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QUALITY CHANGES IN WHOLE, GUTTED AND FILLETED THREE FISH SPECIES (*GADUS EUXINUS*, *MUGIL CEPHALUS*, *ENGRAULIS ENCRASICHOLUS*) AT FROZEN STORAGE PERIOD (–26°C)

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Abstract. The objective of this study was to determine the quality changes in whole, gutted and filleted three fish species, whiting (*Gadus euxinus*), gray mullet (*Mugil cephalus*) and anchovy (*Engraulis encrasicholus*), at frozen storage period (–26°C). Throughout the storage period, anchovy had the lowest values in all sensorial criteria among the fish species. During the storage period, whiting kept its freshness better than gray mullet and anchovy as to chemical criteria. The lowest TVB-N value (17.23 mg/100 g) was determined in whiting whereas the highest value (22.55 mg/100 g) in anchovy. The highest TMA value (3.50 mg/100 g) was found in anchovy. The TBA values increased up to 9th month, depending on fish species. Differences between the species are found to be significant and the highest TBA value (2.55) was obtained in anchovy. Although the TBA and peroxide values in anchovy significantly increase when compared to the others during storage period, acceptable limits expired at the end of 9th month. According to treatments, filleted fish had better color quality wheras gutted fish had better smell, muscle and taste.

Key words: anchovy (*Engraulis encrasicholus*), gray mullet (*Mugil cephalus*), whiting (*Gadus euxinus*), frozen storage

INTRODUCTION

The purpose of refrigerated and frozen storage of seafood is to extend its shelf-life and to limit microbial and enzymatic activity which causes deterioration. Frozen storage has been widely employed to retain fish properties before it is consumed or employed in other technological process [Ericson 1997, Pigott and Tucker 1987]. Once the fish are frozen, bacterial spoilage caused by the exogenous enzymes of the bacterial ceases, and autolytic changes caused by the breakdown of the chemical constituents of the fish by intrinsic enzymes tend to be relatively slow and contribute little to loss of quality [Garthwaite 1992]. Freezing requires lowering the temperature to –18 or lower and is

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a popular method of preserving fish [Regenstein and Regenstein 1991]. Chapman et al. [1993] explained that sensory tests did not show a significant difference in acceptability due to storage temperature. TMA is due to the activity of bacterial enzymatic decomposition of TMAO [Castel et al. 1970, Pedrosa-Menabrito and Regenstein 1988]. According to Chang and Regenstein [1997], loss of protein functionality during frozen storage is due to denaturation of fish proteins. Storage temperature was one of the factors affecting lipolysis [Shewfelt 1981] and loss of protein functionality [Samson and Regenstein 1986] in frozen stored fish. Sotelo et al. [1995] reported that TMA value of frozen hake little changed at –5°C and none at –12°C and –20°C.

Fish lipids which contain relatively high polyunsaturated fatty acids are known as susceptible to oxidative rancidity, particularly during frozen storage. During the frozen storage of fish lipid hydrolysis and oxidation were shown to occur and become an important factor of fish acceptance as influencing rancidity development, protein denaturation and texture changes [Mackie 1993, Verma et al. 1995]. Although freezing is one of the best methods for the preservation of fish, deterioration during frozen storage is the main problem. Lipid oxidation in frozen fish is partially responsible for many problems which shorten the shelf-life of fish products. Oxidative deterioration of frozen fish causes off-flavor [Pedraja 1970] as well as colour and texture changes [Sikorski et al. 1976]. Yamagata and Low [1995] reported that shelf-life of frozen banana shrimp (*Penaeus merguiensis*) remained acceptable after 6 months at –20°C. According to Olgunoğlu et al. [2002], chemical quality of perch fillets did not reach the critical values however, the decrease in the values of sensory analyses was faster than chemical changes during storage of 7 months. Simeonidou et al. [1997] explained that a comparison of quality scores between whole fish and fillets of horse mackerel and Mediterranean hake showed that there were no significant differences at frozen storage.

The objective of this study was to determine the quality changes of whole, gutted and filleted three fish species, whiting (*Gadus euxinus*), gray mullet (*Mugil cephalus*) and anchovy (*Engraulis encrasicholus*) which were frozen stored at –26°C. These fish species are caught in Marmara Sea and widely consumed in this region.

MATERIAL AND METHODS

Whiting, gray mullet and anchovy fish which were caught in the Marmara Sea were used in this study. The length and weight of fish species were determined during the pretreatments. The length of whiting was found between 24-28 cm, gray mullet was 25-33 cm, and anchovy was 11-15 cm. The weights of the fish species were between 113-158 g, 157-188 g, and 11-16 g respectively. Mean oil content of fish species were 2.06% for anchovy, 0.85% for gray mullet and 0.56% for whiting.

