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Quality assessment of seven Mediterranean fish species during storage on ice

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The following seven Mediterranean fish species, bogue (*Boops boops*), chub mackerel (*Scomber japonicus collias*), horse mackerel (*Trachurus trachurus*), Atlantic mackerel (*Scomber scombrus*), Mediterranean hake (*Merluccius mediterraneus*), sardine (*Sardine mediterraneus*), striped mullet (*Mullus barbatus*) were assessed for quality changes during a week of ice storage. All fish were stored whole in ice. Fish tester readings of all fish species were found to be below 35 by the end of ice storage. The pH was not significantly changed ($p > 0.05$), while thiobarbituric acid number (TBA) and formaldehyde (FA) content were significantly increased ($p \leq 0.05$) by the end of ice storage of all fish species. Sensory evaluation showed that better storage life was observed for bogue, sardine and striped mullet by using the European Community (EC) freshness grading scheme of raw fish and for bogue and Mediterranean hake by using sensory panel evaluation of cooked fish fillets. Mediterranean hake may require a different descriptive scheme than the current EC freshness grading scheme. © 1998 Canadian Institute of Food Science and Technology. Published by Elsevier Science Ltd. All rights reserved

Keywords: Mediterranean fish species, thiobarbituric acid number (TBA), formaldehyde (FA), fishtester records, ice storage, sensory evaluation.

INTRODUCTION

Fish quality is assessed by sensory methods based on changes in appearance, odour, colour, flavour and texture. Sensory methods are fast, simple, sensitive and objective, but they rely on human judgement and proper training of panels (Sims *et al.*, 1992; Strachan and Nicholson, 1992). Sometimes sensory tests are also perceived to be inherently subjective (Krzymien and Elias, 1990).

Chemical tests can measure the amounts of breakdown products derived from enzymatic, bacterial or oxidation activity and have also been used for the assessment of fish quality. Among these trimethylamine, hypoxanthine, ammonia, formaldehyde and several other breakdown products can be recorded, in order to evaluate the fish quality. Thiobarbituric acid number (TBA) measurements have been used for the evaluation of lipid oxidation during freezing and frozen storage of fish. Chemical methods, although precise and objective, require laboratory equipment and must performed by technically qualified personel (Krzymien and Elias, 1990). Bligh (1971) and Manthey *et al.* (1988) concluded that common non-sensory evaluation methods such as chemical, physical or microbiological analysis methods do not give a satisfactory picture of freshness deterioration of either freshwater or aquaculture fish species stored in ice.

Several fish species have been examined during storage on ice (Hardy and Smith, 1976; Botta *et al.*, 1978; Ryder *et al.*, 1993). Quality parameters of common Mediterranean fish species have not been as extensively studied as either freshwater or marine fish species from tropical or cold waters. The aim of this work was to study the quality changes of seven Mediterranean fish species during ice storage. Bogue (*Boops boops*), chub

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mackerel (*Scomber japonicus collias*), horse mackerel (*Trachurus trachurus*), Atlantic mackerel (*Scomber scombrus*), Mediterranean hake (*Merluccius mediterraneus*), sardine (*Sardine mediterraneus*), striped mullet (*Mullus barbatus*) were chosen since according to Stergiou (1993) these fish are the most common fish caught annually in Greece. Atlantic mackerel was also examined since this fish is also found in the Mediterranean sea.

MATERIALS AND METHODS

Fish samples

Fish were caught off the southeast coast of Halkidiki peninsula (North Greece), kept on ice overnight, and landed at the Thessaloniki fish port on the next morning. The fish were transported to the laboratory in ice, stored in ice (fish to ice ratio 1:1) in boxes and in a cold room kept at 1–3°C. All fish species were not bled and were iced whole.

The fish were sampled immediately after being delivered to the laboratory on elapsed day 1 and on days 3 and 6. Fish sampling was accomplished in a week, since in the present practice fish are sold within the first few days of their capture and their storage in ice does not exceed a week time in Greece (Stergiou, 1993).

