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Fatty Acids Changes during Frozen Storage in Several Fish Species from South Caspian Sea

S. Pirestani[1], M. A. Sahari[1*], and M. Barzegar[1]

ABSTRACT

Changes in the fatty acid content, during frozen storage at -24°C of Caspian kutum (*Rutilus frisii kutum*), golden grey mullet (*Liza aurata*), common carp (*Caprinus carpio*), pike perch (*Sander lucioperca*) and common kilka (*Clupeonella cultiventris caspia*), caught from south Caspian Sea were studied in the present work. Changes in saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs), ecosapentaenoic acid plus docosahexaenoic acid/palmitic acid (EPA+DHA/C16), *n*3 PUFA/*n*6 PUFA (*n*3/*n*6) and polyunsaturated fatty acids/saturated fatty acids (PUFA/SFA) were investigated during a six month period. Results indicated that due to the decrease in unsaturated fatty acids particularly PUFAs (9.25-23.03%), and lower ratios of *n*3/*n*6 (2.02-6.06), EPA+DHA/C16 (polyene index; 0.21-0.65) and PUFA/SFA (0.18-0.64) the poststorage nutritional values of these species significantly decrease.

Keywords: Caspian Sea, Fatty acid profile, Fish, Frozen storage, PUFA.

INTRODUCTION

Recent studies have clearly shown the importance of polyunsaturated fatty acids' (PUFAs) nutritional values for human health (Kinsella, 1986). Fish is one of the richest sources of dietary supply of these fatty acids. Polyunsaturated fatty acids (especially the *n*3 and *n*6 PUFA) have been found out as the essential fatty acids with curative and/or preventive effects on cardiovascular disease, cancers and neurodevelopment in infants (Conner, 1997). Experimental data indicate that the consumption of fish oil containing PUFA prevents and/or cures arterial hypertention (Millar and Waal-Manning, 1992), colon and prostate cancer (Marchioli, 2001; 2002), human breast cancer growth (Rose and Connoll, 1993), inflammatory diseases (Belluzi *et al.,* 1993; James and Cleland, 1996), asthma (Dry and Vincent, 1991; Hodge *et al.,* 1996), and disorders of the immune system (Levine and Labuza, 1990). Besides, ecosapentaenoic acid (EPA, C20:5*n*3) and docosahexaenoic acid (DHA, C22:6*n*3), found only in fish and sea foods, play a vital role in the development and functioning of the nervous system (brain), photoreception (vision), and the reproductive system (Alasalvar *et al.,* 2002; Sidhu, 2003; Skonberg and Perkins, 2002; Tapiero *et al.,* 2002).

Freezing and frozen storage have been largely employed to retain fish sensory and nutritional properties (Erikson, 1997). A degradation of PUFA induced by auto oxidation during frozen storage of fish oils especially in fatty fish leads to the formation of volatiles associated with rancidity (Pazos *et al.,* 2005), and therefore, it is both lipid and PUFA content of fish that play a deciding role in its health benefits. Although PUFA content constitutes varied amounts body constitutes among fish species, little

[1] Department of Food Technology, College of Agriculture, University of Tarbiat Modares, P. O. Box: 14115-336, Tehran, Islamic Republic of Iran.
[*] Corresponding author, e-mail: sahari@modares.ac.ir

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attention has been paid to and little information obtained regarding changes in fatty acids in different species during the frozen storage process and priod.

As evident from the available literature, there is no available information about the changes of fatty acid contents of major fish species from the Caspian Sea during the frozen storage. The objective of the present study was to investigate the changes in fatty acid and lipid contents of some commercially important fish species caught from South Caspian Sea.

MATERIALS AND METHODS

Fish Species

The fish species were studied Caspian kutum (*Rutilus frisii kutum*), golden grey mullet (*Liza aurata*), common carp (*Caprinus carpio*), pike perch (*Sander lucioperca*) and common kilka (*Clupeonella cultiventris caspia*). These species (in the same genus, weight and size; November 2006; 25-30 specimens) were purchased from three different harbors (Anzalii, Babolsar and Torkaman located in the Northern parts of Iran, representing the West, South and East of South Caspian sea, respectively). The weights and lengths of these species were 60±5 g and 10±2 cm, 840±10 g and 62±3 cm, 760±10 g and 48±2 cm, 830±15 g and 40±3 cm, and 430±15 g and 30±2 cm, respectively. Fish specimens were then transported on ice to the laboratory (Department of Food Technology, College of Agriculture, Tarbiat Modares University) during the first 5 hour after having been caught. Upon arrival in the laboratory, the fish specimens were neither headed nor gutted, rather, they were cut into pieces and the edible sections of each and any species from each harbor mixed. The specimens were, then, packaged in individually celled polyethylene bags in term to be frozen at -30ºC. The specimens were stored under a freezing temperature of -24±2ºC. The Analysis of the frozen fish specimens was carried out after a lapse of 1, 2, 3, 4, 5 and 6 months of the storage.