Freezing and storage procedures of fish

The fish were processed immediately after catching, placed in crushed ice and stored in plastic boxes and transferred to the laboratory for freezing. Each fish species was divided in to three lots, one lot was for the whole (W), the second lot was for gutted (G), and the third lot was for fillet. Fish lots were frozen in blast freezer (Armfield – Blast and Fluid Bed Freezer) at –40°C. They were then packed into plastic refrigerator bags and stored at –26 ±2°C in freezer (Williams HS 1 BCBF). For each specified time, two bags from each treatment were removed for examination.

Sensory evaluation

Cooking test was applied on sensorial analysis of chilled fish. In sensorial analysis a scale of 0-3 were used to determine for color, smell, muscle, structure (chewing) and taste of fish [Kruger 1989].

Physical and chemical analysis

Determination of pH values in all three fish species was carried out by using Hanna 8014 model pH meter [Varlık et al. 1993]. Indication of total Volatile Base Nitrogen (TVB-N) content was determined and evaluated as described by Gökalp et al. [1993] by kjeldahl distillation mechanism. The method was based on water vapor distillation and separation of volatile base. Fixing of first amine compound, Trimethylamine (TMA) values, which are the results of changes seen in fish, were determined by following the procedure explained by Gökalp et al. [1993]. The indication principle of thiobarbituric acid value (TBA) was based on malonaldehit which is the result of dissatisfied fatty acid oxidation, and red colour which is the result of heating by thiobarbituric acid [Tarladgis et al. 1960]. This was determined by using kjeldahl distillation system and spectrophotometer (Hitachi UV/Vis). Peroxide value (PV) indication was done by iodometric Wheeler method according to Schormüller [1969]. For determination of PV value of fish, firstly oil of fish was obtained according to method and mean oil contents were found from calculation of these values.

Statistic analysis

Statistical analysis were made using MSTAT packaged program and performed as two replications and two parallel for randomized complete block factorial test design [MSTAT... 1982].

RESULTS AND DISCUSSIONS

Changes in sensory evaluation of storage fish species at –26°C were given in Table 1 and Figure 1. Throughout the storage period there were decreases and significant changes ($p < 0.05$) in all sensorial criteria. Average values showed that highest decreases were in smell (2.41) and then taste (2.48) among sensorial criteria. Colour quality (2.54) was found to be higher than the other quality criteria (Table 1). Namulema et al. [1990] also reported that there was no significant difference in texture, taste, appearance and overall acceptability, but off-flavours developed during storage period in the frozen Nile perch at –27°C for a period of 12 weeks. In our research, color, smell and taste criteria of whiting were determined higher than other species. However maximum muscle and structure value were found in gray mullet. Anchovy was showed to be significant decline all sensorial criteria during the time of frozen storage ($p < 0.05$). According to treatments that were carried out at fish species, maximum mean colour value