Fish were taken randomly for analysis at each day of sampling.

Freshness recording

Freshness of fish was assessed by recording the electrical resistance of skin and muscle flesh by using the Fishtester VI (Intellectron International Electronics, Germany), on first and each day during the ice storage at the laboratory. Fishtester records were taken by placing the electrodes on either side of the fish body, on the lateral line above the anal opening.

Sensory evaluation

Raw fish

Six whole fish of each fish species were evaluated at each time of sampling by five expert panellists from the laboratory staff, trained in grading fresh fish according to the European Community (EC) grading scheme (Howgate *et al.*, 1992). The appearance of the skin, eyes, gills and internal organs, surface slime, and the odors and texture of each fish were assessed into four quality grades. In this EC grading scheme, excellent quality (perfect condition), high quality (slight loss of excellent characteristics), good quality (some deterioration but fit for sale) and unfit for sale were assigned as E, A, B and C grades, respectively. The total grades of each fish was estimated from the grades attributed by each panellist and the final grade of each fish species was estimated from the fish examined at each day of evaluation. Scores in every grade were expressed as a percentage of the final grades of each fish species at each date of sampling.

Cooked fish fillets

The attributes of cooked fish were evaluated by five experienced panellists on each date of sampling. Fish samples (200 g of skinless fillets) were cooked individually in covered casserole dishes and immediately presented in these dishes to the panellists. Sensory evaluation was accomplished in individual booths under controlled conditions of light, temperature and humidity. Panellists were asked to score odour, taste and texture of fish using a 0–5 acceptability scale, (where 0 was extremely unacceptable, 2 was neither acceptable nor unacceptable, and 5 was extremely acceptable).

Chemical analysis

The pH of the fish flesh was determined according to Vareltzis *et al.* (1988). The thiobarbituric acid number (TBA) was estimated by Pearson's (1976) method as modified by Vareltzis *et al.* (1988) using 10 g of fish flesh. Formaldehyde (FA) was determined by the method of Rehbein (1987). The fat content of the fish was determined according to ISO 1443 (International Standard Organisation, 1973).

Statistical analysis

Statistical analysis of data was carried out using ANOVA and the analytical procedure of SPSS (Version 6, 1993).

RESULTS AND DISCUSSION

Freshness assesment

A decrease in Fishtester readings of all fish species examined was observed as shown in Fig. 1. The highest rate of decrease in Fishtester values was obtained for the Mediterranean hake, from 97.35 ± 2.25 on day 1 to 16.76 ± 3.62 on day 6. All Fishtester values were found to be above 70 on day 1 and below 35 on day 6. However, Rehbein *et al.* (1994) and Manthey *et al.* (1988) obtained Fishtester readings below 35 for redfish (*Sebastes marinus* and *S. mentella*) and European catfish (*Silurus glanis*), on days 12 and 27 of ice storage, respectively. The latter may be due to longer storage lives of the freshwater fish as compared to those of marine fish, since European catfish is a freshwater fish (Lima dos Santos, 1981).

pH

The pH changes are shown in Table 1. All fish species showed an initial low pH due to the production of lactic