Lipid Analysis

The fraction was extracted by the method of Bligh and Dyer (1959). Quantification results were expressed as g lipids 100 g^{-1} of wet muscle.

Fatty acid Analysis

The lipids were saponified and esterified for the fatty acid analysis according to the method reported by Metcalfe *et al.* (1966). The fatty acid methyl esters (FAMEs) were analyzed on a Unicom model 4600 gas chromatograph (GC) with a flame ionization detector (FID). The esters were separated on a 30 m×0.22 mm i.d. wall-coated open tubular fused-silica capillary column (30 m×0.25 mm×0.22 µm film thickness, BPX70; SGE, Melbourne, Australia) at isothermal temperature of 190°C with helium as the carrier gas (50 psi) being used to separate the fatty acids. A splitless injector (1.2 µL injection) was also used at 240°C and a FID at 250°C during the separation process. The peaks were identified based on their retention times using fatty acid methyl ester standards and all samples run in triplicate. An internal standard method (C15:0) was employed to calculate the fatty acid composition.

Statistical Analysis

The data were presented as Mean±Standard deviation (SD) and were subjected to the analysis of variance (ANOVA). The significant mean was compared by the least significant difference (LSD) at α= 1% level. The correlations were estimated to determine the relationship between the storage time and lipid damage

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indices. The results are presented as the mean of three determinations. In the tables, the statistical significance is indicated by appropriate letters within the tables.

RESULTS AND DISCUSSION

Table 1 shows the lipid content of the fish species which ranged from 1.97% for pike perch to 10.23% for common kilka, also classified as lean or high fat fish (< 2% lean, 2-4% medium, 4-8% fat and >10% high-fat). Based on the lipid content, golden grey mullet, common carp and pike perch were categorized as lean and medium fat fish with lipid content less than 5% (Bennion, 1997) while Caspian kutum and common kilka were classified as fat and high-fat fish. According to Feeley *et al.* (1972) low-fat fish species have higher water content and, as a result, their flesh is broghter in color. Lipid deterioration is the main cause of low shelf life of fatty fish due to progressive oxidation and enzymatic hydrolysis of unsaturated fatty acids in them (Sarma *et al.,* 2000).

SFAs, MUFAs, PUFAs, EPA+DHA/C16 (polyene index) and *n*3/*n*6 changes during the frozen storage are summarized in Table 2. In all the fish species, the distribution of fatty acids was as SFAs> MUFAs> PUFAs. Furthermore, PUFAs were more than SFAs (SFAs< PUFAs+ MUFAs), while during frozen storage polyunsaturated fatty acids decreased as compared with the saturated fatty acids.

Among SFAs, those occurring in the highest proportions during the storage period were palmitic (C16:0) and stearic (C18:0) acids. However, a significant difference was observed among the SFAs content during frozen storage except in the case of the first month of storing. As for carp this exception lasted for two months.

Oleic acid (C18:1*n*9) was the main fatty acid among the MUFAs in all the fish species. Except for months 5 and 6 in kutum and kilka, and months 3, 4, 5 and 6 in mullet, there was no significant difference among the MUFAs content during the storage priod. In addition, no significant difference could be observed among the MUFAs content in carp and pike perch. It seems that the MUFAs content in all the species are approximately fixed.

The flesh of the five fish species contained high concentrations of *n*3 PUFAs including ecosapentaenoic acid (EPA, C20:5*n*3), docosahexaenoic acid (DHA, C22:6*n*3) as the major components. EPA is the most important essential fatty acid of the *n*3 series in human diet because it is the precursor to the 3-series ecosanoids (Chen *et al.,* 1995). The highest EPA was found in mullet, accounting for 7.53% of its total fatty acids. It has been reported that DHA decreases the concentration of low density lipoprotein cholesterol in plasma (Child *et al.,* 1990). The high proportion of DHA was found in

Table 1. Lipid content of five fish species from South Caspian Sea during frozen storage (-24°C) [a, b].