Table 1. Comparison of three fish species in terms of sensory evaluation

Criteria	Fish species	T	Storage period, month					Means		
			0	2	4	7	9	mean	mean	mean
1	2	3	4	5	6	7	8	9	10	11
Colour	whiting	W	3.00	2.91	2.70	2.58	2.09	2.66 a	2.58 a	Whole: 2.53 b
		G	3.00	2.76	2.71	2.32	2.06	2.57 d		Gutted: 2.51 c
		F	3.00	2.96	2.74	2.14	2.01	2.57 d		Fillet: 2.59 a
	gray mullet	W	3.00	3.00	2.34	2.26	2.01	2.52 e	2.55 b	
		G	3.00	3.00	2.50	2.13	1.98	2.52 e		
		F	3.00	2.95	2.85	2.26	2.01	2.61 b		
	anchovy	W	3.00	2.73	2.64	2.03	1.95	2.47 f	2.50 c	
		G	3.00	2.70	2.51	2.01	1.95	2.43 g		
		F	3.00	2.80	2.69	2.25	2.21	2.59 c		
	mean		3.00 a	2.87 b	2.63 c	2.20 d	2.03 e	general mean: 2.54		
LSD values ($p < 0.05$), storage period: 0.09, species: 0.007, treatment: 0.007										
Smell	whiting	W	3.00	2.61	2.50	2.26	1.91	2.45 c	2.45 a	Whole: 2.36 c
		G	3.00	2.51	2.37	2.32	2.00	2.44 d		Gutted: 2.45 a
		F	3.00	2.51	2.41	2.38	1.96	2.45 c		Fillet: 2.42 b
	gray mullet	W	2.91	2.51	2.32	2.01	1.90	2.33 g	2.44 b	
		G	2.90	2.81	2.45	2.15	2.00	2.46 b		
		F	2.90	2.86	2.51	2.26	2.11	2.52 a		
	anchovy	W	3.00	2.61	2.44	1.81	1.71	2.31 h	2.35 c	
		G	3.00	2.57	2.30	2.07	1.84	2.35 f		
		F	3.00	2.66	2.51	1.91	1.81	2.38 e		
	mean		2.97 a	2.62 b	2.42 c	2.13 d	1.91 e	general mean: 2.41		
LSD values ($p < 0.05$), storage period: 0.03, species: 0.004, treatment: 0.004										
Muscle	whiting	W	2.91	2.71	2.51	2.14	2.01	2.45 e	2.52 b	Whole: 2.48 c
		G	2.81	2.83	2.64	2.39	2.11	2.55 d		Gutted: 2.52 a
		F	2.81	2.80	2.64	2.36	2.16	2.55 d		Fillet: 2.49 b
	gray mullet	W	3.00	2.80	2.70	2.39	2.01	2.58 b	2.58 a	
		G	3.00	2.80	2.79	2.26	2.00	2.57 c		
		F	3.0	2.81	2.76	2.39	2.03	2.59 a		
	anchovy	W	2.90	2.81	2.64	1.88	1.86	2.42 g	2.39 c	
		G	2.83	2.81	2.65	2.06	1.80	2.43 f		
		F	2.80	2.40	2.39	2.06	2.01	2.33 h		
	mean		2.89 a	2.75 b	2.63 c	2.21 d	2.00 e	general mean: 2.50		
LSD values ($p < 0.05$), storage period: 0.001, species: 0.001, treatment: 0.002										

Table 1 – cont.

1	2	3	4	5	6	7	8	9	10	11
Structure (chew-ing)	whiting	W	2.91	2.81	2.59	2.34	2.16	2.56 cd	2.56 b	Whole: 2.53 a
		G	2.81	2.81	2.59	2.51	2.21	2.58 abc		Gutted: 2.49 b
		F	2.81	2.71	2.70	2.34	2.16	2.54 d		Fillet: 2.50 b
	gray mullet	W	3.00	2.96	2.61	2.51	1.91	2.59 d	2.59 a	
		G	3.00	2.90	2.68	2.43	1.86	2.57 bc		
		F	3.00	2.93	2.76	2.51	1.81	2.60 a		
	anchovy	W	2.91	2.76	2.59	2.0	1.96	2.44 e	2.37 c	
		G	2.81	2.61	2.59	1.84	1.81	2.33 f		
		F	2.81	2.61	2.51	1.93	1.88	2.34 f		
	mean		2.89 a	2.79 b	2.62 c	2.26 d	1.97 e	general mean: 2.51		
LSD values ($p < 0.05$), storage period: 0.09, species: 0.007, treatment: 0.007										
Taste	whiting	W	3.00	2.81	2.59	2.34	2.16	2.58 b	2.59 a	Whole: 2.43 c
		G	3.00	2.59	2.56	2.51	2.21	2.57 b		Gutted: 2.52 a
		F	3.00	2.84	2.80	2.34	2.16	2.63 a		Fillet: 2.49 b
	gray mullet	W	2.90	2.62	2.33	2.17	1.95	2.39 d	2.46 b	
		G	2.90	2.70	2.51	2.34	2.00	2.49 c		
		F	2.91	2.56	2.76	2.17	2.11	2.50 c		
	anchovy	W	3.00	2.59	2.56	2.00	1.51	2.33 e	2.39 c	
		G	3.00	2.76	2.46	2.39	1.86	2.49 c		
		F	3.00	2.56	2.36	1.96	1.81	2.34 e		
	mean		2.97 a	2.67 b	2.54 c	2.24 d	1.97 e	general mean: 2.48		
LSD values ($p < 0.05$), storage period: 0.09, species: 0.007, treatment: 0.007										

T – treatment, W – whole, G – gutted, F – fillet.

Over 2.7 and 2.7 very good (first quality), between 2-2.7 good (second quality), between 1-2 average (third quality), between 0-1 spoiled [Kruger 1989].

was found in fillet while maximum smell and muscle values found in gutted fish (Table 1, Fig. 1). Lakshmanan et al. [1990], reported that from 36 to 44 weeks frozen samples whole and fillet were still acceptable quality but showed loss of characteristic flavours and texture in rock cod (*Epiephelus* spp.) at –20°C. Our study showed similar results and end of ninth month treatments were acceptable quality, but there was significant decline ($p > 0.05$) in all sensorial quality. Tokur et al. [2006] reported that the scores did not exceed acceptable levels of filleted Trout (*Oncorhynchus mykiss* W., 1792) during frozen storage (–18°C) for 12 month. Differences may be result from differences between fish species. Köse et al. [2001] determined that acceptable quality of anchovy only lasted three months of frozen storage at –18°C. This study important because it shows that decline of storage temperature provides extent of storage time of fish.

