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Effect of different storage conditions on the dielectric properties of the sea bass (*Dicentrarchus labrax, L.*)

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Dielectric properties and sensory assesment of sea bass (Dicentrarchus labrax, L.) *stored under six different conditions over a period of 75 hours were investigated. Declines of torrymeter values over time were established under all storage conditions, but showed variability. The correlations between torrymeter readings and Quality Index Method (QIM) results were studied. Significant negative correlations were found between QIM results and torrymeter readings for samples stored in sea water (20-22 °C), storage room (16-18 °C), refrigerated room (2-4 °C) and sea water (10-12 °C). QIM and torrymeter values in slurry ice and ice box samples were not in correlation.*

Key words: fish, dielectric properties, storage conditions, Quality Index Method (QIM)

INTRODUCTION

Seafood is highly susceptible to spoilage and deterioration due to autolysis and growth of postmortem microbial populations (DAINTY, 1982). Freshness and spoilage are the principal terms used to describe quality changes of fresh fish. The final quality is affected by factors such as handling, gutting, size, season and storage temperatures. Although refrigeration and freezer storage can extend the shelf life of seafood products, proliferation of psychotropic bacteria at refrigerated temperatures still contributes to spoilage (GIBSON *et al.*, 1984). While spoilage is an important criterion for determining the overall quality of seafood products, considerable effort has been expended in searching for suitable methods with which to assess freshness while the product is still edible (PIVARNIK *et al.*, 1990). Primary loss of freshness is caused by endogenous biochemical changes in fish muscle, and not by bacterial action, which causes fish to spoil. Freshness declines before the fish is spoiled by microorganisms (EHIRA & UCHIYAMA, 1987). Postmortem biochemical changes in fish tissues are strongly influenced by the holding temperature after catch, the capture method and the previous condition of the live fish (SIKORSKI *et al.,* 1990), therefore post-capture handling of fish affects directly the quality of the product. Traditionally, assessment of freshness methods in the seafood industry has relied on sensory evaluation panels to classify products as fresh, bad or spoiled. Although fast, simple and usually accurate sensory analysis is sometimes perceived to be inherently subjective. No matter how skilled, the sensory panel is not on-call during all phases of production, nor can it function efficiently for prolonged periods of time. Methods using chromatographic and chemical techniques to determine seafood freshness are precise and objective, but also time-consuming, expensive and species-dependent. Laboratory space is further required and analyses must be performed by technically qualified personnel. Therefore, the need exists to develop new technologies which can give instantaneous and objective classification of seafood quality and freshness, so that the processing industry and angling associations can quickly determine and maintain the quality and freshness of their products.

The Fish Freshness Meter Torrymeter (TM) is used around the world as an objective method of measurement of fish freshness for those caught, processed and sold. TM measures the dielectric properties of the fish; as the fish spoil bacteriological and enzyme activity within the muscle structure breaks down the cellular structure in a slow systematic way, causing dielectric changes in the fish. The TM is used for various applications such as to estimate the freshness and quality of fish, to grade fish according to European Standards (E-A-B), to determine if fish have been frozen or irradiated, to estimate shelf-life and to check the time storage of fish during Angling Competitions. The TM allows an objective method of assessing the relative freshness of the fish simply and easily. Each species of fish will have different dielectric properties. The operational "value" range of the TM is governed by the dielectric range of the fish.

The most commonly used method for the quality assessment of whole fish in Europe is the European Union Freshness Grading (or EU scheme), published in Council Regulation No. 2406/96 (EUROPEAN COMMUNITY, 1996) which takes into account recommendations published by HOWGATE *et al.* (1992). This scheme does not take into account differences between species, because only general parameters for groups of fish are used and each table is valid for several species.

Alternative sensory methods such as the Quality Index Method (QIM) have been suggested where the description of the individual grades is precise, objective and independent. This scheme was developed specifically for some well-defined species and products. When compared to the EU scheme, the main advantages of the QIM method include its specificity for each species and minimizing fluctuations between assessors (OLAFSDOTTIR *et al.*, 1997).

The objectives of this study were to investigate dielectric changes in farmed sea bass samples with time and under different storage conditions, as well as its correlation with changes in sensory quality.

MATERIAL AND METHODS

In this study 200 individuals of cage-cultured sea bass (*Dicentrarchus labrax, L.*) were obtained directly from a farm and a total of 180 commercial-size fish (350–560 g) were used. The fish were killed with a single stab in the heart.