Month of storage	Caspian kutum	Golden grey mullet	Common carp	Pike perch	Common kilka
0	6.71 ± 0.01a	4.93 ± 0.03a	3.61 ± 0.03a	1.97 ± 0.05a	10.23 ± 0.09a
1	6.39 ± 0.07b	3.66 ± 0.09b	3.27 ± 0.08b	1.24 ± 0.03c	10.46 ± 0.08a
2	4.78 ± 0.07c	3.74 ± 0.08b	3.26 ± 0.07b	1.36 ± 0.03b	9.17 ± 0.18bc
3	4.81 ± 0.04c	3.34 ± 0.17c	2.92 ± 0.06c	1.13 ± 0.02d	9.42 ± 0.09b
4	3.81 ± 0.10d	2.68 ± 0.06d	3.08 ± 0.18bc	1.13 ± 0.02d	8.97 ± 0.21c
5	3.74 ± 0.08d	2.45 ± 0.08d	2.49 ± 0.03d	1.17 ± 0.17cd	8.57 ± 0.24d
6	2.96 ± 0.01e	2.19 ± 0.14e	1.73 ± 0.05e	1.15 ± 0.04cd	7.25 ± 0.03e

[a] Data is expressed as Mean±SD (n= 3).
[b] Value in the same column with different letters within a same strain are significantly different at a level of 0.01.

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Table 2. Changes in fatty acids content[a] of five fish species from South Caspian Sea during frozen storage (-24°C) [h, i].