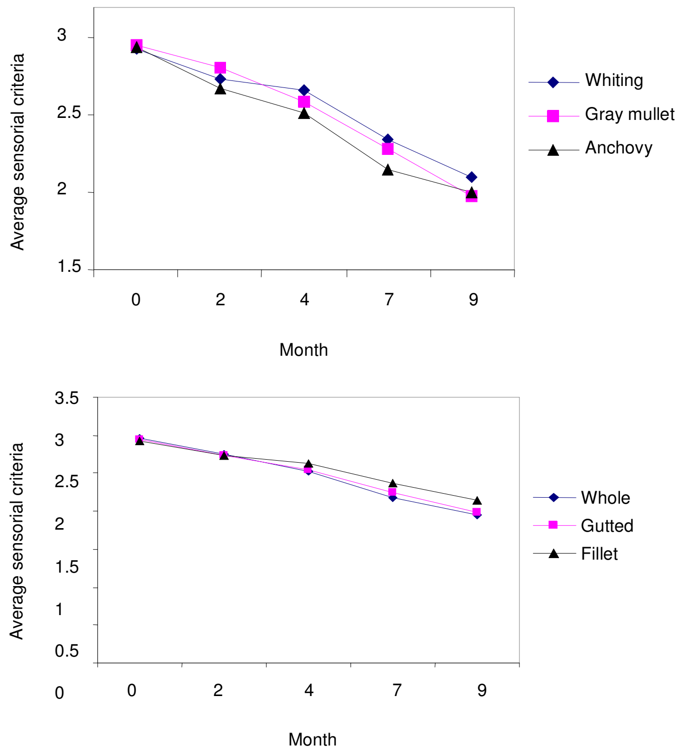

Fig. 1. Average sensorial criteria of three fish species and treatments during storage period

According to storage period, a decline was observed in the pH values of fish species. Differences between the species and treatments were significant ($p < 0.05$) in terms of pH value. Suarez et al. [2002] reported that storage time caused significant differences in pH value of frozen sardines (*Sardinella aurita*). Simeonidou et al. [1997] were found that the pH values significantly different in frozen whole and fillet of horse mackerel (*Trachurus trachurus*) and similar with us. The highest pH value was obtained in whiting comparing with other species. However, when the treatments were compared, the highest pH value was found in fillets (6.56) and the lowest pH (6.50) value was found gutted fish (Table 2, Fig. 2). Olgunoğlu et al. [2002] found that pH value increased from 6.80 to 7.02 in frozen pike perch fillets at –20°C throughout 7 months, however, Lakshmanan et al. [1990] reported that there was a decline in pH after 36 weeks in whole, gutted and fillet frozen rock cod (*Epinephelus* spp.) at –20°C. Catfish muscle pH after frozen storage for various times was not significantly different from fresh muscle pH [Eun et al. 1994]. In our research, a slightly decrease was observed in fish species throughout 9 months storage. Similarly, Tokur et al. [2006] found that the pH value of filleted Trout decreased significantly during frozen storage ($p < 0.05$).

Table 2. Changes in pH, TVB-N, TMA, TBA and peroxide values of three fish species during storage period