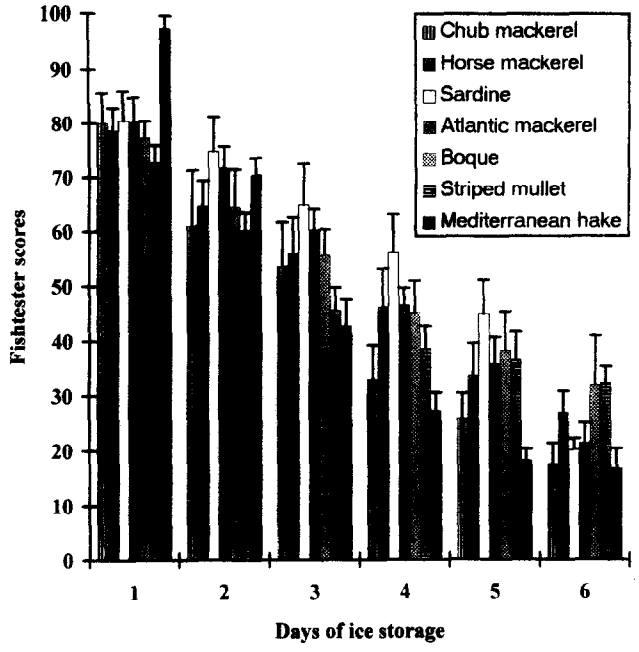

Fig. 1. Fishtester scores of seven Meditteranean fish species stored in ice (mean scores of six fish).

acid and an increase by the sixth day of ice storage due to the production of basic components induced by growth of bacteria. However, the changes in pH values were not significant ($p \geq 0.05$) until day 6 for all fish species examined. The pH changes are in agreement with the findings of Scott *et al.* (1986), Manthey *et al.* (1988) and Ryder *et al.* (1993) for other fish species stored in ice. The pH records revealed that examination of pH may not be useful for monitoring quality changes of the fish species examined. This is in agreement with the conclusions made by Scott *et al.* (1992).

TBA

The TBA records are shown in Table 1. Results showed a significant increase ($p \leq 0.05$) in TBA records on days 3 and 6 of ice storage as compared to those of day 1. The TBA number is a measure of malonaldehyde (MA) which is a byproduct of lipid oxidation. TBA records revealed an increase rate of lipid oxidation during the ice storage of the examined fish species. The highest increase in TBA values were obtained for the sardine, striped mullet and bogue, indicating a high rate of lipid oxidation and this could be due to the fact that all of these fish species are fatty fish as shown by their fat contents (Table 1). However, it may also be seen in Table 1 that chub mackerel had a high fat content and showed the lowest TBA records. It is also important to note that TBA records may not reveal the actual rate of lipid oxidation since MA can interact with other components of fish body such as amines, nucleosides and nucleic acid, proteins, amino acids of phospholipids, or other aldehydes that are end products of lipid oxidation and this interaction may vary greatly with species of fish (Auburg, 1993).

FA

The formaldehyde levels of ice-stored fish species are shown in Table 1. It may be seen that each type of fish showed an initial measurement different from the other fish species of day 1. FA levels were found to show a significant increase ($p \leq 0.05$) on days 3 and 6 of storage. The highest initial and final levels of FA were observed for the Mediterranean hake, indicating a high rate of FA production. This may due to the fact that the Mediterranean hake belongs to the Gadidae family. In this family, it has long been known that FA and DMA (dimethylamine) are formed from TMAO (trimethylamine oxide) as a result of the action the TMAO-ase enzymatic system (Gill *et al.*, 1979; Herrera and Mackie, 1994). Atlantic mackerel and striped mullet showed higher FA values on day 3 than those on day 6. This may be explained by the reaction FA with myofibrillar proteins, sarcoplasmic proteins and collagen which results in a denaturation of these proteins and toughening of fish muscles (Gill *et al.*, 1979; Ang and Hultin, 1989; Herrera and Mackie, 1994; Simeonidou *et al.*, 1997). Therefore, these variations in FA values of Atlantic mackerel and striped mullet during the ice storage, may be a result of a binding rate higher than that of production of FA. It is also important to note that Mediterranean hake showed the highest acceptability scores in texture (Table 2) and highest records in FA by the end of ice storage, as compared to those of the rest of fish.

