Yoshinaga and Frank 1982). Plates were incubated at 37°C for 48 h. After appropriate incubation, the number of suspected colonies developed on the plates were counted and expressed as cfu · g.

The most probable number (MPN) technique was followed for the enumeration of total coliforms and total anaerobic sulphite reducers using Lauryl Sulphate Tryptose Broth (LSTB) and Differential Reinforced Clostridial Medium (DRCM), respectively. The inoculated tubes were incubated at 37°C for 24 h for the enumeration of total coliforms. The tubes showing acid and gas productions were counted as positive and expressed as MPN · g, whereas, for total anaerobic sulphite reducers, the tubes were incubated in a water bath at 37°C for 9 h. The tubes exhibiting black precipitate were counted as positive and expressed as MPN · g.

Biochemical quality indices studied included trimethylamine nitrogen (TMA-N) and histamine. The TMA-N content was determined using the Conway micro-diffusion method (Cobb et al. 1973). The histamine content of the fish was analyzed following the standard spectrofluorometric method (AOAC 1990).

The physical parameters studied were temperature and gas composition. Changes in temperature in all the packages were recorded using the Ultrafreezer temperature probe (Consort Model T 852, Belgium). The gas composition of the different packaging environment was measured using a gas analyzer (PBI Dansensor CheckMate 9900, Denmark).

Analysis of variance (ANOVA) was performed using the statistical package (SPSS 10.0) to examine whether any significant difference exists between different treatments, with respect to the different fish quality characteristics at 5% level.

Results and Discussion

Overall sensory scores of seerfish (*S. commersonii*) steaks preserved in dry ice and ice are shown in [figure 1](#). Raw steaks exhibited fresh seaweedy odor, shiny appearance, very firm texture and reddish white meat. No remarkable change was observed in packages II and III on the 1st h, whereas the steaks in package I was completely frozen and this condition was maintained up to the 6th h of storage. On the 6th h, packages II and III exhibited more or less similar characteristics like slight seaweedy odor and shiny appearance with a score of 9.3 and 9.4, respectively. No characteristic odor was observed up to the 12th h in packages II and III, but the meat color in package II was slightly better than that of package III. On the 18th h, package III exhibited slight ammonia odor, pale yellowish meat color and slight loss in texture with a sensory score of 6.7, package II exhibited the same characteristics only on the 24th h. On the other hand, steaks in package I, which was in frozen condition up to the 6th h, became normal due to the change of state in dry ice from solid to gas on the 12th h. On the 18th h, the muscle color became faded and slightly lost its firmness with a score of 8.4. On the 24th h, package III was sensorially unacceptable with strong ammonia odor and package II exhibited the same characteristics on the 30th h. A significant difference ($P < 0.05$) was observed in the sensory quality of seerfish steaks stored in different packages of ice. It was earlier reported that a combination of dry ice and ice extended the shelf life of seerfish when compared to ice only ([Sasi et al. 2003](#)).

Sensory results of salmon (*Salmo salar*) steaks showed a shelf life extension of 6 days under 20% CO₂ enriched atmosphere, when compared with air ([De la Hoz et al. 2000](#)). [Scott et al. \(1986\)](#) observed a shelf life extension of 9 days in snapper (*Chrysophrys auratus*) when stored in 100%

carbon dioxide atmosphere at -1°C when compared to normal atmospheric storage. However, package I exhibited unacceptable sensory characteristics only on the 36th h of storage. The extension in the shelf life of steaks stored in dry ice and combination of dry ice and ice was 12 and 6 h, respectively in comparison with ice.