Quality criteria	Fish species	T	Storage period, month					Means		
			0	2	4	7	9	mean	mean	mean
1	2	3	4	5	6	7	8	9	10	11
pH	whiting	W	6.94	6.93	6.76	6.81	6.85	6.86 a	6.83 a	Whole: 6.52 b
		G	6.94	6.70	6.71	6.82	6.92	6.83 b		Gutted: 6.50 c
		F	6.94	6.80	6.73	6.77	6.83	6.80 c		Fillet: 6.56 a
	gray mullet	W	6.49	6.49	6.24	6.34	6.28	6.37 e	6.40 b	
		G	6.48	6.22	6.32	6.76	6.27	6.33 h		
		F	6.48	6.57	6.45	6.56	6.42	6.50 d		
	anchovy	W	6.50	6.39	6.29	6.29	6.30	6.35 f	6.36 c	
		G	6.51	6.39	6.30	6.25	6.28	6.34 g		
		F	6.51	6.48	6.29	6.32	6.29	6.37 e		
	mean		6.64 a	6.55 b	6.45 d	6.50 c	6.49 c	general mean: 6.52		
LSD values ($p < 0.05$), storage period: 0.09, species: 0.007, treatment: 0.007										
TVB-N	whiting	W	12.70	13.65	16.54	16.78	24.14	16.76 d	17.23 c	Whole: 19.02
		G	13.39	16.52	17.36	18.86	18.41	16.91 d		Gutted: 20.07
		F	17.47	16.14	17.26	19.27	19.98	18.02c d		Fillet: 19.89
	gray mullet	W	15.20	12.73	18.78	24.95	25.28	19.39b c	19.20 b	
		G	15.89	19.89	21.12	23.93	21.27	20.42 b		
		F	16.45	19.99	14.83	17.83	19.85	17.79 cd		
	anchovy	W	16.14	20.37	18.71	19.45	29.19	20.92 b	22.55 a	
		G	17.33	17.41	22.96	23.06	33.70	22.89 a		
		F	17.77	23.59	23.55	23.47	30.92	23.86 a		
	mean		15.81 d	17.81 c	19.01 c	20.84 b	24.83 a	general mean: 19.66		
LSD values ($p < 0.05$), storage period: 1.363, species: 1.055, treatment: ns										
TMA mg/100 g	whiting	W	1.75	3.32	2.63	2.61	3.48	2.56 d	2.51 b	Whole: 3.15 a
		G	1.76	1.55	3.01	2.85	3.29	2.49 d		Gutted: 2.60 b
		F	1.75	1.94	2.22	2.80	3.76	2.49 d		Fillet: 2.66 b
	gray mullet	W	2.03	3.35	2.30	2.51	2.86	2.61 d	2.40 b	
		G	2.31	2.75	2.49	2.53	2.04	2.42 de		
		F	2.62	2.51	2.00	1.77	1.89	2.16 e		
	anchovy	W	2.54	2.49	5.12	4.92	6.38	4.29 a	3.50 a	
		G	2.48	2.31	2.70	2.89	4.06	2.89 c		
		F	2.60	2.75	3.20	3.25	4.84	3.33 b		
	mean		2.20 d	2.44 c	2.85 b	2.90 b	3.62 a	general mean: 2.80		
LSD values ($p < 0.05$), storage period: 0.195, species: 0.151, treatment: 0.151										

Table 2 – cont.

1	2	3	4	5	6	7	8	9	10	11
TBA	whiting	W	0.16	0.17	0.33	0.47	0.54	0.33 cd	0.35 b	Whole: 1.18 a
		G	0.17	0.17	0.32	0.43	0.45	0.31 cd		Gutted: 0.97 b
		F	0.17	0.44	0.36	0.50	0.61	0.41 c		Fillet: 0.98 b
	gray mullet	W	0.09	0.09	0.26	0.57	0.79	0.36 cd	0.24 c	
		G	0.09	0.17	0.19	0.33	0.34	0.23 de		
		F	0.10	0.10	0.12	0.13	0.16	0.12 e		
	anchovy	W	0.17	1.25	2.04	4.00	6.80	2.85 a	2.55 a	
		G	0.22	1.71	2.87	2.68	4.41	2.38 b		
		F	0.21	1.68	2.15	3.26	4.75	2.41 b		
	mean		0.15 e	0.64 d	0.96 c	1.37 b	2.10 a	general mean: 1.04		
LSD values ($p < 0.05$), storage period: 0.104, species: 0.081, treatment: 0.81										
PV meQO$_2$/kg	whiting	W	–	–	1.87	1.78	2.41	1.21 de	1.34 b	Whole: 1.77
		G	–	–	2.41	2.05	2.37	1.37 d		Gutted: 1.62
		F	–	–	1.60	2.78	2.84	1.45 d		Fillet: 1.76
	gray mullet	W	–	–	2.40	2.67	3.83	1.78 c	1.16 c	
		G	–	–	1.12	1.08	1.54	0.75 f		
		F	–	–	1.65	1.20	1.91	0.96 ef		
	anchovy	W	–	–	2.00	2.20	7.29	2.30 b	2.35a	
		G	–	–	2.11	3.00	8.58	2.74 a		
		F	–	–	1.87	1.78	6.41	2.01 c		
	mean		–	–	2.00 b	2.20 b	4.13 a	general mean: 1.72		
LSD values ($p < 0.05$), storage period: 0.199, species: 0.154, treatment: ns										

T – treatment, W – whole, G – gutted, F – fillet.

TVB-N value, 25 mg/100 g very good, 30 mg/100 g good, 35 mg/100 g can be marketed, 35-100 mg/100 g spoiled [Gökalp 1993].