Species	ST [a]	SFA [b]	MUFA [c]	PUFA [d]	EPA+DHA/ C16 [e]	*n*3/*n*6 [f]	PUFA/SFA [g]
Caspian kutum	0	28.99 ± 0.23f	56.25 ± 0.62a	14.76 ± 0.38a	0.57 ± 0.02a	4.54 ± 0.39ab	0.51 ± 0.01a
	1	29.71 ± 0.55ef	56.33 ± 0.58a	13.94 ± 0.13c	0.52 ± 0.02b	4.96 ± 0.39a	0.47 ± 0.01b
	2	30.75 ± 0.47e	56.07 ± 0.23a	13.21 ± 0.31c	0.47 ± 0.04c	4.44 ± 0.42abc	0.43 ± 0.01c
	3	31.84 ± 0.32d	55.48 ± 0.45ab	12.71 ± 0.06c	0.42 ± 0.01d	3.72 ± 0.54bcd	0.40 ± 0.00d
	4	33.73 ± 0.20c	55.25 ± 0.40ab	10.94 ± 0.87d	0.33 ± 0.01e	3.15 ± 0.54d	0.32 ± 0.01e
	5	36.02 ± 0.53b	54.34 ± 0.52bc	9.72 ± 0.21e	0.28 ± 0.02f	3.36 ± 0.21d	0.27 ± 0.01f
	6	37.13 ± 0.57a	53.55 ± 0.49c	9.32 ± 0.29e	0.25 ± 0.01f	3.46 ± 0.40cd	0.25 ± 0.01f
Golden grey mullet	0	41.06 ± 0.80e	44.72 ± 0.78a	14.22 ± 0.67a	0.41 ± 0.03a	4.72 ± 0.27a	0.35 ± 0.02a
	1	42.21 ± 0.32de	44.17 ± 0.09a	13.6 ± 0.24ab	0.38 ± 0.01ab	4.39 ± 0.42a	0.32 ± 0.01ab
	2	43.09 ± 0.14d	43.96 ± 0.16ab	13.03 ± 0.20bc	0.36 ± 0.01bc	4.44 ± 0.46a	0.30 ± 0.00bc
	3	44.54 ± 0.71c	43.01 ± 0.31b	12.28 ± 0.46c	0.33 ± 0.01cd	4.28 ± 0.25ab	0.29 ± 0.01c
	4	45.61 ± 0.07c	42.94 ± 0.32b	11.45 ± 0.44d	0.31 ± 0.01d	4.24 ± 0.39ab	0.25 ± 0.01d
	5	48.05 ± 0.08b	41.65 ± 0.14c	10.08 ± 0.25e	0.25 ± 0.01e	3.54 ± 0.20bc	0.21 ± 0.00e
	6	49.89 ± 0.66a	41.05 ± 0.66c	9.25 ± 0.02e	0.21 ± 0.00f	3.05 ± 0.17c	0.18 ± 0.00e
Common carp	0	36.04 ± 1.13c	48.21 ± 2.30a	15.75 ± 1.26a	0.52 ± 0.02a	3.35 ± 0.16a	0.44 ± 0.02a
	1	36.65 ± 1.63c	47.68 ± 0.60a	15.44 ± 0.57a	0.50 ± 0.03a	3.06 ± 0.27ab	0.42 ± 0.03a
	2	37.66 ± 0.84bc	47.41 ± 1.29a	15.05 ± 0.75ab	0.46 ± 0.04a	2.91 ± 0.02ab	0.40 ± 0.02ab
	3	39.02 ± 0.76ab	47.68 ± 1.12a	14.14 ± 0.73ab	0.40 ± 0.01b	2.61 ± 0.13bc	0.36 ± 0.01bc
	4	39.53 ± 0.23ab	47.19 ± 0.64a	13.29 ± 0.13bc	0.36 ± 0.02b	2.50 ± 0.42bc	0.34 ± 0.00cd
	5	40.68 ± 0.99a	47.46 ± 0.19a	11.83 ± 1.02cd	0.30 ± 0.03c	2.25 ± 0.17c	0.29 ± 0.03de
	6	41.00 ± 0.62a	47.23 ± 1.50a	11.30 ± 0.70d	0.28 ± 0.01c	2.09 ± 0.21c	0.27 ± 0.01e
Pike perch	0	35.99 ± 0.58e	40.99 ± 0.82	23.03 ± 0.26a	0.57 ± 0.01a	2.10 ± 0.08	0.64 ± 0.01a
	1	37.45 ± 1.20de	40.63 ± 1.01	21.80 ± 0.35ab	0.51 ± 0.05ab	2.03 ± 0.24	0.58 ± 0.02a
	2	39.45 ± 0.22cd	39.78 ± 1.05	19.98 ± 1.00bc	0.47 ± 0.03ab	2.52 ± 0.28	0.51 ± 0.02b
	3	39.78 ± 1.60bc	41.08 ± 2.09	19.16 ± 1.11c	0.41 ± 0.04bc	2.02 ± 0.49	0.48 ± 0.03bc
	4	40.84 ± 0.42bc	41.20 ± 0.81	18.22 ± 0.69c	0.40 ± 0.04c	2.44 ± 0.73	0.45 ± 0.01bc
	5	41.93 ± 0.66b	40.04 ± 1.53	18.00 ± 1.06c	0.38 ± 0.06cd	2.33 ± 0.73	0.43 ± 0.02c
	6	45.30 ± 1.14a	39.27 ± 0.55	15.32 ± 1.77d	0.29 ± 0.03d	2.20 ± 0.24	0.34 ± 0.05d
Common kilka	0	36.88 ± 0.65d	43.68 ± 0.82a	19.43 ± 1.10a	0.65 ± 0.07a	6.60 ± 1.38a	0.53 ± 0.04a
	1	38.52 ± 1.05cd	43.02 ± 1.21a	18.60 ± 0.82ab	0.57 ± 0.04ab	4.75 ± 0.28bc	0.48 ± 0.03ab
	2	39.28 ± 1.05c	43.25 ± 0.64a	17.49 ± 0.47bc	0.52 ± 0.03bc	5.61 ± 0.90ab	0.44 ± 0.02bc
	3	41.58 ± 1.71b	42.08 ± 1.39ab	16.47 ± 0.53cd	0.44 ± 0.03cd	3.52 ± 059cd	0.40 ± 0.03cd
	4	42.03 ± 0.11b	42.12 ± 0.49a	15.97 ± 0.35cd	0.40 ± 0.01de	2.79 ± 0.36d	0.38 ± 0.01d
	5	44.80 ± 0.78a	40.01 ± 0.21b	15.32 ± 0.97de	0.35 ± 0.02e	3.41 ± 0.65cd	0.34 ± 0.03de
	6	45.07 ± 0.30a	41.61 ± 0.59b	13.78 ± 0.35e	0.32 ± 0.01e	3.69 ± 0.19cd	0.30 ± 0.01e

[a] Storage time in month (s); [b] Saturated fatty acid, [c] Monounsaturated fatty acid; [d] Polyun saturated fatty acid, [e] Ecosapentaenoic acid+docosahexaenoic acid/palmitic acid; [f] *n*3 PUFA/*n*6 PUFA, [g] Polyunsaturated fatty acid/saturated fatty acid. [h] Value in the same column with different letters within a same strain are significantly different at a level of 0.01. [i] Data is expressed as Mean±SD (n= 3).

