SEASONAL VARIATION OF FATTY ACIDS IN MUSCLES OF TUNISIAN SWORDFISH (*Xiphias gladius* L.1758)

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RESUME: L'objectif de cette étude est de déterminer la variation saisonnière des acides gras totaux (AGT) ainsi que la composition en acides gras des muscles blanc (D_1) et rouge (MR) de l'Espadon tunisien (*Xiphias gladius*). Les AGT affichent une variation saisonnière ($p < 0,05$) dans les muscles blanc et rouge, avec un pic au printemps (33,7 ± 7,2%) et en été (26,8 ± 3,2%). Dans D_1, on note une variation en acides gras polyinsaturés (AGPI) plus importante que celle des acides gras saturés (AGS) et des acides gras monoinsaturés (AGMI). L'acide palmitique ($C_{16:0}$) prévaut chez les acides gras saturés (AGS) (58.2-64.3% des AGT), alors qu'en toute saison, l'acide oléique ($C_{18:1n-9}$) est le principal composant des AGMI (56,5% - 68,1%), l'acide linoléique ($C_{18:2n-6}$) (0,7 ± 0,3% - 9,2 ± 4,2%) , l'acide eicosapentaénoïque ($C_{20:5n-3}$) (2,6 ± 0,3% - 3,5 ± 1,1%) et l'acide docosahexaénoïque ($C_{22:6n-3}$) (19,2 ± 2,6% - 29,2 ± 1,8%), sont les plus importants des AGPI. Quelle que soit la saison, les acides gras de la série (n-3) sont plus importants que ceux de la série (n-6) avec des ratios respectifs de 6.8 (automne), 6.9 (hiver), 4.1 (printemps) et 6.7 (été).

Mots clés : Acides gras totaux, acides gras polyinsaturés (n-3), acides gras polyinsaturés (n-6), acide eicosapentaénoïque, acide docosahexaénoïque, muscle blanc, muscle rouge, espadon.

ABSTRACT : The objective of this study is to determine the seasonal variation of the total fatty acids (**TFA**) level and fatty acids (FA) in white and red muscles of Tunisian swordfish (X*iphias gladius*). There is a seasonal variation ($p < 0.05$) of total fatty acids (**TFA**) and fatty acids both in white and red muscles, with a peak in spring (33.7 ±7.2 %) and summer (26.8±3.2 %). In D_1, the seasonal variation of polyinsaturated fatty acids (**PUFA**) is higher than that of the saturated fatty acids (**SFA**) and monounsaturated fatty acids (**MUFA**). Palmitic acid ($C_{16:0}$) prevails in the **SFA** (58.2-64.3 % of the total **SFA**), disregarding the season, oleic acid ($C_{18:1n-9}$) is the main **MUFA** component (56.5 % - 68.1 %), whereas linoleic acid ($C_{18:2n-6}$) (0.7 ± 0.3 % - 9.2 ± 4.2 %), eicosapentaenoic acid EPA ($C_{20:5n-3}$) (2.6 ± 0.3 % - 3.5 ± 1.1 %) and docosahexaenoic acid DHA ($C_{22:6n-3}$) (19.2 ± 2.6% - 29.2 ± 1.8 %), are the most important in the **PUFA** series. Compared to the percentage of (n-6) series fatty acids contained in the **TFA** of swordfish, the part of the (n-3) series is more important, yielding n-3/n-6 ratios of respectively 6.8, 6.9, 4.1 and 6.7 in autumn, winter, spring and summer. (n-3) and (n-6) fatty acids contained in white muscle of swordfish undergo significant seasonal variations.

Key words: Total fatty acids, poly-unsaturated fatty acids (n-3), poly-unsaturated fatty acids (n-6), eicosapentaenoic acid, docosahexaenoic acid, white muscle, red muscle, swordfish.