TMA must be between 1 mg/100 g and 8 mg/100 g. Water products having over 8 mg/100 g TMA values are spoiled [Varlık at al. 1993].

TBA value must be between 3 and 5 in a good water product. Limit value of consumption is between 7 and 8 [Schomüller 1969].

PV must be under 2 in excellent seafood and not exceed 5 in consumed seafood products [Schormüller 1969, Ludoff and Meyer 1973].

TVB-N is used for determination of the spoilage level of fish during the storage period [Oehlenschlager 1981]. The level of 35 mg/100 g has been considered the upper limit, above which fishery products are considered spoiled [Ludoff and Meyer 1973, Schormüller 1969]. TVB-N values of three fish species increased during the storage period. According to the TVB-N values, the differences between the fish species were significantly important ($p < 0.05$) whereas treatments did not show significant differences. During the storage period, according to TVB-N value whiting kept its freshness better than gray mullet and anchovy (Table 2 and Fig. 2). The lowest TVB-N value

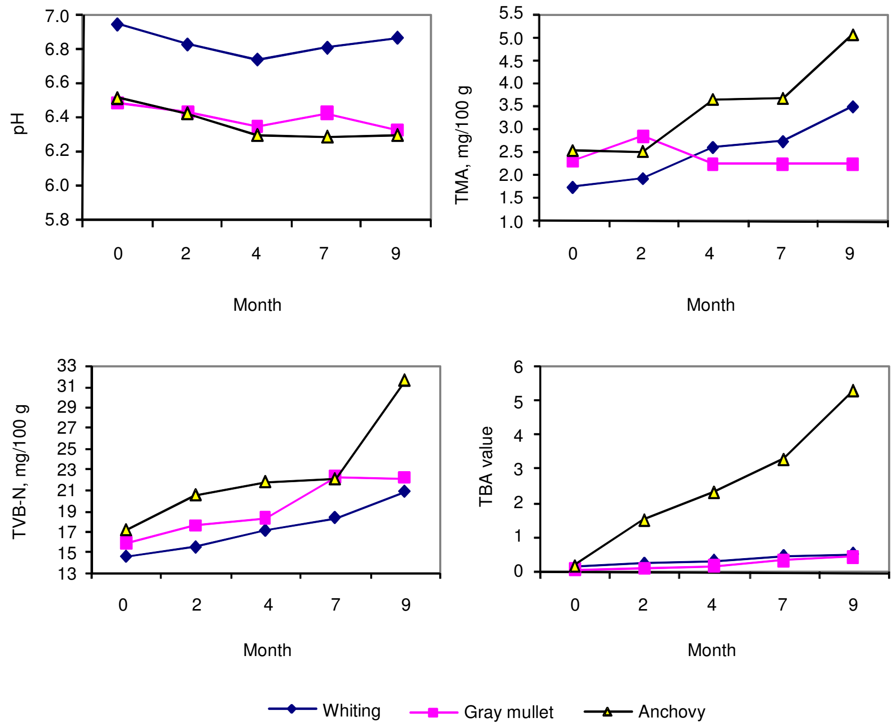

Fig. 2. pH, TVB-N, TMA and TBA mean values of three species during storage period

(17.23 mg/100 g) was determined in whiting, the highest value in anchovy (22.55 mg/100 g). Anchovy showed more increase than the other species at 9th month of storage period. According to TVB-N value, while whiting and gray mullet were very good quality, anchovy was within acceptable limit end of storage period. Pons-Sanchez--Cascado et al. [2005] determined the levels of TVBN values for fresh anchovies ranging from 3.79 ±0.30 mg/100 g to 13.7 ±0.46 mg/100 g and lower our findings. Lakshmanan et al. [1990] found that after 52 weeks, TVB-N values (18.2 mg/100 g) in fillet rock cod (*Epinephelus* spp.) frozen at –20°C were the lowest from the all frozen fish (29.4 mg/100 g). Our results were similar with findings of Simeonidou et al. [1997]. Kemal et al. [1996] reported that TVB-N increased from 5.60 to 27.20 mg/100 g in frozen hilsa fish at –20°C throughout 75 days. The other researchers stated that TVB--N value was 4.19 at the beginning but increased to 14.90 at the end of 7th month of storage in pike fish at –18°C [Olgunoğlu et al. 2002]. However, in this study, a relatively smaller increase (from 15.81 mg/100 g average value to 24.83 mg/100 g) determined as to this finding. This lower increasing in TVB-N value may result from lower storage temperature.