Sensory evaluation

Raw fish

Day 1: Freshness grades of raw fish attributed by panellists according to EC grading scheme during the ice storage are shown in Fig. 2. It may be seen that grades of raw fish characteristics on day 1 varied from excellent and very good (grades E and A) to moderate (grade B). The highest score (90) in E grade was obtained by sardine, followed by bogue with a score of 49.2 in the same grade. All fish showed the lowest score in B grade as compared to E and A grades. The highest score (35.8) in B grade was recorded for the horse mackerel, as compared to these of the rest of the fish. Similar variation in freshness grades for ice-stored redfish on first day was obtained by Rehbein *et al.* (1994). Such variations in freshness on day 1 may be due to several factors such as onboard handling of fish, fishing techniques, initial number of bacteria of fish, season of fishing etc. (Botta *et al.*, 1987). However, inspection parameters of fish appearance may not be the same in all fish species and may not be applicable to other fish species exactly as they are described in the EC grading scheme.

It is important to note that the Mediterranean hake was evaluated with the lowest score (20) in E grade, as compared to those of the rest of the fish, since its gills

Table 1. Fat content and changes in TBA, FA and pH of seven Mediterranean fish species during ice storage

Analytical parameters	Days of storage	Fish species[a] Chub mackerel	Horse mackerel	Sardine	Atlantic mackerel	Bogue	Striped mullet	Mediterranean hake
TBA (10^{-1}mg MA kg^{-1})	0	18.2±0.05	19.1±0.05	24.6±0.07	20.3±0.04	30.2±0.08	15.1±0.02	12.8±0.03
	3	31.5±0.07	63.4±0.03	90.2±0.07	52.5±0.09	106.4±0.09	78.9±0.04	75.6±0.04
	6	74.3±0.10	95.8±0.06	183.2±0.09	101.3±0.10	209.8±0.05	146.1±0.15	85.4±0.11
FA (μg g^{-1})	0	70±0.01	99±0.02	90±0.01	91±0.01	102±0.04	83±0.01	145±0.07
	3	101±0.01	122±0.06	92±0.04	110±0.04	122±0.06	104±0.02	211±0.04
	6	106±0.03	128±0.05	101±0.02	107±0.02	167±0.08	97±0.02	399±0.06
PH	0	6.50±0.20a	6.60±0.18b	6.56±0.10c	6.62±0.17d	6.80±0.16e	6.92±0.10f	6.56±0.23g
	3	6.60±0.11a	6.62±0.14b	6.52±0.13c	6.58±0.19d	6.76±0.14e	6.90±0.14f	6.58±0.20g
	6	6.61±0.08a	6.65±0.12b	6.60±0.09c	6.67±0.14d	6.82±0.12e	7.10±0.15f	6.60±0.18g
Fat content (%)		16.85±1.6	4.39±1.3	12.96±1.9	6.23±2.1	11.15±2.3	9.3±1.2	2.2±0.4

[a]Mean values of six fish fillets ± standard deviation. The fat content is of skinless fillets. Values of each analytical parameter within the same column followed by the same letter are not significantly different ($p \geq 0.05$).

were found to be brown-grey, its eyes were sunken and opaque, its skin had incisions, its texture was fairly soft and the fish body had lost its *rigor mortis*. The present findings in appearance of the Mediterranean hake are in agreement with those of Panetsos (1967), who concluded that the appearance of the Mediterranean hake after catching would be typical of that of a spoiled fish, if that appearance were found in other fish species. The same worker stated that the only criterion for the inspection of spoilage in the Mediterranean hake was a yellow mucus with an unpleasant odour that initially covered the gills and head and later spread to the body. It is important to note that the Mediterranean hake showed the highest initial values with the Fishtester and the highest acceptability scores of cooked fish attributes as compared to those of the rest of the fish. Therefore, some other grading description than that of the EC may be required for the Mediterranean hake.

Day 3: On third day of ice storage, it may be seen that higher scores were obtained in A and B grades as compared to those of fish on first day, since quality had deteriorated. As on first day, the highest scores in E grades, among those of the rest of the fish, were obtained for sardine and bogue with scores of 38.1 and 34, respectively.