INTRODUCTION

Fish meat is one of the most important nutriments of man. It could be due to the presence of (n-3) polyunsaturated fatty acids (PUFA) in fish meat [1,2] that fish lipids are so beneficial for human health [3]. Both the eicosapentaenoic acid (EPA) and the docosahexaenoic acid (DHA) are the most important long-chain polyunsaturated fatty acids (PUFA) of the (n-3) series occurring mainly in fats of fish, molluscs, crustaceans and sea mammals.

The biochemical composition of sea organisms undergoes seasonal variations [4-7]. The fatty profile of fish depends on the season and the characteristics of the specific sea area [6,8,9]. This fatty profile is determined by certain factors like salinity and temperature [10], periods of sampling,

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fishing area and individual variability [11]. A better knowledge of the fatty acid profile, especially that of (n-3) PUFA in fish as influenced by seasonal factors can help the consumer choose a given fish at the moment of its optimal fatty acid profile [12].

Fish life history itself can be influenced by water temperature at various stages [40] i.e. it affects the timing of food availability. Temperature is also known to influence the production and distribution of plankton [43] and subsequently, the food resource for juvenile and adult bluefin tuna [41].

A study on three species of tilapia (*Oreochromis niloticus, Oreochromis macrochir and Tilapia rendalli*) during two seasons (autumn and winter) has shown that the ratio (n-3) / (n-6) varies from each species according to season. The results indicate that the fatty acids (n-3) decrease in autumn and increase in winter. This has been explained by a decrease of the percentages in PUFA (n-3) of 12% to 7.3% for *Oreochromis niloticus*, de 13.9 à 7.7% for *Tilapia rendalli* and 14.4 to 8.3% for *Oreochromis macrochir* and by an increase of PUFA (n-6) of 13.3 to 15.6%, of 10.7 to 13% and 8.7 to 16% respectively [39]. The content and the nature of muscle lipids from fatty fish vary greatly depending of the seasons. Phospholipid content in within the muscle is changing the same way. The water content evolves inversely proportional to the amount of fat while the protein content remains constant [38].

To optimise their fatty acid profile [13], fish are able to synthesize *de novo* the saturated fatty acids (SFA) and the mono-unsaturated fatty acids (MUFA), and to absorb and metabolise selectively nutritional fatty acids comprising poly-unsaturated fatty acids (PUFA) [14,15]. Certain authors [13,16] found a correlation between the water temperature and certain lipidic characteristics, such as the PUFA / SFA and the (n-3)/(n-6) ratios. The physiologically active fatty acids necessary for a normal development of vertebrates are the arachidonic acids (ARA) ($C_{20:4n-6}$), the eicosapentaenoic acids (EPA) ($C_{20:5n-3}$) and the docosahexaenoic acids (DHA) ($C_{22:6n-3}$).

Lipids and particulary composition present quantitative variations. According to [13], the fish adapt the composition of their lipids to the requirements of the environment and to their own physiological requirements. Their behaviour and their food preferences are directed toward this objective [13]. The study of the seasonal impact on the composition in fatty acids of the white and red muscles allows determining the most favourable periods to the composition of fish for a referred dietetics.

Swordfish is well known and extensively caught in Tunisian waters; it is particularly targeted because of its high economic value and for the quality of its flesh. The production of swordfish has developed considerably between 1992 and 2001, with an annual average of 383 tons, to achieve a maximum of 1138 tons during the year 2002[42]. The share of swordfish in the catches of large pelagic species was between 4.5% and 6.6% of the total of landings, with a maximum of 17.1% in 2002 [42].

It must also be noted that the tissues of swordfish have been very little studied so far. It is true, there do exist a certain number of studies of the chemical composition of swordfish from the Atlantic Ocean [11] and the Indian Ocean [4], in the Mediterranean Sea [17] but they do not take into account any seasonal influence on the composition of fatty acids. The objective of this study is to study the seasonal influence on the contents of total fatty acids and fatty acids in white and red muscular tissues of swordfish.