TMA accumulation is a result of bacterial breakdown of TMAO and this occurs to a significant level only during logarithmic phase of microbial growth [Huss 1988]. Throughout nine-month storage period, there was an increase in TMA values of whiting and anchovy, however there was a decline gutted and filleted gray mullet. The differences between whiting and gray mullet were not significant ($p < 0.05$). On the other hand, anchovy was significantly different from the other two species. There was no significant difference in TMA values of fillet and gutted while TMA values in whole fish significantly changed in all species (Table 2, Fig. 3). Anderson [2008] reported the levels of TMA increased in all fish samples throughout the day, with the greatest increase occurring in Zubaidi, which increased from 11.3 ±0.1 mg/100 g in the morning to 17.3 ±2.5 mg/100 g in the evening, an increase of 53%. In this study the TMA value of fish species still acceptable end of 9th month of storage. Therefore this study shows that temperature is very important in increasing of TMA value. Natseba et al. [2005] reported that freezing inhibits bacterial activity, it is expected that it would also inhibit TMA accumulation. Sotelo et al. [1995] observed that little change occurred at –5°C and none at –12 and –20°C in frozen hake (*Merluccis merluccis*). Yamagata and Low [1995], found that TMA value of Banana shrimp (*Penaeus merguiensis*) did not change during the 6 month storage. Some research explained that at lower temperatures of storage, no changes were found [Babbitt et al. 1972, Mackie and Thompson 1974]. Our study indicated that species is important for increasing the TMA value. Some researchers [Le Blanch et al. 1988, Rehbein 1988] also found changes in TMA-N during storage

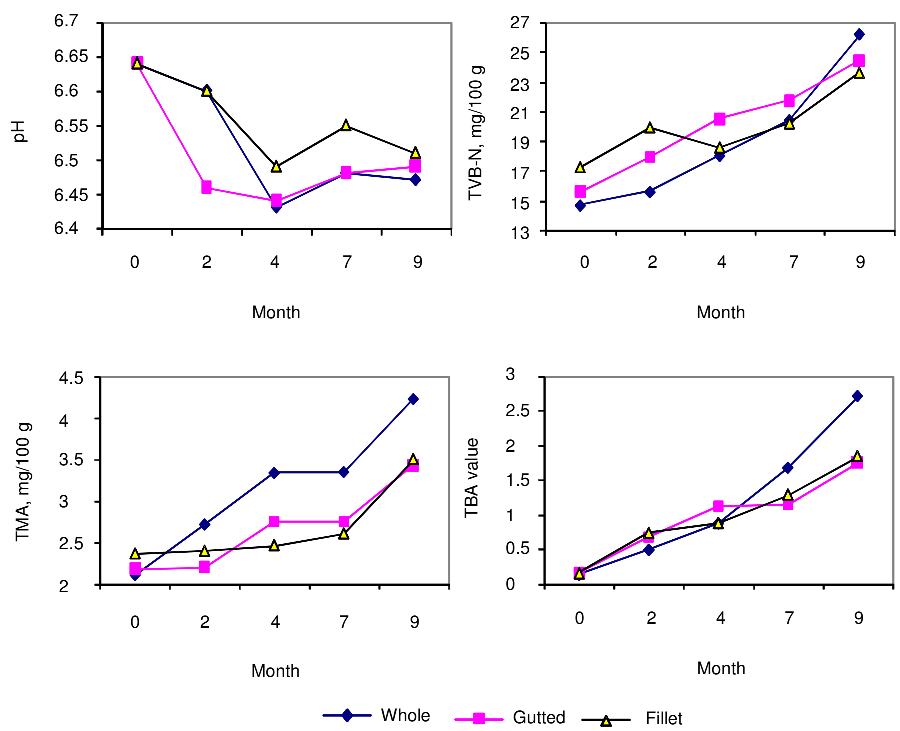

Fig. 3. pH, TVB-N, TMA and TBA mean value of treatment during storage period in three fish species

of cod (*Gadus morhua*) and hake (*Merluccis merluccis*) at –12 and –8°C respectively. Lakshmanan et al. [1990] determined that TMA value of frozen rock cod (*Epinephelus* spp.) fillet was nil at the beginning but increased to 4.2 mg/100 g at the end of storage. Increasing of TMA value of whiting and anchovy results were in agreement with earlier results.