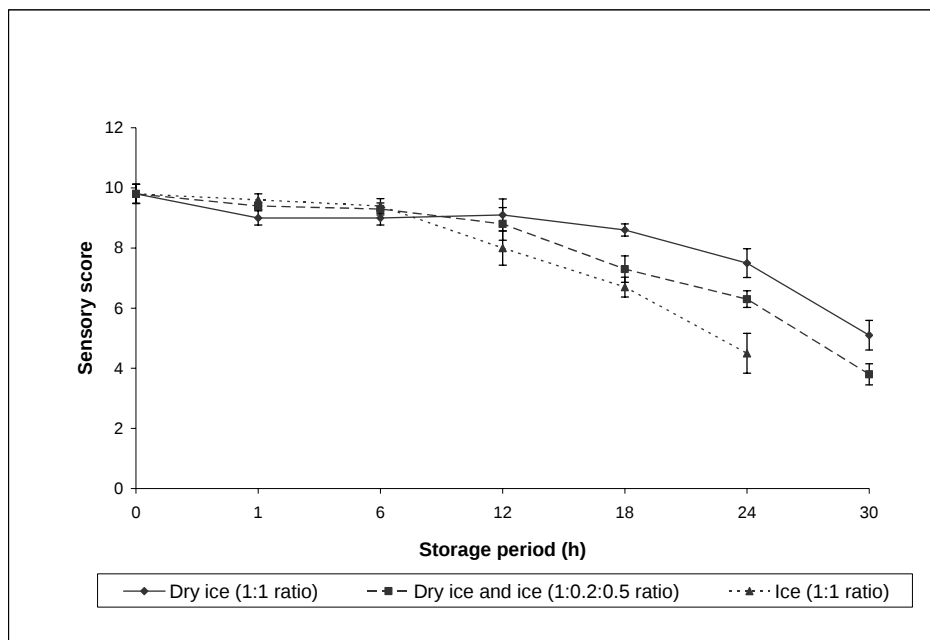


Figure 1. Changes in sensory quality of seerfish (*Scomberomorus commersonii*) steaks preserved in dry ice and ice

The changes in TPC (total bacterial load) of seerfish steaks preserved in dry ice and ice are shown in figure 2. Fresh fish had an initial bacterial population of 10^6 cfu · g, which was reduced to 10^4 and 10^5 cfu · g on the 12th h in packages I and II and on further storage, the population increased to a count of 10^8 and 10^7 cfu · g, respectively at the end of the storage period. Clark and Lentz (1969) reported that the application of CO_2 gaseous environment inhibits bacterial growth during the lag phase. Exposure to low temperature also inhibits bacterial growth (Jay 1987). On the other hand, in package III, the initial count was maintained up to the 18th h and reached to 10^8 cfu · g at the end of the storage period. A significant difference ($P < 0.05$) in the TPC (total bacterial load) of seerfish steaks stored in different packages of ice was observed.

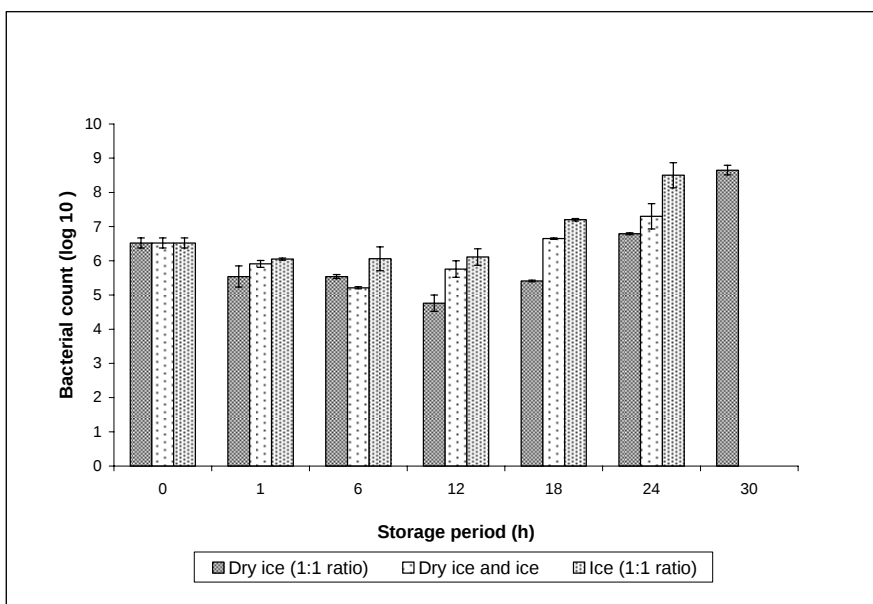


Figure 2. Changes in total bacterial population (cfu/g) of seerfish (*Scomberomorus commersonii*) steaks preserved in dry ice and ice