Inspection parameters of horse mackerel, chub mackerel and Mediterranean hake were assesed in C grade with scores of 5.2, 4.1 and 1.5, respectively. However, no odors of any fish examined were ranked as C grade. It is well known to consumers and retailers that odour is one of the most important factors in freshness assessment.

Day 6: As expected, freshness of all fish had deteriorated on the sixth day of ice storage. All fish found to have scores in the C grade category. The higher scores in C grade were obtained by fish of the Scombridae family, namely horse mackerel, chub mackerel and Atlantic mackerel, with scores of 33.4, 31.7 and 26.7, respectively. It is also important to note that the odors of the same fish were assesed in C grade with scores of 3.3, 2.8 and 1.6 for the horse mackerel, Atlantic mackerel and chub mackerel, respectively. The odours of the rest of the fish examined were ranked as C grade. Inspection parameters of sardine, bogue and striped mullet were assessed as E grade with scores of less than 3.4.

Table 2. Acceptability scores for cooked fillets of seven Mediterranean fish species stored whole on ice

Attributes	Days of storage	Fish species[a] Chub mackerel	Horse mackerel	Sardine	Atlantic mackerel	Bogue	Striped mullet	Mediterranean hake
Odour	0	4.4±0.3	4.8±0.1	4.8±0.1	4.6±0.2	4.8±0.1b	4.5±0.3	4.7±0.2
	3	3.6±0.4	4.0±0.1	4.2±0.1	3.9±0.4	4.8±0.2b	3.5±0.5c	4.5±0.3
	6	2.6±0.2	2.5±0.3	3.6±0.2	3.7±0.2	4.7±0.2b	3.2±0.4c	4.0±0.2
Taste	0	4.6±0.1	4.5±0.1	4.7±0.2	4.5±0.3a	4.7±0.1b	4.4±0.3	4.8±0.2
	3	3.8±0.2	4.0±0.3	4.0±0.2	4.3±0.5a	4.6±0.3b	3.9±0.2	4.1±0.3
	6	2.8±0.5	2.6±0.4	3.8±0.3	3.1±0.4	4.3±0.4	3.3±0.4	3.8±0.1
Texture	0	4.8±0.1	4.6±0.2	4.5±0.3	4.7±0.3	4.8±0.2	4.7±0.1	4.8±0.1
	3	4.3±0.4	3.8±0.4	3.7±0.2	4.1±0.4	4.2±0.1	3.8±0.3c	4.6±0.1
	6	2.5±0.3	2.3±0.2	3.5±0.3	3.7±0.2	4.0±0.4	3.9±0.3c	4.2±0.3

[a]Mean scores of 30 observations ± standard deviation. Attribute scores within the same column followed with the same letter are not significantly different ($p \geq 0.05$).