pike perch (11.36% of the total fatty acids); whereas mullet showed lower DHA content among the studied fish species. The DHA/EPA (C22:6*n*3/C20:5*n*3) ratio of studied species were 1.4, 0.53, 1.18, 3.28 and 1.71 in Caspian kutum, golden grey mullet, common carp, pike perch and common kilka, respectively. C20:5*n*3 has been recognized as beneficial for fir human health by reducing the risk of cardiovascular disease (Hall *et al.,* 2008), while C22:6*n*3 has been recognized as developing relevant functions related to nervous system and visual functions in human beings (Linko and Hayakawa, 1996). PUFAs in pike perch were the highest among the fish species with a significant decrease in the amount of these fatty acids during the frozen storage priod (37%, 35%, 28%, 33% and 29% in kutum, mullet, carp, pike perch and kilka, respectively). The oxidative changes in the frozen fish lipids may be caused by the occurrence of radical indicators of the process. These types of radicals are easily

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formed in pike perch, because of its lipid content of a higher PUFA. During the frozen storage, pike perch is very susceptible to lipid peroxidation due to its high content of PUFA (Hedayatifar *et al.,* 2001; Dragoev *et al.,* 1998).

Figures related to EPA+DHA/C16 ratio (polyene index) as a nutritional factor are presented in Table 2. Although this ratio in kilka was the highest, it decreased in kutum (56%) as compared to other species during the frozen storage priod (49%, 46%, 49% and 51% in mullet, carp, pike perch and kilka, respectively).

It has been suggested that EPA+DHA/C16 ratio (polyene index) is a good index for a determination of lipid oxidation (Jeong *et al.,* 1990).

The results also indicatet that the fish were richer in *n*3 than *n*6 PUFAs. There was a significant (P≤ 0.01) difference observed in *n*3/*n*6 ratio during the storage period in all the fish species except for pike perch. The decrease (31%, 35%, 38% and 44% for Caspian kutum, golden grey mullet, common carp and common kilka, respectively) of this ratio was an indication of the nutritional loss in the given fish species during the process of frozen storage. The *n*3/*n*6 ratio is a useful criterion for comparing the relative nutritional values of fish oils. It has been suggested that a ratio of 1:1-1:5 would contribute to a healthy human diet (Osman *et al.,* 2001).

In all the species, the PUFA/SFA (P/S) ratio was less than 1 (Table 2) and the decrease of PUFAs, in contrast to SFA, led to a significant decrease in this ratio (P≤ 0.01) during the process of frozen storage. This ratio among all the species except for golden grey mullet was more than the minimum value (0.45) of PUFA/SFA ratio recommended (HMSO, 1994).

Correlation

The correlation of storage time and fatty acid indices were tested. The storage time (Table 3) showed the closest correlation with such parameters as SFAs, PUFAs, EPA+DHA/C16 (polyene index) and PUFA/SFA in all the fish species. Storage time showed to be most correlated with MUFAs for Caspian kutum (r= - 0.88), golden grey mullet (r= - 0.94) and for common kilka (*r*= - 0.71). The storage time (Table 3) showed to be best correlated with *n*3/*n*6 ratio for all fish species except pike perch (r= 0.13). Among the fatty acid indices (Table 3), the most satisfactory results yielded after comparing PUFA content with the PUFA/SFA ratio and EPA+DHA/C16 (polyene index) the PUFA/SFA ratio. Overall changes in fatty acid contents of five fish species from south Caspian Sea during frozen storage (0, 3 and 6 months at -24°C) are presented in Table 4.

CONCLUSIONS

The effects of storage time on the lipid quality of various fish species were examined in the study. It was found that the storage time (at -24°C) had a significant impact on the storage stability of fish. The observed changes in SFA, MUFA, PUFA, EPA+DHA/C16 (polyene index), *n*3/*n*6 and PUFA/SFA reveal that all the fish species are susceptible to significant change during the frozen storage, especially if the storage time is long. In addition, the decrease in unsaturated fatty acids, especially polyunsaturated fatty acids and EPA+DHA/C16 (polyene index), *n*3/*n*6 and PUFA/SFA ratios, showed that nutritional values of these species have decreased.