MATERIAL AND METHODS

Sampling

Fresh samples of swordfish were collected at the wholesale market of Tunis between December 2005 and February 2007. The sampled individuals hadn't yet reached first sexual maturity which is considered to be 140 cm in case of Mediterranean swordfish [18]. The lower jaw fork length (Ljfl) of our samples varied between 55 and 104cm, gutted weight (GW) between 1.4 and 10.5kg. The data of the temperature of the sea

surface (SST) for the Central Mediterranean were carried out by remote sensing [40]. The values represent the monthly averages established between 1895 and 2006. The sample characteristics are shown in Table I.

Table I: Seasonal variation in the lower jaw fork length (Ljfl) and gutted weight (GW) from the swordfish, *Xiphias gladius* and water temperature

	Ljfl (cm)	GW (kg)	Water temperature (°C)
2005-2006 Winter	55 – 104	5– 10.4	18-16
Spring	95 – 100	9 – 10	16-18
Summer	90 – 96	7 – 8	22-27
Autumn	85 – 90	5 – 7	25-21
2006- 2007 Winter	85 – 90	5 – 6	18-15

White muscle samples were taken from the frontal section A (Figure 1) next to the first dorsal fin D_1 and red muscle RM samples from the rear part next to the second dorsal fin (Figure 1). On the whole, our analyses are based on two anatomical samples of muscular tissue, i.e., D_1, and RM. Figures 2 and 3 reflect the sections B and A with the location of the red muscle and white muscle.

Extraction, identification and quantification of the total fatty acids (TFA).

Only white and red muscles were analysed, disregarding dermal or any other type of lipids. Two one-gram samples of white and red muscles were taken from each of the two sections A and B. All samples were fixed in boiling water to completely inactivate enzymatic activity, especially phospholipases [44]. Samples along with the fixing liquid were stored in a freezer at -28°C. The total lipids were extracted from the tissues in a chloroform/methanol mixture (2:1, vol/vol) [19] and the fatty acids were transformed into methyl esters [20].

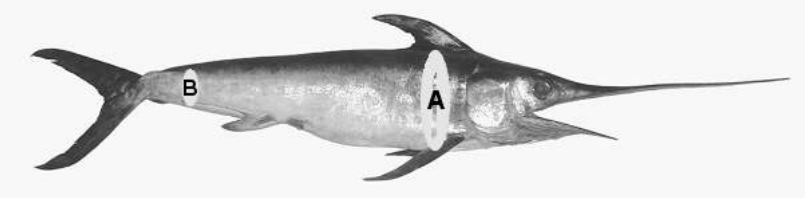

Figure 1: Sampling areas of section A and B

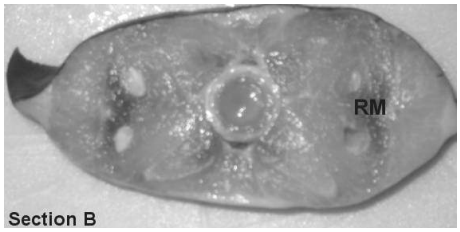

Figure 2: Section B with red muscle RM

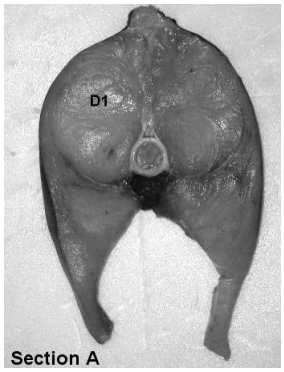

Figure 3: Section A with white muscle D_1

A gas chromatograph type HP series 6890 with a split/splitless injector and a flame ionisation detector was used for the analysis. The device includes a 30 m long HP Innowax capillary column with an internal diameter of 250 µm and a 0.25 µm film, the stationary polar phase of the column being polyethylene glycol. The data of the chromatographic analysis figure in table II. The comparison of the retention times of the fatty acids under study and those of standard fatty acid methyl esters Supelco (PUFA-3) allowed to identify the different fatty acids. An internal standard not existing in our sample that is nonadecanoate methyl ($C_{19:0}$) served to quantify the fatty acids. The area percentage and weight (mg/g in oil) of each fatty acid methyl esters were calculated as follows:

Area percent fatty acid x = [*A*x / (*A*T-*A*IS)] × 100

Where *A*x = area counts of methyl ester X; *A*T = total area counts for chromatogram and *A*IS = area counts of internal standard.