Ungutted fish were divided into six groups of 30 and immediately placed under six different storage conditions prepared earlier that day. Conditions were thermostatically controlled: ice boxes at -1 °C (IB), slurry ice sea water at 0-2 °C (SISW 0-2), sea water at 10-12 °C (SW 10-12), sea water at 20-22 °C (SW 20-22), refrigerated room at 2-4 °C (REF 2-4) and storage room at 16-18 °C (SR 16-18). Of the remaining 20 fish five were immediately frozen and kept at -18 °C for 5 days. All the fish were in closed containers, excess water was continuously drained and fresh ice was added as required. TM measurements were taken every 5 hours until 75 hours since death had passed. Temperature measurements were taken with each sampling. Changes in the dielectric properties of sea bass were determined using the GRTorrymeter (Distell Industries Ltd., Scotland). A single measurement was obtained on each fish by applying the probe of the meter above and parallel to the lateral line, just behind the gill cover. The electrodes were cleaned in-between measurements to remove scales and slime, and any remaining ice was cleared from the measuring surface. Instrument readings were read on a digital display with a high value being 17 and a low value of zero. The device was used according to manufacturer's instruction.

Sensory assessments of the raw ungutted fish were carried out by a sensory panel of 6 members having previous experience in evaluating fresh fish. All the fish were evaluated using both European Union freshness grading (EU scheme) and Quality Index Method (QIM) for sea bass previously described in KNOWLES *et al.*, (2007). The panelists were requested to evaluate and score quality on evaluation sheets by feeling, smelling and examining the samples, describing whether differences occur between samples, commenting on sample characteristics and rating intensity of specific sensory attributes such as color, odour, texture and presence of rigor mortis.

RESULTS AND DISCUSSION

TM values, QIM and European Union freshness grading of the sea bass samples stored under six different conditions over a period of 75 hours are shown in Table 1. The correlation between TM readings and QIM results were investigated.

The decline of TM values of differently stored fish with storage time is shown in Fig.1. Immediately after death TM values ranged from 13.6 to 15. The study of post death changes in TM readings over the first 75 hours showed that a maximum freshness value is reached between 12-24 hours. TM readings with storage time show no significant changes ($p>0.05$) for samples stored in ice box and slurry ice. Dielectric properties of fish remained high in these two storages, as well as QIM and EU scheme grades. After 75 hours a small decline in sensory values was detected (Table 1). ALASALVAR *et al.* (2002) found that the sensory scores of the sea bass increased linearly with time, and the level of freshness was acceptable for both wild and cultured sea bass stored in ice during a period of 16 to 18 days.

However, TM values for other storage conditions showed significant declines with time. The fastest decline was notable in sea bass stored in sea water at 20-22 °C. A strong nega-

Table 1. Torrymeter readings (TM) (mean values), European Union Freshness Grading (EU) and Quality Index Method (QIM) values for each group of the sea bass (Dicentrarchus labrax, L.) *in hours (h) after catch*

Time of storage (h)	STORAGE CONDITIONS																	
	IB[1]			SISW 0-2[1]			SW 10-12[1]			SW 20-22[1]			REF 2-4[1]			SR 16-18[1]		
	EU	QIM	TM	EU	QIM	TM	EU	QIM	TM	EU	QIM	TM	EU	QIM	TM	EU	QIM	TM
0	E	0	15	E	0	13,8	E	0	14,6	E	0	13,6	E	0	14	E	0	14,4
5	E	0	15	E	0	14,8	E	2	15	A	8	13,6	E	0	13,8	E	3	13,4
10	E	0	16,7	E	0	15,4	E	4	14	B	18	12,4	E	2	13,8	A	6	13,4
15	E	0	17	E	0	15,8	A	4	14,4	C	22	11,4	A	3	13,6	B	13	13,2
20	E	0	17	E	0	16	A	6	14,4	C	22	7,8	A	3	12,8	B	13	12,4
25	E	0	17	E	0	16	A	7	14,4	C	22	6,2	B	4	12,8	B	15	11,2
30	E	0	16,8	E	0	16	A	8	13,6	C	22	5,4	B	4	12,2	B	17	11,2
35	E	0	16,4	E	0	16	B	13	13	C	22	5,2	B	6	12,2	B	18	11,4
40	E	0	16,2	E	0	16	B	10	12,4	C	22	4,8	B	8	12	C	20	11
45	E	0	16,2	E	1	16,2	B	16	11,8	C	22	4	B	9	12	C	22	10,6
50	E	1	16	E	1	16	B	17	11,4	C	22	4	B	9	11	C	22	10,6
55	E	1	16	E	2	15,8	B	18	11,4	C	22	2,8	B	10	11	C	22	9,8
60	E	2	15,8	E	2	15,8	C	20	10,8	C	22	2	B	11	9,8	C	22	8,8
65	E	2	15,4	E	3	15,4	C	22	10,4	C	22	2	B	11	9,6	C	22	8,2
70	E	2	15,4	E	3	15	C	22	8	C	22	2	B	12	9	C	22	8,2
75	E	2	15,2	E	3	14,6	C	22	8	C	22	2	C	14	8,8	C	22	7,6