Bacterial flora associated with raw, and dry ice, combination of dry ice and ice, and ice stored seerfish steaks are shown in figure 3. Raw seerfish steaks used in this study carried a bacterial flora of *Staphylococcus*, *Proteus*, *Pseudomonas*, *Aeromonas*, *Bacillus*, *Alcaligenes*, *Micrococcus*, *Acinetobacter* and *Flavobacterium*. *Staphylococcus* constituted about 37% of the flora. Liston (1980) reported that the flora on tropical fish often carries a slightly higher load of Gram-positive bacteria compared with fish from colder waters. *Pseudomonas* was the dominant flora in packages I and II with varying percentage. In package I, *Pseudomonas* constituted about 31% followed by *Bacillus*, *Staphylococcus*, *Plesiomonas*, *Acinetobacter*, *Corynebacterium*, *Alcaligenes*, *Moraxella* and *Proteus*. In package II, *Pseudomonas* constituted about 37% followed by *Staphylococcus*, *Proteus*, *Plesiomonas*, *Alcaligenes*, *Corynebacterium*, *Bacillus*, *Micrococcus* and *Escherichia*. However, *Proteus* was found to be high (20%) in the steaks stored in 100% ice followed by *Pseudomonas*, *Alcaligenes* *Staphylococcus*, *Klebsiella*, *Bacillus*, *Flavobacterium*, *Corynebacterium*, *Hafnia* and *Micrococcus*. Callow (1932) suggested that displacement of oxygen by CO₂ inhibits the growth of aerobic microorganisms and results in shift of dominant flora. The present investigation also observed the shift of dominant flora between ice and dry ice stored steaks. It was observed by Lindsay et al. (1986) that *Pseudomonas* and *Shewanella* were the dominant

spoilage flora in fish stored under aerobic refrigerated conditions and were effectively inhibited by atmospheres enriched with 20% or more CO₂.

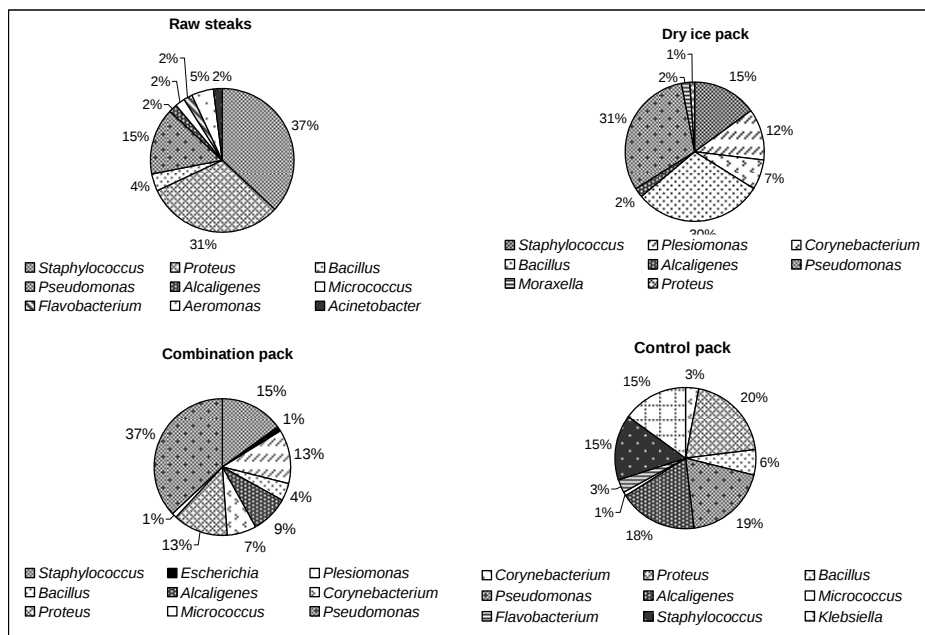


Figure 3. Bacterial flora associated with raw, and dry ice, dry ice and ice, and ice stored seerfish (*Scomberomorus commersonii*) steaks

Changes in total psychrophiles of seerfish steaks preserved in dry ice and ice are presented in [figure 4](#). Raw fish exhibited an initial psychrophilic population of 10^2 cfu · g, which was maintained up to 6th h and 1st h in packages I and III, respectively while, increased by a log on the 1 h and maintained up to the 6th h in package II. With further storage, the psychrophilic population increased gradually and reached to 10^5 cfu · g in all the three packages. A significant difference ($P < 0.05$) was observed in the psychrophilic bacterial population among the different packages. [Jeyasekaran et al. \(2004a\)](#) observed a total psychrophilic population of 10^4 cfu · g at the end of storage period when lethrinus (*Lethrinus miniatus*) was stored in a combination of dry ice and ice. However, bacterial population of 10^6 cfu · g was observed by [Jeyasekaran et al. \(2004b\)](#) in ice stored barracudas (*Sphyraena barracuda*) and suggested that the variation observed by several authors were mainly because of the differences in species, region and post-harvest delay.