While for weight in mg/g was as:

Weight in mg/g = *A*x × WIS /AIS × WS ×1000

Where *A*x = area counts of methyl ester X; *A*IS = area counts of internal standards; WIS = weight of internal standard added to the sample, (µg); WS = sample weight, (mg)

Table II: Data of the chromatographic analysis

Carrier Gas	Nitrogen
Gas Flow vector	1.52 ml per minute
Temperature inlet	250° C
Temperature detector	275° C
Programme temperature column	- oven isotherm 150°C for 1minute,
	- 150 to 200° C for a rate of 15° C per minute,
	- 200 to 242° C for a rate of 2° C per minute,
Injected volume	0.5 µl

SFA: $C_{14:0} + C_{15:0} + C_{16:0} + C_{17:0} + C_{18:0}$;
MUFA: $C_{16:1} + C_{18:1n-7} + C_{18:1n-9} + C_{20:1n-9} + C_{22:1n-11} + C_{22:1n-9}\ C_{24:1n-9}$;
PUFA: $C_{16:2n-6} + C_{16:3n-4} + C_{16:4n-3} + C_{18:2n-6} + C_{18:3n-3} + C_{18:4n-3} + C_{20:4n-6} + C_{20:4n-3} + C_{20:5n-3} + C_{22:6n-3}$.

Statistics

The results represent the average of six fish (n = 6) per season. In total, 24 fish have been analysed. The statistical analyses were carried out with the SAS software program version 6.12. Different mean values were analysed according to the Duncan's multiple range test. The result is considered significant if $p < 0.05$.

RESULTS AND DISCUSSION

The total fatty acids (TFA) (in grams per 100g wet weight) contained in the muscles of swordfish (D_1 and RM) throughout the four seasons are listed in figure 4.

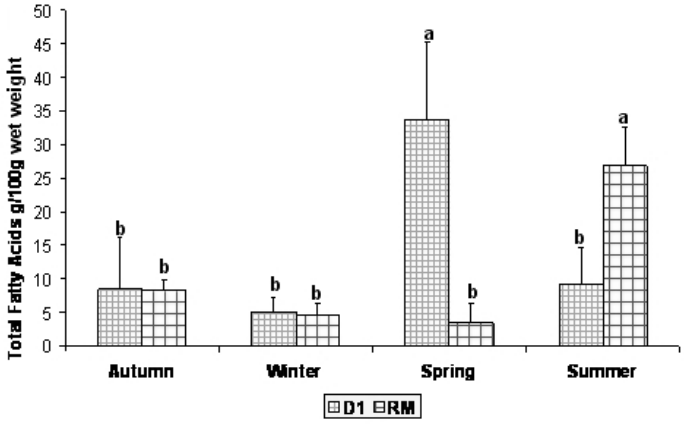

Figure 4: Seasonal variation in TFA (g/100g) content. TFA values with different subscripts (a–b) were significantly different ($p < 0.05$) for each muscle type at different seasons.

The TFA content in both the white and the red muscle of swordfish varies significantly according to the season and the origin of the sample (frontal section D_1 and rear part RM). The

quantity of stored lipids directly depends on food availability [21]. If the latter is low, the variations are low as well, if food is abundant, the variations are more important [22, 23, 24, 25]. In the white muscle sample (D_1), the TFA content of swordfish ranges from 5.1 ± 1% to 33.7 ± 7.2%, and in the red muscle (RM), from 3.4 ± 1.8% to 26.8 ± 3.2%. A substantial seasonal variation of the TFA is to be noted. The TFA content in the white muscle (Figure 4) reaches its peak in spring, in the red muscle in summer (Figure 4) with respectively 33.7 ± 7.3 % and 26.8 ± 3.2%. The lipidic level of certain fish species may vary of about 10% [26], depending on the season of capture. The lipids present in the fillets and muscles of a certain number of freshwater species [27] varied between 0.7 and 25.8 % (wet weight). In five marine species [28], the percentages vary between 0.94% and 10.6%. As to the samples under study, the lipid contents ranging between 5 and 33 % in the white muscle and between 3 and 26 % in the red muscle confirm the findings of [27] and [28].