Based on the present study, all fish species can be stored for four months in a frozen state with low undesirable changes of fatty acid profile. However, it is suggested that the effects of frozen storage on fatty acid compounds should be further investigated, in a large scale study, preferably as a socio-economic evaluation and as well as a thorough evaluation of long term frozen storage on the changes in fatty acid profile.

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Table 3. Correlation coefficient for different parameters (storage time and fatty acids content) measurement during frozen storage in five fish species [h].

	Caspian kutum					
	SFA [b]	MUFA [c]	PUFA[d]	EPA+DHA/C16[e]	*n*3/*n*6[f]	PUFA/SFA[g]
ST [a]	0.98	- 0.88	- 0.98	- 0.99	- 0.75	- 0.99
SFA		- 0.94	- 0.98	- 0.98	- 0.75	- 0.99
MUFA			0.87	0.89	0.70	0.88
PUFA				0.99	0.74	0.99
EPA+DHA/C16					0.81	0.99
*n*3/*n*6						0.76
	Golden grey mullet					
	SFA [b]	MUFA [c]	PUFA[d]	EPA+DHA/C16[e]	*n*3/*n*6[f]	PUFA/SFA[g]
ST [a]	0.98	- 0.94	- 0.97	- 0.97	- 0.82	- 0.98
SFA		- 0.97	- 0.98	- 0.99	- 0.86	- 0.99
MUFA			0.93	0.95	0.83	0.94
PUFA				0.99	0.84	0.99
EPA+DHA/C16					0.89	0.99
*n*3/*n*6						0.84
	Common carp					
	SFA [b]	MUFA [c]	PUFA[d]	EPA+DHA/C16[e]	*n*3/*n*6[f]	PUFA/SFA[g]
ST [a]	0.91	- 0.23	- 0.91	- 0.96	- 0.91	- 0.94
SFA		- 0.45	- 0.82	- 0.93	- 0.83	- 0.91
MUFA			- 0.06	0.20	0.29	0.09
PUFA				0.94	0.78	0.98
EPA+DHA/C16					0.88	0.97
*n*3/*n*6						0.83
	Pike perch					
	SFA [b]	MUFA [c]	PUFA [d]	EPA+DHA/C16 [e]	*n*3/*n*6 [f]	PUFA/SFA [g]
ST [a]	0.94	- 0.29	-0.92	- 0.91	0.13	- 0.95
SFA		- 0.49	- 0.92	- 0.89	0.19	- 0.96
MUFA			0.12	0.12	- 0.35	0.26
PUFA				0.95	- 0.10	0.99
EPA+DHA/C16					0.16	0.95
*n*3/*n*6						- 0.15
	Common kilka					
	SFA [b]	MUFA [c]	PUFA [d]	EPA+DHA/C16 [e]	*n*3/*n*6 [f]	PUFA/SFA [g]
ST [a]	0.95	- 0.71	- 0.94	- 0.95	- 0.72	- 0.96
SFA		- 0.84	- 0.94	- 0.96	- 0.68	- 0.97
MUFA			0.60	0.69	0.60	0.70
PUFA				0.97	0.61	0.99
EPA+DHA/C16					0.70	0.99
*n*3/*n*6						0.66

[a] Storage time in month (s); [b] Saturated fatty acid, [c] Monounsaturated fatty acid; [d] Polyun saturated fatty acid, [e] Ecosapentaenoic acid+docosahexaenoic acid/palmitic acid; [f] *n*3 PUFA/*n*6 PUFA, [g] Polyunsaturated fatty acid/saturated fatty acid.
[h] Significant values (P≤ 0.01) are expressed in bold print.

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Table 4. Changes in fatty acids content of five fish species from south Caspian Sea during frozen storage (-24°C) [a, b].