Changes in total lactics of seerfish steaks preserved in dry ice and ice are shown in [figure 5](#). Initial lactics population was 10^2 cfu · g, which

was reduced by a log in packages I and II on the 1st h and the same population was maintained up to the 12th h in package I. De la Hoz et al. (2000) observed that the growth of lactic acid bacteria was not promoted by the enrichment of the atmosphere with 20% CO₂, although it resulted in a greater presence of this group in the microbiota responsible for the spoilage. On the 18th h, all the three packages exhibited a lactic acid bacterial population of 10² cfu · g. At the end of storage, packages I and II attained a population of 10⁴ cfu · g. Sasi et al. (2003) observed a higher lactic count of 10⁵ cfu · g in seerfish (*S. commersonii*) stored in dry ice at the end of the storage period and stated that dry ice provided a favorable environment for the growth of lactics. A significant difference ($P < 0.05$) in the total lactics of seerfish steaks stored in different packages of ice was observed.

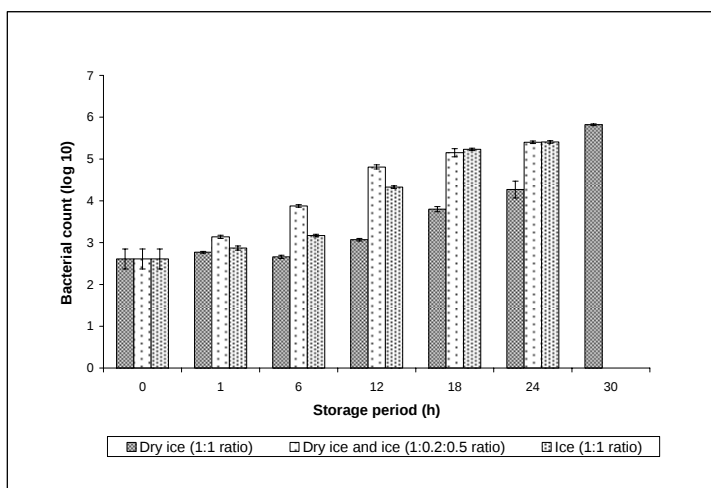


Figure 4. Changes in total psychrophiles (cfu/g) of seerfish (*Scomberomorus commersonii*) steaks preserved in dry ice and ice

Changes in H₂S producers of seerfish steaks preserved in dry ice and ice are given in figure 6. Fresh fish exhibited a H₂S producers population of 10¹ cfu · g, which was maintained up to the 6th h of storage in package III and 18th h in packages I and II. On the 18th h, the population increased to 10³ cfu · g in package III. The H₂S producers population reached to 10³, 10⁴ and 10⁵ cfu · g in packages II, I and III, respectively at the end of the storage period. A significant difference ($P < 0.05$) was observed in the total H₂S producers of seerfish steaks stored in different packages of ice. However, Sasi et al. (2003) observed a H₂S producing bacterial population of 10⁵ cfu · g in dry ice and ice stored seerfish. It has been reported earlier that CO₂ has an inhibitory effect on H₂S producing bacteria and their popu-

lation was comparatively lower than the total bacterial population (Jensen et al. 1980; Huss, 1988).

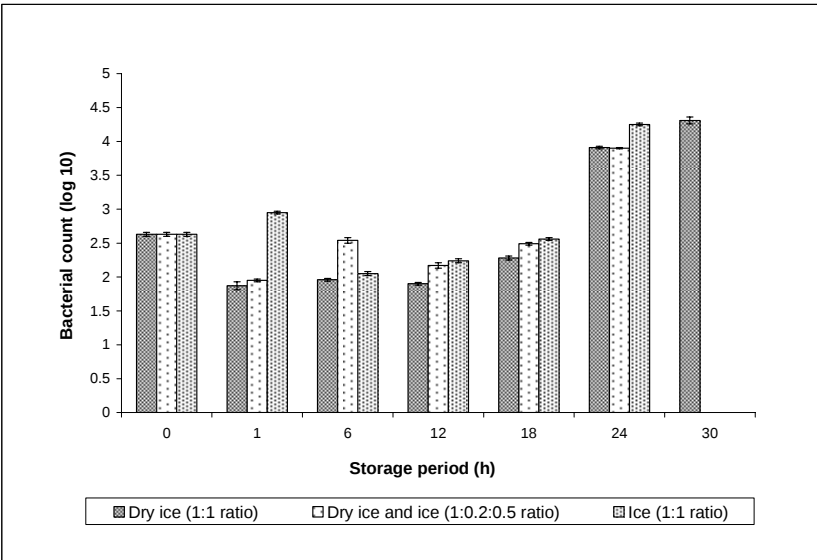


Figure 5. Changes in total lactics (cfu/g) of seerfish (*Scomberomorus commersonii*) steaks preserved in dry ice and ice