Both the fatty acids and the families of fatty acids are expressed as % of the TFA. The seasonal variations of the composition of fatty acids of swordfish are illustrated in table III and IV. The main fatty acids in D_1 (Table III) and in RM (Table IV), whatever the season, were the DHA ($C_{22:6n-3}$), the palmitic acid ($C_{16:0}$), the oleic acid ($C_{18:1n-9}$) and the stearic acid ($C_{18:0}$). The palmitic acid is the major fatty acid of the SFA family, making up about 58.2 % to 64.3 % of the total satured fatty acids (SFA) in D_1 and about 51.7 % to 59.4 % in RM. The palmitic acid has a key part in the metabolism of lipids in fish [29], its percentage being independent of food availability and totalling almost 60 % [30]. The SFA may not be considered as a whole because they differ in their structure, their metabolism, their cellular functions and even their deleterious effects in case of excess [45]. They must distinguish between the subgroup " lauric acid ($C_{12:0}$), myristic ($C_{14:0}$) and palmitic ($C_{16:0}$)" which is atherogenic in case of excess. For this subgroup, the AFSSA (2010) has established a maximum contribution of 8% of total energy intake, this contribution is 19.5g/day for man and 16.5g/day for adult women. According to our data in Tables III and IV, the area D_1 display a minimum of SFA in Spring whereas the MR would display of maximum low levels in autumn and winter.

The quantity of monounsatured fatty acids (MUFA) and oleic acids are strongly correlated. As illustrated in table III 3 and IV, the oleic acid represents about 56.5 % to 68.1 % of the total MUFA in D_1 and 53.3 % to 75.7 % in RM. The results of some authors [12] confirmed that the oleic acid is the main MUFA in the muscles of three Sparidae species. Its involvement as metabolic energy source explains the decrease of the oleic acid in D_1 in winter and spring and in the RM in winter. TFA being bio-synthesized *de novo* in most animals [31] quite independently of fatty acids available in the fish food [32], it is presumably this endogenous origin which accounts for the relatively high part of TFA as compared to that of the mono-unsaturated fatty acids. Oleic acid intake for the French population [46] represent 20% of total energy intake (TEI) being 49g/day for a man and 40g/day and for woman. Eventhough the oleic acid has interesting features; its tissues content of swordfish are not sufficient. They vary between 12.9 to 19.4g/100g FM at the level of D_1 and between 14.2 to 21g/100g FM at the level of RM. These values represent respectively 26.3 to 39.5% and 28.9 - 42.8% of the recommended dietary oleic acid. According to allegations of the AFSSA[47] the zones D_1 and RM are rich (30% of the Daily Dietary Intake DDI) in oleic acid.

The polyunsaturated fatty acids (PUFA) make up the biggest part in the muscles (Table III and IV). These findings are confirmed by many authors [33, 34, 5], and In the white muscle D_1 (Table III), the PUFA were found to undergo seasonal variations, peaks being observed in winter and spring, whereas no variations were observed in the red muscle RM (Table IV). The high percentages of the PUFA (Table III and IV) seem to be due to the abundance of the n-3 PUFA. Their level in D_1 (Table III) varying according to the season. Peaks are observed in winter (49.2 ± 2.5 %) and in spring (50.1 ± 6.1 %). The alpha linolenic (ALA) acid is an essential fatty acid. It is the precursor of (n-3) and feebly converted into docosahexaenoic acid (DHA). Its recommended dietary intake is 1.8g/day [45]. The muscles of the Swordfish with respective contents 0.6 - 1.49%

(D_1) and 0.7 - 1.15% (RM) are rich (30% of the daily dietary intake DDI) in ALA and this whatever the season.