The TBA values of fish species increased up to 9th month, depending upon storage time. It has been proposed that a maximum TBA value (indicating the good quality of the fish frozen, chilled or stored with ice) is 5 mg malonaldehyde/kg, while the fish may be consumed up to a level of 8 mg malonaldehyde/kg in TBA value [Schormüller 1969]. In this study differences between species was found significantly important ($p < 0.05$) and TBA value of anchovy was significantly increased (Table 2). Conclusions concerned the peroxide values and were found to be parallel to TBA values in fish. While the TBA and peroxide values in anchovy showed significant increase during the storage period, acceptable limits expired at the end of 9th month. Along the frozen storage time, a progressive peroxide formation ($p < 0.05$) was observed in all species after the second month. On the other hand, TBA values of filleted fish (0.97 b) were not found significantly different from gutted (0.98 b) while whole fish was found to be significantly higher (1.18 a). In addition, according to peroxide values significant differences were not found among the treatments. Namulema et al. [1999] recorded that TBA value was extremely low in frozen Nile perch at –27°C. Other research found that TBA value of frozen pike perch (*Sander lucioperca*) fillets were changed from 0.0208 to 0.0533 mg malonaldeyde [Olgunoğlu et al. 2002]. The decline in TBA values was probably due to the reaction of malonaldehyde with various other constituents of muscle as reported by Bidlack et al. [1972]. Aubourg [1999], reported that the PV at –30°C was only slightly different during the fist 9 months of storage; a sharp increase at month 12 in blue whiting. Previous studies proved that PV value of frozen oil sardine mince was increased from 4.12 to 18.63 meq/kg [Verma et al. 1995], from 5.53 meq/kg to 16.2 meq/kg in frozen hilsa [Kamal et al. 1996] at –20°C for 75 days. Losada et al. [2007] determined that PV and TBA value of slurry iced sardine from 1.50 to 7.57 and from 0.26 to 1.04 respectively end of four month storage at –20°C. In our research, although whiting and G. mullet had consumed limits, anchovy had expired limit end of 9th month according to PV value.

CONCLUSIONS

In the study, it is necessary to state that, whiting and gray mullet had better quality than anchovy during 9-month storage period according to sensorial and chemical quality criteria. Higher oil content of anchovy may be promoting the spoilage of fish and keep on oxidation of oil even at low temperature affected the sensorial and chemical quality as negative. According to chemical criteria anchovy acceptable at 7th month but exceed consumption limits at 9th month from the point of PV and lost freshness concerning the other chemical criteria. Anchovy had second quality at 7th and third quality at 9th month as to sensory evaluation. Although whiting and gray mullet had acceptable limits at 9th month as to chemical criteria, whiting better quality than the gray mullet according to sensorial criteria. In addition, related to treatments, there were significant differences found in whole fish however, there were no significant differences between gutted and filleted fish within most of the criteria. Gutted and filleted fish were found to be better than whole fish end of storage as to general chemical means.

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ZMIANY JAKOŚCI NIEPATROSZONYCH, PATROSZONYCH I FILETOWANYCH RYB TRZECH GATUNKÓW (*GADUS EUXINUS*, *MUGIL CEPHALUS*, *ENGRAULIS ENCRASICHOLUS*) PRZECHOWYWANYCH W STANIE ZAMROŻONYM (–26°C)

Streszczenie. Celem badań była ocena zmian jakości niepatroszonych, patroszonych i filetowanych próbek trzech gatunków ryb: witlinka (*Gadus euxinus*), cefala (*Mugil cephalus*) i sardeli (*Engraulis encrasicholus*) przechowywanych w stanie zamrożonym (–26°C). Najniższe oceny jakości sensorycznej uzyskały próbki sardeli. Najlepszymi ocenami utrzymania świeżości, mierzonymi za pomocą wyróżników chemicznych, charakteryzowały się próbki witlinka. Były one lepsze niż u cefala i sardeli. Najmniejszą wartość TVB-N (17,23 mg/100 g) otrzymano w wypadku witlinka, a najwyższą (22,55 mg/100 g) dla sardeli. Najwyższa wartość TMA (3,5 mg/100 g) wyróżniała sardelę. Wartości TBA rosły aż do dziewiątego miesiąca przechowywania prób i były zależne od gatunku ryby. Różnice te były statystycznie istotne i najwyższe wartości TBA (2,55) uzyskano dla sardeli. Chociaż wartości TBA i liczby nadtlenkowe dla sardeli były wyższe niż dla pozostałych gatunków ryb, to dopuszczalny limit osiągały one dopiero pod koniec dziewiątego miesiąca ich przechowywania. Ryby filetowane odznaczały się lepszą barwą, natomiast patroszone miały lepszy zapach, smak i strukturę.

Słowa kluczowe: sardela (*Engraulis encrasicholus*), witlinek (*Gadus euxinus*), cefal (*Mugil cephalus*), przechowywanie w stanie zamrożonym

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