Fish species	Fatty acid	Storage time (Month) 0	3	6
Caspian kutum	C14:0	2.67 ± 0.12 [c]	3.33 ± 0.1 [b]	3.76 ± 0.16 [a]
	C16:0	20.42 ± 0.88 [e]	22.81 ± 0.22 [bc]	27.00 ± 0.30 [a]
	C16:1	16.81 ± 0.59 [a]	16.65 ± 0.30 [a]	16.17 ± 0.29 [a]
	C17:0	1.65 ± 0.03 [abc]	1.24 ± 0.10 [a]	1.70 ± 0.11 [ab]
	C17:1	2.50 ± 0.97 [a]	1.79 ± 0.11 [a]	1.41 ± 0.13 [a]
	C18:0	4.26 ± 0.69 [a]	4.46 ± 0.14 [a]	4.66 ± 0.43 [a]
	C18:1	36.94 ± 0.28 [a]	37.53 ± 0.32 [a]	35.97 ± 0.43 [a]
	C18:2	1.94 ± 0.30 [a]	2.01 ± 0.30 [a]	1.47 ± 0.11 [a]
	C18:3	0.29 ± 0.01 [a]	0.34 ± 0.04 [a]	0.40 ± 0.10 [a]
	C20:4	0.74 ± 0.07 [a]	0.70 ± 0.01 [a]	0.62 ± 0.10 [a]
	C20:5	4.55 ± 0.11 [a]	3.82 ± 0.19 [c]	2.89 ± 0.15 [d]
	C22:6	7.14 ± 0.10 [a]	5.83 ± 0.39 [c]	3.93 ± 0.32 [e]
Golden grey mullet	C14:0	3.76 ± 0.16 [a]	8.59 ± 0.11 [c]	10.07 ± 0.27 [a]
	C16:0	27.00 ± 0.30 [a]	29.27 ± 0.46 [c]	32.65 ± 0.53 [a]
	C16:1	16.17 ± 0.29 [a]	25.40 ± 0.48 [ab]	23.82 ± 0.43 [c]
	C17:0	1.70 ± 0.11 [ab]	1.41 ± 0.26 [a]	1.70 ± 0.22 [a]
	C17:1	1.41 ± 0.13 [a]	1.93 ± 0.10 [a]	1.70 ± 0.15 [a]
	C18:0	4.66 ± 0.43 [a]	5.27 ± 0.28 [ab]	5.48 ± 0.35 [a]
	C18:1	35.97 ± 0.43 [a]	15.68 ± 0.23 [a]	15.53 ± 0.16 [a]
	C18:2	1.47 ± 0.11 [a]	1.97 ± 0.19 [a]	1.94 ± 0.08 [a]
	C18:3	0.40 ± 0.10 [a]	0.30 ± 0.01 [abc]	0.27 ± 0.02 [c]
	C20:4	0.62 ± 0.10 [a]	0.37 ± 0.01 [a]	0.34 ± 0.01 [a]
	C20:5	2.89 ± 0.15 [d]	6.3 ± 0.17 [cd]	4.25 ± 0.14 [e]
	C22:6	3.93 ± 0.32 [e]	3.43 ± 0.12 [ab]	2.44 ± 0.11 [d]
Common carp	C14:0	3.14 ± 0.11 [d]	3.46 ± 0.18 [bcd]	4.11 ± 0.10 [a]
	C16:0	22.25 ± 2.13 [c]	23.57 ± 0.82 [bc]	26.11 ± 0.22 [a]
	C16:1	15.87 ± 1.88 [a]	15.53 ± 0.64 [a]	15.16 ± 0.23 [a]
	C17:0	4.22 ± 0.55 [a]	4.18 ± 0.18 [a]	4.28 ± 0.33 [a]
	C17:1	4.24 ± 1.77 [a]	4.21 ± 0.26 [a]	4.19 ± 0.06 [a]
	C18:0	6.43 ± 0.80 [a]	6.45 ± 0.70 [a]	6.49 ± 0.18 [a]
	C18:1	28.09 ± 0.73 [a]	27.67 ± 1.06 [a]	27.89 ± 1.28 [a]
	C18:2	3.34 ± 0.33 [a]	3.30 ± 0.07 [a]	3.06 ± 0.41 [a]
	C18:3	0.62 ± 0.36 [a]	0.25 ± 0.02 [a]	0.25 ± 0.02 [a]
	C20:4	0.29 ± 0.13 [a]	0.55 ± 0.11 [a]	0.61 ± 0.03 [a]
	C20:5	5.31 ± 0.20 [a]	4.94 ± 0.49 [abc]	3.32 ± 0.20 [e]
	C22:6	6.20 ± 0.68 [a]	6.01 ± 0.11 [a]	4.06 ± 0.29 [d]
Pike perch	C14:0	2.96 ± 0.10 [a]	3.29 ± 0.59 [a]	3.61 ± 0.10 [a]
	C16:0	25.72 ± 0.48 [f]	28.53 ± 0.28 [cd]	34.09 ± 1.06 [a]
	C16:1	16.62 ± 0.17 [a]	16.25 ± 0.27 [ab]	15.10 ± 0.13 [c]
	C17:0	2.50 ± 0.43 [a]	2.58 ± 0.27 [a]	2.58 ± 0.34 [a]
	C17:1	0.73 ± 0.14 [a]	0.78 ± 019 [a]	0.82 ± 0.28 [a]
	C18:0	4.82 ± 0.49 [a]	5.38 ± 0.58 [a]	5.02 ± 0.13 [a]
	C18:1	23.54 ± 1.10 [a]	24.05 ± 2.17 [a]	23.34 ± 0.14 [a]
	C18:2	5.70 ± 0.18 [a]	4.87 ± 1.05 [a]	3.89 ± 0.86 [a]
	C18:3	1.02 ± 0.09 [a]	0.94 ± 0.05 [a]	0.58 ± 0.09 [a]
	C20:4	1.74 ± 0.11 [a]	1.57 ± 0.18 [ab]	0.95 ± 0.04 [c]
	C20:5	3.22 ± 0.19 [a]	2.80 ± 0.51 [a]	2.49 ± 0.49 [a]
	C22:6	11.36 ± 0.14 [a]	8.97 ± 0.92 [bcd]	7.41 ± 0.33 [d]
Common kilka	C14:0	6.11 ± 0.06 [c]	7.57 ± 0.48 [ab]	7.98 ± 0.33 [a]
	C16:0	24.23 ± 1.78 [c]	26.86 ± 0.67 [bc]	31.88 ± 0.29 [a]
	C16:1	11.09 ± 0.12 [a]	9.8 ± 0.93 [a]	10.36 ± 0.14 [a]
	C17:0	1.42 ± 0.12 [a]	1.51 ± 0.49 [a]	1.14 ± 0.13 [a]
	C17:1	1.76 ± 0.68 [a]	2.07 ± 0.50 [a]	0.99 ± 0.50 [a]
	C18:0	5.13 ± 1.16 [a]	5.64 ± 0.96 [a]	4.06 ± 0.14 [a]
	C18:1	30.83 ± 0.49 [a]	30.21 ± 0.24 [a]	30.25 ± 0.81 [a]
	C18:2	2.26 ± 0.29 [b]	2.95 ± 0.13 [a]	2.69 ± 0.08 [ab]
	C18:3	1.21 ± 0.10 [a]	0.81 ± 0.10 [bc]	0.57 ± 0.15 [c]
	C20:4	0.36 ± 0.24 [a]	0.72 ± 0.35 [a]	0.25 ± 0.07 [a]
	C20:5	5.68 ± 0.18 [a]	4.17 ± 0.40 [b]	3.85 ± 0.20 [b]
	C22:6	9.93 ± 0.63 [a]	7.80 ± 0.58 [bc]	6.42 ± 0.24 [d]