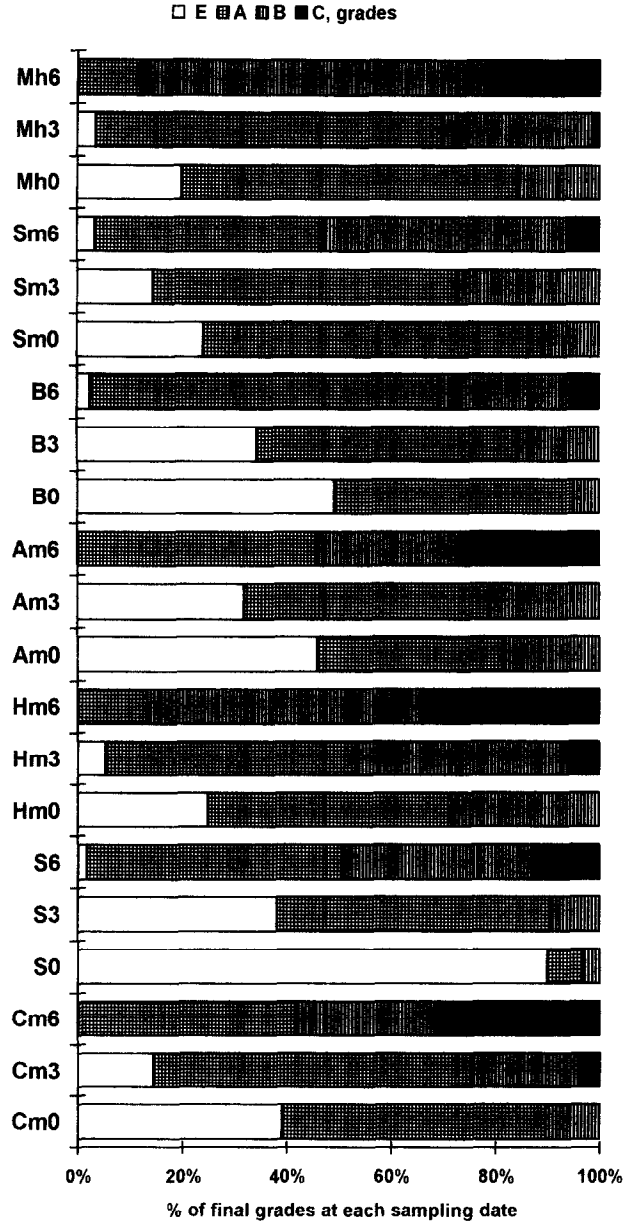

Fig. 2. Freshness grading of fish into four grades (E, A, B, C) according to EC grading scheme. (0, 3, 6 are for days 0, 3, 6 of sampling. Cm, chub mackerel; S, sardine; Hm, horse mackerel; Am, Atlantic mackerel; B, bogue; Sm, striped mullet; Mh, Mediterranean hake).

In general, evaluation according to the EC freshness grading scheme showed that the best keeping quality fish were sardine, bogue and striped mullet.

Cooked fish fillets

Acceptability scores of odour, taste and texture of fish evaluated by the panellists decreased significantly ($p \leq 0.05$) with time of ice storage (Table 2). An exception may be seen for the odour of bogue, which was not significantly changed ($p \geq 0.05$). By day 6 of ice storage attributes of chub mackerel and horse mackerel indicated lower acceptability scores than those of the other fish. A score of 2 was considered as a limit of acceptability and this is in agreement with Maia *et al.* (1983), who used a 5 point acceptability scale. Sensory assessment of cooked fish fillets showed that no one score of the fish attributes reached the limit of acceptability, since all mean acceptability scores were still above 2 by the end of ice storage. The present findings showed that the raw fish scored in C grade by using the EC grading scheme of freshness were not ranked in the cooked status with scores below the limit of acceptability. Manthey *et al.* (1988) also reported that quality deterioration was noticed somewhat later in cooked samples than in the raw fish. Rehbein *et al.* (1994) concluded that grades of EC grading scheme do not reflect the quality assessment of cooked fish fillets.

Sensory assessment of cooked fish fillets showed that the bogue and Mediterranean hake had kept their quality better during the ice storage of the present study, since cooked samples of these fish were evaluated with higher scores than those of the rest of fish.

CONCLUSIONS

Results showed that examination of pH may not be useful for quality evaluation of the seven Mediterranean fish species during a week of ice storage. Fishtester values of all fish species examined were found to be above 70 on day 1 and below 35 on day 6. TBA and FA records of all fish were significantly increased ($p \leq 0.05$) by the end of ice storage. Therefore, Fishtester, TBA and FA records may be useful for monitoring quality changes of all fish species examined. A different descriptive scheme than that of the current EC grading scheme may be required for the Mediterranean hake. Results of sensory evaluation showed that freshness deterioration may be noticed somewhat later in cooked fish fillets than in the raw fish by using the EC freshness grading scheme.

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