Table III: Fatty acid profile in the white muscle (D_1) of swordfish (in % of TFA, mean ± SE; n = 6 per saison; p <0.05) area. Values with different subscripts (a–b) were significantly different ($p < 0.05$) at different seasons

	Red muscle (RM)			
Fraction %	Autumn	Winter	Spring	Summer
C14 :0	2.3±0.33^{a}	2.5±0.58^{a}	3.08±0.37^{a}	2.25±0.28^{a}
C15 :0	0.81±0.12^{a}	1.78±0.6^{a}	0.87±0.07^{a}	0.66±0.04^{a}
C16 :0	17.6±1.69^{a}	17.08±1.38^{a}	19.02±1.24^{a}	17.91±1.18^{a}
C16 :1n-7	3.48±0.34^{a}	3.2±0.38^{a}	3.8±0.46^{a}	2.62±0.36^{a}
C16:2n-6	1.48±0.11^{a}	1.29±0.13^{ab}	0.93±0.29^{b}	1.19±0.12^{ab}
C16:3n-4	1.33±0.13^{a}	1.19±0.11^{a}	1.15±0.11^{a}	1.24±0.11^{a}
C16:4n-3	1.29±0.25^{a}	1.05±0.15^{a}	1±0.1^{a}	1.11±0.09^{a}
C17:0	0.67±0.14^{a}	0.63± 0.11^{a}	0.59±0.15^{a}	0.63±0.2^{a}
C18:0	7.54±0.64^{b}	6.5±0.5^{b}	7.55±1.13^{b}	12.53±2.15^{a}
C18:1n-9	18.01±1.75^{a}	14.2±2.04^{a}	18.58±2.67^{a}	21.02±1.23^{a}
C18:1n-7	2.22±0.27^{a}	2.07±0.19^{a}	2.48±0.04^{a}	0.74±0.35^{b}
C18:2n-6	1.06±0.12^{a}	1.2±0.12^{a}	1.17±0.13^{a}	0.91±0.2^{a}
C18:3n-3	0.94±0.29^{a}	1.15±0.36^{a}	0.73±0.2^{a}	0.67±0.12^{a}
C18:4n-3	0.57±0.11^{a}	0.43±0.09^{a}	0.7±0.19^{a}	0.37±0.09^{a}
C20:1n-9	1.77±0.17^{ab}	1.2±0.17^{b}	1.62±0.38^{ab}	2.18±0.21^{a}
C20:4n-6	1.47±0.19^{a}	1.51±0.2^{a}	1.59±0.4^{a}	1.73±0.36^{a}
C20:4n-3	0.8±0.16^{a}	0.6±0.15^{a}	0.75±0.17^{a}	0.54±0.12^{a}
C20:5n-3	2.52±0.3^{a}	2.89±0.66^{a}	2.88±0.36^{a}	2.62±0.4^{a}
C22:1n-11	1.1±0.39^{a}	0.98±0.4^{a}	0.28±0.02^{a}	0.15±0.1^{a}
C22:1n-9	0.86±0.41^{a}	0.56±0.23^{a}	0.79±0.3^{a}	0.49±0.23^{a}
C22:4n-6	0.97±0.45^{a}	0.96±0.44^{a}	0.88±0.35^{a}	0.81±0.34^{a}
C22:5n-5	1.51±0.26^{a}	1.81±0.26^{a}	1.16±0.17^{a}	1.63±0.45^{a}
C22:5n-3	2.85±0.41^{a}	2.75±0.6^{a}	2.42±0.33^{a}	2.04±0.44^{a}
C22:6n-3	24.19±1.16^{a}	28.12±3.22^{a}	23.81±1.69^{a}	23.31±2.24^{a}
C24:1n-9	2.55±0.39^{ab}	4.4±1.4^{a}	2.08±1.59^{ab}	0.54±0.22^{b}
SFA	29.59±2.05^{a}	29.08±2.07^{a}	31.69±2.27^{a}	34.61±3.1^{a}
MUFA	30.02±1.7^{a}	26.64±1.89^{a}	29.65±4.06^{a}	27.76±0.64^{a}
PUFA	40.38±1.49^{a}	44.27±3.19^{a}	38.66±2.67^{a}	37.63±3.67^{a}
EPA + DHA	26.72±1.24^{a}	31.02±3.04^{a}	26.7±1.92^{a}	25.94±2.6^{a}
Σ ω 3	32.58±1.21^{a}	36.6±3.35^{a}	31.91±2.34^{a}	30.21±0.64^{a}
Σ ω 6	4.99±0.62^{a}	4.8±0.34^{a}	4.58±0.45^{a}	4.65±0.57^{a}
Σ ω 3 / Σ ω 6	6.98±0.49^{a}	8.09±1.06^{a}	7.09±0.52^{a}	6.72±0.87^{a}