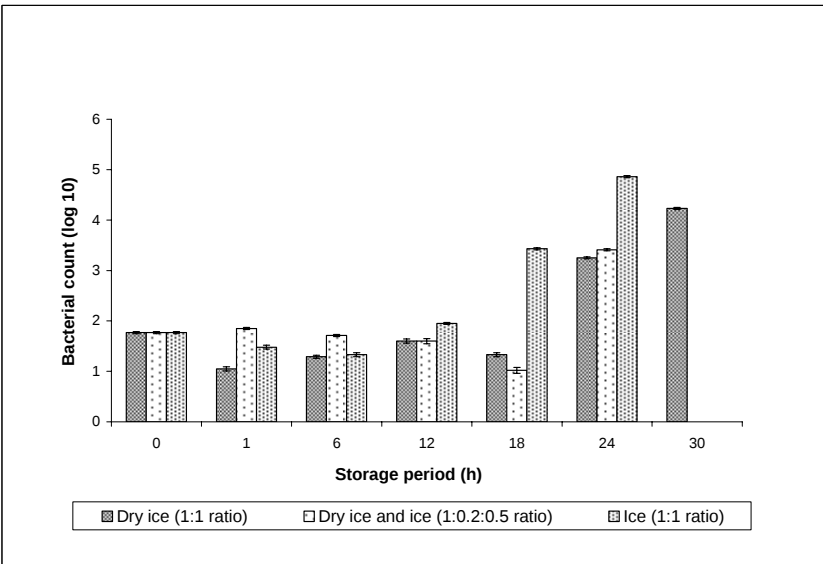


Figure 6. Changes in H₂S producers (cfu/g) of seerfish (*Scomberomorus commersonii*) steaks preserved in dry ice and ice

Changes in total histamine formers of seerfish steaks preserved in dry ice and ice are given in figure 7. Initial histamine formers population was 10^2 cfu · g, which was in a slightly increasing trend up to the 18th h in package I and 6th h in packages II and III. On the 12th h, the population increased to 10^4 cfu · g in packages II and III and the same was maintained till the end of storage. On the other hand, in package I the population increased gradually from 10^2 to 10^4 cfu · g, when they were stored further. Shakila et al. (1996) also reported that the proliferation of bacteria capable of producing histamine begins only in post-rigor condition, which normally takes place in fish after 12 to 15 h of catching. A significant difference ($P < 0.05$) in the total histamine formers of seerfish steaks stored in different packages of ice was observed.

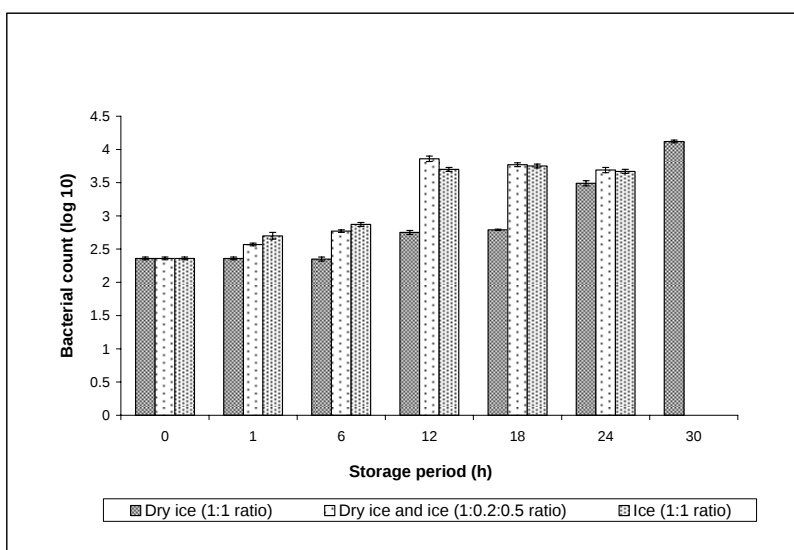


Figure 7. Changes in total histamine formers (cfu/g) of seerfish (*Scomberomorus commersonii*) steaks preserved in dry ice and ice