[a] Values in the same row with different superscript letters within a same strain are significantly different (P< 0.01).
[b] Data is expressed as Mean±SD (n= 3).

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تغییرات اسیدهای چرب پنج گونه مهم از ماهی های دریای خزر طی نگهداری به حالت انجماد

ص. پیرستانی، م. ع. سحری و م. برزگر

چکیده

در این مطالعه تغییرات اسیدهای چرب ماهی های سفید، کفال طلایی، کپور معمولی، سوف معمولی و کیلکای معمولی از دریای خزر طی نگهداری به حالت انجماد در۲۴- درجه سانتی گراد بررسی شد. برای این منظور، تغییرات اسیدهای چرب اشباع، تک غیر اشباع، چند غیر اشباع، نسبت مجموع اسیدچرب ایکوزاپنتاانوئیک اسید و دیکوزاهگزاانوئیک اسید به پالمیتیک اسید، نسبت اسیدهای چرب امگا سه به امگا شش و نسبت اسیدهای چرب چند غیر اشباع به اشباع طی یک دوره شش ماهه مورد بررسی قرار گرفت. کاهش مقدار اسیدهای چرب غیر اشباع به خصوص اسیدهای چرب چند غیر اشباع (۲۳/۰۳ -۹/۲۵٪)، نسبت اسیدهای چرب امگا سه به امگا شش (۶/۰۶-۲/۰۲٪)، نسبت مجموع اسیدچرب ایکوزاپنتاانوئیک اسید و دیکوزاهگزاانوئیک اسید به پالمیتیک اسید (شاخص پلی ان؛ ۰/۶۵ -۰/۲۱٪) و نسبت اسیدهای چرب چند غیر اشباع به اشباع (۰/۶۴ -۰/۱۸٪) نشان دهنده کاهش ارزش تغذیه ای این گونه ها بود.

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