The part of arachidonic acid shows hardly any seasonal variation. In New Zealand [4] we found percentages of acid linoleic and arachidonic acid of about 1.1 and 1 %. The (n-3) / (n-6) ratio is very useful to compare the relative nutritional value of fish oils [36]. It would be extremely profitable to human health to consume more fish and fishery products because of their high content of PUFA (n-3), and their low content of PUFA (n-6) [37]. The ratios (n-3) / (n-6) (Table III) established for D1 are 6.7 in summer, 6.8 in autumn, 6.9 in winter, the lowest having been found in spring with 4.1. A high percentage of PUFA type n-6 in spring of 12.3 ± 3.8 % is believed to account for the n-3/n-6 ratio. In the RM (Table IV), the ratios n-3/n-6 are of 7 ± 0.5 % in autumn, 8.1 ± 1 % in winter, 7.1 ± 0.5 % in spring and 6.7 ± 0.9 % in summer. Some authors [4] established a ratio of 5.8 for the swordfish of the Indian Ocean.

Table IV: Fatty acid profile in the red muscle (RM) of swordfish (in % of TFA , mean ± SE; n = 6; p <0.05). Values with different subscripts (a–b) were significantly different (p < 0.05) at different seasons.

	White muscle (D_1)			
Fraction %	Autumn	Winter	Spring	Summer
C14 :0	2.53±0.35^{ab}	2.19 ±0.45^{ab}	1.21±0.39^{b}	4.63±2.14^{a}
C15 :0	0.78±0.05^{ab}	0.97±0.09^{a}	0.53±0.1^{b}	1.12±0.3^{a}
C16 :0	18.98±0.82^{a}	18.1±1.04^{a}	17.74±2.74^{a}	19.97±3.34^{a}
C16 :1n-7	3.46±0.35^{a}	3.02±0.34^{ab}	2.01±0.47^{b}	4.06±0.66^{a}
C16: 2n-6	1.16±0.1^{ab}	1.28±0.06^{a}	0.84±0.11^{b}	1.38±0.2^{a}
C16: 3n-4	0.94±0.03^{b}	1.03±0.05^{b}	0.78±0.12^{b}	1.34±0.16^{a}
C16: 4n-3	1.53±0.82^{a}	1.09±0.16^{a}	0.69±0.1^{a}	0.74±0.14^{a}
C17: 0	0.53±0.08^{b}	0.57± 0.08^{b}	0.26±0.06^{b}	1.42±0. 54^{a}
C18: 0	6.6±0.45^{a}	5.82±0.29^{a}	6.79±1.24^{a}	7.22±1.32^{a}
C18:1n-9	19.43±2.15^{a}	12.94±1.56^{a}	12.9±2.6^{a}	15.72±3.32^{a}
C18:1n-7	2.04±0.09^{a}	1.62±0.16^{a}	0.86±0.11^{b}	1.76±0.8^{a}
C18: 2n-6	2.03±0.79^{b}	1.24±0.13^{b}	9.21±4.21^{a}	0.65±0.27^{b}
C18: 3n-3	0.64±0.11^{a}	0.99±0.3^{a}	1.49±0.25^{a}	1.06±0.28^{a}
C18: 4n-3	0.47±0.09^{a}	2.63±1.92^{a}	1.49±0.6^{a}	0.33±0.1^{a}
C20:1n-9	1.14±0.21^{a}	1.52±0.38^{a}	1.27±0.72^{a}	2.34±0.6^{a}
C20: 4n-6	1.66±0.25^{a}	2.22±0.23^{a}	1.24±0.61^{a}	1.53±0.36^{a}
C20: 4n-3	0.67±0.12^{b}	0.63±0.07^{b}	0.37±0.09^{b}	1.73±0.65^{a}