Changes in total coliforms and total anaerobic sulphite reducers of seerfish steaks preserved in dry ice and ice are presented in table 2. Initial coliforms count was 12 MPN · g. On the 12th h of storage, coliforms count became zero in packages I and II, while it declined to 2 MPN · g in package III, which could be due to cold shock. Upon further storage, the population recovered and increased to a higher count of 1600 MPN · g in all the three packages at the end of the storage period. The same trend was also observed by Jeyasekaran et al. (2004a), when lethrinus (*L. miniatus*) was preserved in dry ice and ice. Lilabati and Viswanath (1998) also reported

the presence of coliforms throughout the storage study of *Notopterus chitala* in ice. Initial total anaerobic sulphite reducers were 0.9 MPN · g. During the storage period, the population did not exhibit any consistent trend. It exhibited a high count of 110 MPN · g in package I at the end of storage, which shows that anaerobic sulfite reducers can grow rapidly when the steaks were about to spoil in dry ice stored condition. However, this inconsistent trend has earlier been reported by Jeyasekaran et al. (2004a) and suggested that the partial aerobic and anaerobic conditions prevailing during storage could be a reason to cause such differences.

Table 2. Changes in total coliforms and total anaerobic sulphite reducers of seerfish (*Scomberomorus commersonii*) steaks preserved in dry ice and ice

Storage period (h)	Total coliforms (MPN · g)			Total anaerobic sulphite reducers (MPN · g)		
	Package I	Package II	Package III	Package I	Package II	Package III
0	12.0	12.0	12.0	0.9	0.9	0.9
1	11.0	11.0	4.0	0.9	0.9	0.4
6	2.0	9.0	5.0	4.5	0.7	4.5
12	0.0	0.0	2.0	1.5	0.9	0.4
18	11.0	33.0	348	0.4	4.5	7.5
24	70.0	1600	1600	7.5	15.0	20.0
30	1600	*DC	DC	110	DC	DC

*DC - Discontinued

Package I - Dry ice (1:1 ratio); Package II - Dry ice and ice (1:0.2:0.5 ratio); Package III - Ice (1:1 ratio)

Changes in TMA-N contents of seerfish steaks preserved in dry ice and ice are given in figure 8. The initial TMA-N content was 3.78 mg%, which was in decreasing trend up to the 18th h in package I, 6th h in package II and 1st h in package III. Upon further storage, the content increased to 4.44, 1.93 and 4.22 mg% in packages I, II and III, respectively at the end of the storage period. The TMA-N content did not exceed the limit of acceptability in all the packages of fish. A significant difference ($P < 0.05$) was observed in the TMA-N contents of seerfish steaks stored in different packages of ice. Earlier studies reported that in marine fish, the rate of increase in TMA-N varies considerably from species to species (Amu and Disney 1973; Huss 1988). LeBlanc and LeBlanc (1992a) also found that the cod and winter flounder fillets superchilled with carbon dioxide snow

had lower TMA-N contents than in iced fillets. The differences observed in the rate of accumulation of TMA-N contents could be due to the differences in the growth of bacteria capable of reducing TMAO (Hebard et al. 1982). It has also been observed that fish stored in dry ice pack contained lower content of TMA-N when compared to ice and suggested that CO₂ has an inhibitory effect on TMO reducing bacteria (Sasi et al. 2000; 2003).

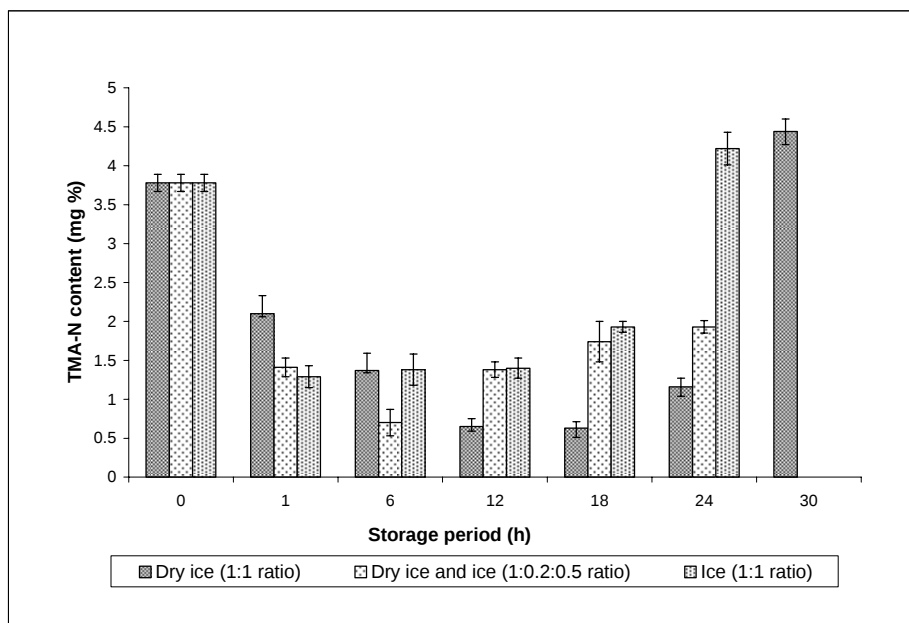


Figure 8. Changes in TMA-N content of seerfish (*Scomberomorus commersonii*) steaks preserved in dry ice and ice