[1] *Ice boxes at -1 °C (IB), slurry ice sea water at 0-2 °C (SISW 0-2), sea water at 10-12 °C (SW 10-12), sea water at 20-22 °C (SW 20-22), refrigerated room at 2-4 °C (REF 2-4), storage room at 16-18 °C (SR 16-18)*

Table 2. Values of regression lines for the torrymeter readings with time under different storage conditions

Storage conditions	Slope ± SE	Intercept ± SE	Correlation coefficient
IB	-0.009 ± 0.008	16.41 ± 0.34*	0.300
SISW 0-2	0.004 ± 0.007	15.38 ± 0.33*	0.300
SW 10-12	-0.089 ± 0.008*	15.70 ± 0.35*	0.948
SW 20-22	-0.169 ± 0.016*	12.53 ± 0.70*	0.943
REF 2-4	-0.071 ± 0.004*	14.46 ± 0.18*	0.978
SR 16-18	-0.085 ± 0.004*	14.16 ± 0.19*	0.983

**Slopes and intercepts significantly different from zero (p<0.05)*
(±SE – standard error)

tive correlation was found between TM values and QIM results for samples stored in sea water at 20-22 °C (Table 1).

The regression line slopes (b), for TM value changes as a function of time, showed similar declines for samples stored in sea water at 10-12 °C (b=-0.089) and in the storage room (b=-0.085) (Fig.1), while the rate of TM value decline for refrigerated room samples was somewhat smaller but significantly different ($p<0.05$) from the first two storage types (Table 2). However, the regression line intercept for torrymeter dependence with time showed a significant difference ($p<0.05$) in samples from the sea water at 10-12 °C (intercept=15.7) and the storage room values (intercept=14.16) (Fig. 1). This explains the TM readings of fish samples stored in sea water at 10-12 °C above the TM values of the same fish stored in a storage room at 16-18 °C.

QIM values of sea bass samples under different storage conditions after harvest show a general trend of growth over time (Fig. 2). The beginning of sensory changes during storage is somewhat different in slurry ice and ice box samples, with the first changes detected 40 hours after death. Sensory rejection point (value 22) of fish samples stored in sea water at 20-22 °C, storage room and sea water at 10-12 °C was achieved after 15, 45 and 65 hours respectively. Sea bass samples from the refrigerated room, sea water at 10-12 °C and the storage room reached sensory rejection point, but dielectric properties

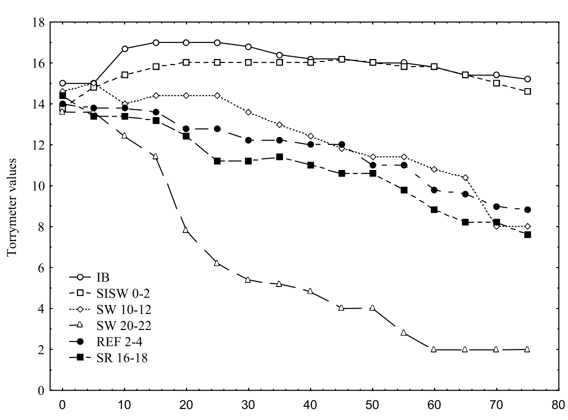

Fig. 1. Torrymeter readings (TM) of the sea bass (Dicentrarchus labrax, L.) *stored under six storage conditions: ice boxes at -1 °C (IB), slurry ice sea water at 0-2 °C (SISW 0-2), sea water at 10-12 °C (SW 10-12), sea water at 20-22 °C (SW 20-22), refrigerated room at 2-4 °C (REF 2-4), storage room at 16-18 °C (SR 16-18) with storage time*