C20: 5n-3	2.61±0.34^{a}	3.53±0.08^{a}	3.37±0.18^{a}	3.54±1.14^{a}
C22:1n-11	0.32±0.04^{a}	0.99±0.21^{a}	3.35±3.32^{a}	1.6±1.41^{a}
C22:1n-9	0.43±0.07^{a}	0.6±0.14^{a}	0.5±0.2^{a}	0.63±0.31^{a}
C22: 4n-6	0.61±0.13^{a}	1.54±0.47^{a}	1.02±0.15^{a}	1.26±0.32^{a}
C22: 5n-5	1.31±1.2^{b}	1.71±0.33^{ab}	1.57±0.28^{ab}	2.66±0.53^{a}
C22: 5n-3	2.77±0.23^{a}	2.49±0.32^{a}	1.57±0.28^{a}	2.66±0.75^{a}
C22: 6n-3	25.73±2.05^{ab}	29.19±1.78^{a}	27.78±2.09^{a}	19.24±2.57^{b}
C24: 1n-9	1.68±0.19^{a}	1.96±0.43^{a}	1.91±1.33^{a}	1.54±0.79^{a}
SFA	29.71±1.08^{a}	28.13±1.33^{a}	27.05±3.95^{a}	34.3±6.54^{a}
MUFA	28.53±2.63^{a}	22.67±2.15^{a}	22.83±3.45^{a}	27.68±4.86^{a}
PUFA	41.76±2.32^{ab}	49.19±2.48^{b}	50.09±6.12^{a}	38.01±3.63^{b}
EPA + DHA	28.34±2.11^{ab}	32.73±1.79^{a}	31.16±2.16^{a}	22.787±3.08^{b}
Σ ω3	33.44±2.11^{ab}	40.08±2.48^{a}	35.51±2.46^{ab}	29.97±3.17^{b}
Σ ω 6	5.47±0.74^{b}	6.29±0.55^{b}	12.32±3.81^{a}	4.83±0.6^{b}
Σ ω3 / Σ ω 6	6.84±0.71^{a}	6.93±0.83^{a}	4.1±1.16^{a}	6.7±0.96^{a}

CONCLUSION

The TFA content in both the white (D1) and the red muscles (RM) of swordfish varies significantly according to the season and the origin of the sample. A substantial seasonal variation of the TFA is to be noted in spring (D1) and in summer (RM). The SFA do not change significantly during the seasons. Low contents of SFA are observed in spring for D_1 and in autumn and winter for RM.

The MUFA and oleic acids are strongly correlated. Its involvement as metabolic energy source explains the decrease of the oleic acid in D_1 (in winter and spring) and in the RM (in winter). The PUFA make up the biggest part in the muscles. In D_1, the PUFA were found to undergo seasonal variations, peaks being observed in winter and spring, whereas no variations were observed in the RM. Their high percentages seem to be due to the abundance of the PUFA (n-3). The DHA prevails among the PUFA (n-3), with significant seasonal variations in the white muscle (D1). The seasonal

influence on the (n-6) PUFA appears only in the white muscle with a peak in spring. The linoleic acid is the most abundant of the PUFA (n-6) (in D1) with a significant variation in spring. The ratios (n-3) / (n-6) established for D1 are high in summer, autumn and winter but low in spring.

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