Changes in histamine contents of seerfish steaks preserved in dry ice and ice are shown in figure 9. Fresh seerfish had a histamine content of 1.78 ppm, which decreased to 0.11 and 0.89 ppm in packages I and III, whereas the content became zero in package II on the 1st h. Slight increase in histamine content was observed up to the 18th h in all the three packages. Only at the end of the storage period, histamine content drastically increased from 1.58 to 20.20 ppm in package I, from 1.24 to 17.70 ppm in package II and from 0.99 to 17.77 ppm in package III. A significant difference ($P < 0.05$) in the histamine contents of seerfish steaks stored in different packages of ice was observed. It has been earlier reported that the histamine content in tuna stored at an abused refrigerated temperature of 10°C increased to 27 ppm at the end of storage period (Jeyasekaran et al.

2004c). In our study, the formation of histamine was not in tune with the growth of histamine formers, which shows that histamine formers could not produce histamine consistently. Shakila et al. (2003) also reported that there was no increase in the histamine content, despite the high incidence of histamine forming bacteria in tuna. However, the histamine content in all the packages of ice in the present study did not exceed the maximum permissible limit of 50 ppm prescribed for raw fish by USFDA (FDA 1996).

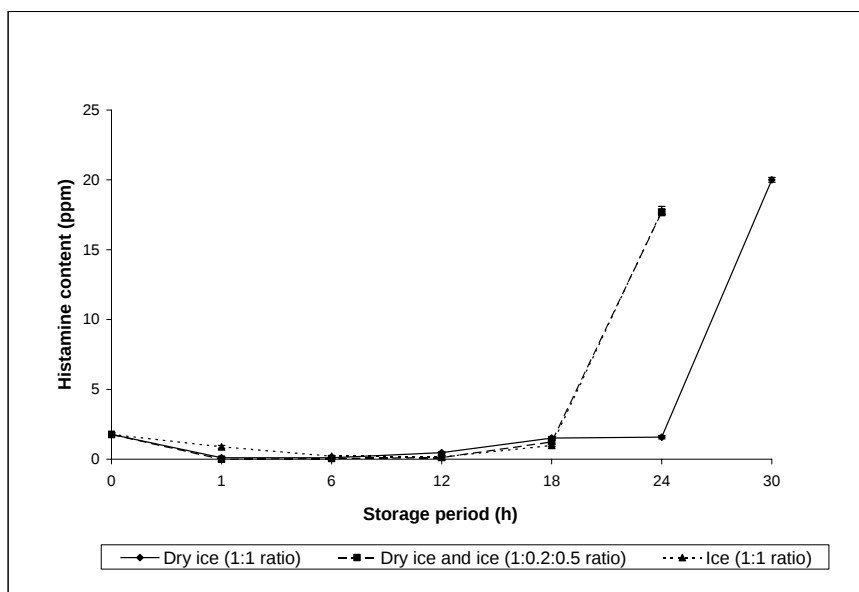


Figure 9. Changes in histamine content of seerfish (*Scomberomorus commersonii*) steaks preserved in dry ice and ice

Temperature profile of seerfish steaks preserved in dry ice and ice is shown in figure 10. Immediately after packaging, the temperatures recorded in packages I, II and III were 1.6, 12.1 and 4.8°C, respectively. At that time, room temperature was 29.6°C. A lowest temperature of – 11.9°C was observed in package I on the 4th h. Sub-zero temperature was observed even on the 8th h of storage. However, LeBlanc and LeBlanc (1992b) observed a lowest temperature of –1°C when the haddock fillets were packed with 25% CO₂ snow. Jeyasekaran et al. (2004a) recorded a subzero temperature of –1°C in lethrinus (*L. miniatus*) stored in a combination of dry ice and ice at a ratio of 1:0.2:0.5 (fish:dry ice:ice). Whereas, in packages II and III the lowest temperatures recorded were 2.7°C at 2 h and

2.2°C at 3 h of storage, respectively. After that, it gradually increased throughout the storage period.