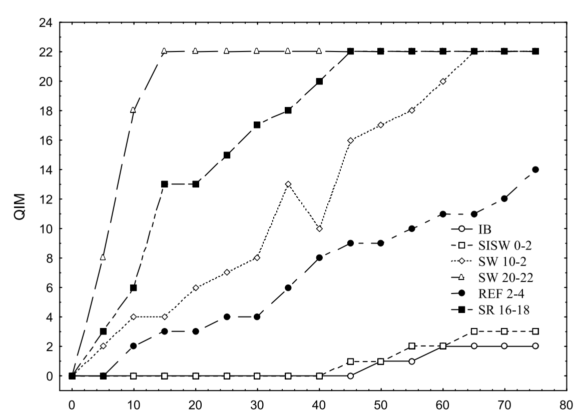

Fig. 2. Quality Index Methods (QIM) values of the sea bass (Dicentrarchus labrax, L.) *stored at six storage conditions: ice boxes at -1 °C (IB), slurry ice sea water at 0-2 °C (SISW 0-2), sea water at 10-12 °C (SW 10-12), sea water at 20-22 °C (SW 20-22), refrigerated room at 2-4 °C (REF 2-4), storage room at 16-18 °C (SR 16-18) with storage time*

indicated good quality fish (TM readings of 6 or more). The study showed that the dielectric proprieties of the sea bass were the highest at the rigor mortis phase.

Spearman rank correlation coefficients indicate a strong statistically significant ($p<0.01$) negative correlation within QIM results and TM readings for samples stored in sea water at 20-22 °C, store room, refrigerated room and sea water at 10-12 °C. However, QIM and TM values in slurry ice sea water and ice box samples were not correlated. Since freshness loss is delayed in fish stored in slurry ice and ice boxes, 75 hours is not long enough to find a correlation between sensory attributes and dielectric readings. Some authors found a high correlation with sensory assessment of different fish species (PIVARNIK *et al.*, 1990; OEHLENSCHLAGER, 2003).

TM readings of 5 individual fish that were frozen for 5 days at -18 °C ranged from 1-3, which indicates that with TM it is not possible to determine the original freshness of thawed fish due to the drastic effect freezing has on the cellular constituents of muscle. The TM readings on the fresh fish would also be affected by bruising due to handling and packing as the integrity of the muscle and skin can be damaged (PIVARNIK *et al.*, 1990). Between different storage conditions high variability of TM readings was detected. Disruption by mechanical abuse and freezing affects the readings, but apart from this studies showed an excellent correlation of TM readings with QIM, agreeing to within ±0.5 days of chilled storage (OEHLENSCHLAGER, 2003). However, for other types of storage this conclusion could not be applied.

CONCLUSIONS

Different storage conditions influence the changes in dielectric properties of sea bass. At low temperatures the conduction of the muscle is the strongest and the sensory attributes are preserved. Maximum dielectric properties are achieved for the fish in ice, while for other methods of storage conductivity of the muscle is lost as fast as the sensory properties. Higher temperature effects cause changes in TM readings which results in rapid loss of dielectric properties.

Measuring dielectric properties alone is not an "absolute" in fresh fish quality assessment although, in combination with sensory analysis, fish muscle conduction ability is a practical and objective measurement of fish quality.

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Utjecaj različitih uvjeta skladištenja na dielektrična i senzorska svojstva lubina (*Dicentrarchus labrax, L.*)

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SAŽETAK

Promatrana su dielektrična i senzorska svojstva lubina (*Dicentrarchus labrax,L.*) pohranjenog u šest različitih uvjeta skladištenja kroz 75 stati od uginuća. U svim uvjetima skladištenja zabilježen je pad očitanih torimetar vrijednosti (TM) kroz vrijeme koji ukazuju na varijabilnost dielektričnih svojstava. Istraživana je korelacija između TM vrijednosti i senzorskih svojstava ocijenjenih metodom indeksa kvalitete (QIM). Između rezultata QIM metode i TM vrijednosti, u uzorcima skladištenim u morskoj vodi (20-22 °C), skladištu (16-18 °C), ohlađenom skladištu (2-4 °C) i morskoj vodi (10-12 °C), zamjećena je statistički značajna negativna korelacija. U uzorcima iz polеđene morske vode i leda QIM ocjene senzorskih svojstava i TM očitanja nisu u korelaciji.

Ključne riječi: riba, dielektrična svojstva, uvjeti skladištenja, metoda indeksa kvalitete (QIM)