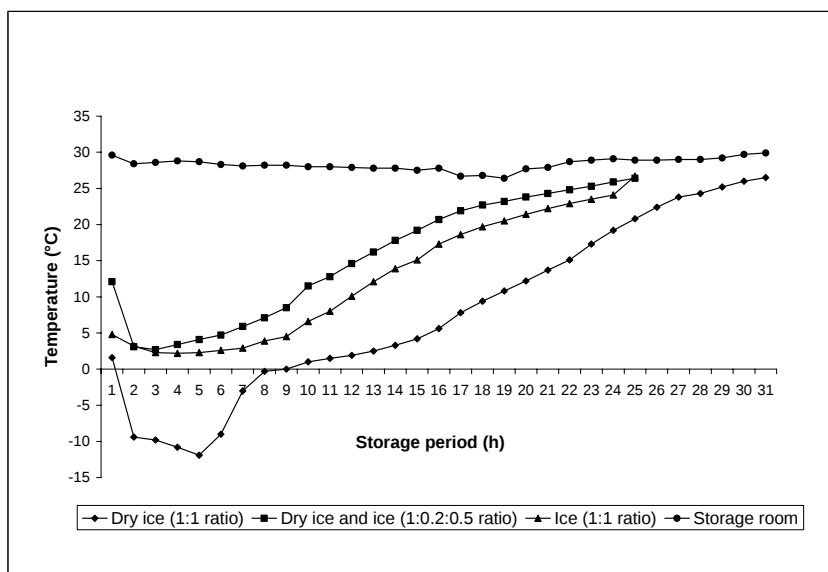


Figure 10. Temperature profiles of seerfish (*Scomberomorus commersonii*) steaks preserved in dry ice and ice

Changes in gas composition of seerfish steaks preserved in dry ice and ice are presented in [table 3](#). The atmospheric gas composition during this study was oxygen at 21.1%, carbon dioxide 0.6% and nitrogen 78.3%. After 1 h of packing, the oxygen, carbon dioxide and nitrogen content were 0.032%, 100% and 0% in package I, 0.05%, 100% and 0% in package II and 20.8%, and 1.9% and 77.3% in package III. Highest level of 100% CO₂ was noticed on the 1st h in packages I and II, which was due to the packing of steaks with dry ice. On the other hand, slight variation was observed in package III throughout the storage period. It can be observed that the changes in gas composition of the packages had a bearing on the total bacterial population in steaks. High level of CO₂ observed inside the dry ice and combined packages during the beginning stages of storage suppressed the growth of aerobic bacteria. The longer shelf life obtained in dry ice packed steaks might be due to high content of CO₂ in such packages (Villemure et al., 1986; Dhananjaya and Stroud, 1994; Randell et al., 1999).

Table 3. Changes in gas composition of seerfish (*Scomberomorus commersonii*) steaks preserved in dry ice and ice

Storage period (h)	Package I			Package II			Package III		
	O ₂ (%)	CO ₂ (%)	N ₂ (%)	O ₂ (%)	CO ₂ (%)	N ₂ (%)	O ₂ (%)	CO ₂ (%)	N ₂ (%)
0	21.1	0.6	78.3	21.1	0.6	78.3	21.1	0.6	78.3
1	0.032	100	0.0	0.050	100	0.0	20.8	1.9	77.3
6	0.023	100	0.0	6.42	68.7	24.9	21.8	0.9	77.5
12	0.414	98.4	1.2	10.2	50.8	39.0	20.8	1.6	77.6
18	17.1	20.4	62.5	16.2	23.4	60.4	20.8	1.1	78.1
24	12.3	41.5	46.2	18.7	8.9	72.4	20.3	1.3	78.4
30	16.8	18.5	64.7	18.7	5.7	75.6	*DC	DC	DC

*DC – Discontinued

Package I – Dry ice (1:1 ratio); Package II – Dry ice and ice (1:0.2:0.5 ratio); Package III – Ice (1:1 ratio)

Conclusion

It can be concluded that, based on the results of various quality analysis, dry ice and a combination of dry ice and ice improved the quality and increased the shelf life of fish steaks by about 12 h and 6 h, respectively when compared to ice alone. Since the combination of dry ice and ice is economical than dry ice alone, fresh fish can be chilled in the combined dry ice and ice package and transported more effectively by air through out the world to meet the demand of fresh raw fish consumption.

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