GLOBAL CHEMICAL COMPOSITION OF THE MEDITERRANEAN HORSE MACKEREL *TRACHURUS MEDITERRANEUS*: VARIATIONS ACCORDING TO MUSCLE TYPE AND FISH SEX

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ABSTRACT: This work investigates the global chemical composition of the Mediterranean horse mackerel *Trachurus mediterraneus* (Steindachner, 1863), a coastal catch fish of the Gulf of Gabes (Tunisia). The moisture, protein, fat and ash contents variations of the fish muscle, according to the sex and the muscle type (white and red muscles) were examined. The global chemical composition of the eviscerated fish was also determined. These variations are considerable as regards moisture and fat contents. The male of eviscerated *Trachurus mediterraneus* presents a slightly more elevated fat content than the female (2.20 ± 0.01 against 1.60 ± 0.01 %). Calcium and sodium contents are high (234.51 ± 19.01 and 135.36 ± 26.29 mg / 100 g respectively) whereas those of iron and magnesium are low (1.43 ± 0.19 and 28.74 ± 5.25 mg / 100 g respectively). Unlike the red muscles which are rich in fat (9.86 ± 0.01 %), the white muscles are rich in moisture and protein (73.93 ± 0.70 % and 24.78 ± 0.14 % respectively).

Key words: *Trachurus mediterraneus*, global chemical composition, mineral elements, sex, muscle.

RÉSUMÉ : Le but de ce travail est d'étudier la composition chimique globale du saurel *Trachurus mediterraneus* (Steindachner, 1863), espèce de poisson de la pêche côtière du golfe de Gabès (Tunisie). Les variations des teneurs en eau, en protéines, en lipides et en cendres dans le muscle des poissons, en fonction du sexe et la nature du muscle (muscle rouge, muscle blanc) ont été examinées. La composition chimique globale du poisson éviscéré a été aussi déterminée. Ces variations sont considérables pour les teneurs en eau et en lipides. Le saurel *Trachurus mediterraneus* éviscéré entier mâle présente une teneur en lipides plus élevée que la femelle (2.20 ± 0.01 contre 1.60 ± 0.01 %). Le saurel contient des teneurs en calcium et en sodium élevées (234.51 ± 19.01 et 135.36 ± 26.29 mg / 100 g respectivement) alors que le fer et le magnésium sont présents en faibles teneurs (1.43 ± 0.19 et 28.74 ± 5.25 mg / 100 g respectivement). Les muscles rouges du saurel sont plus riches en lipides que les muscles blancs (9.86 ± 0.01 %). De plus, ils sont moins riches en eau. Les muscles blancs sont plus riches en eau et en protéines que les muscles rouges (73.93 ± 0.70 % et 24.78 ± 0.14 % respectivement).

Mots clés : *Trachurus mediterraneus*, composition chimique globale, éléments minéraux, sexe, muscle.

INTRODUCTION

Fish muscle presents high biological and nutritive values [1]. The muscle of fatty fish has an energetic value equivalent to that of the mammal meat, but it has the advantage of containing a greater quantity of iodine, phosphorus, liposoluble vitamins, especially vitamin D. The fish proteins present an effective protein coefficient which is higher than that of ox proteins and eggs. Mackerel is a semi pelagic carnivore fish characterized by red muscles developed under the skin along the body on its sides used for propulsion. The proportions of red and white muscles vary

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largely according to each fish species. The red proportion becomes larger in the active pelagic fish which swim continuously such as sardine, tuna and mackerel [2]. Moisture, protein and fat contents are the major components of the marine products. Moisture and fat contents are very variable. They vary from 28 to 90 % (wet basis) for moisture and from 0.20 to 64 % for fat (wet basis) [3]. The chemical composition of a fish muscle varies greatly from one species to another depending on environment, nutrition and season [4-8]. For the same species, the chemical composition of the fish could vary according to the sex, the meat localisation in the fish body [9] and to the muscle type (red and white).

A review of the literature has revealed information about proximate composition of mediterranean horse mackerel. The moisture, proteins and fat contents of *Trachurus mediterraneus* (Northern Greece) are significantly affected by seasonal sampling [8]. Microorganisms are found on the outer surfaces (skin and gills) and in the gastro-intestinal tract but not in the flesh of healthy live or newly-caught Mediterranean horse mackerel. This fish has a good microbiological quality ([8,10,11]. There is little data in literature concerning the effect of the type of the muscle (red and white) and the fish sex on the fish global chemical composition.

According to the literature [12], this fish species reproduces in summer; its first sexual maturity is about 22 cm overall length. The gonads are filament, white for males and red for females. The mediterranean horse mackerel belongs to the Carangidaes family. Mackerel was found throughout the Mediterranean, Marmara and Black seas, and along the eastern Atlantic coast from Morocco to the English Channel [12-13]. It is a migratory species, live in large benches of surface until approximately 600 m of depth on muddy and sablo-muddy funds, closer to the coast in summer [12]. The fish nutrition is especially, based on small fishes (sardines and anchovy) and shellfish (shrimps and mysidacés). Mackerel is identified by the presence on the side line scuttles and scales in a number from 75 to 89 [12].

The aim of this work is to study the global chemical composition of the eviscerated *Trachurus mediterraneus*. The mineral elements (Ca, Na, Mg and Ir) were also determined. The effects of the fish sex and the type of the muscle (red and white) on the global chemical composition were investigated.

MATERIAL AND METHODS

1. Raw material

Trachurus mediterraneus (Steindachner, 1863) was obtained from the local fish market of Sfax (south of Tunisia) in spring 2006. Figure 1 shows the chart of the gulf of Gabes, Mediterranean Sea of Tunisia.

In order to separate the red muscle from the white muscle, one initially preceded by removing the skin. After that the red muscle is separate visually and easily with a blade from the white muscle. The red muscle has a red colours and the white muscle has a white colours. Figure 2 shows the eviscerated fish, the red and white muscles.

The length (21.95 ± 0.85 mm) and the weight (106.50 ± 4.90 g) of the fish with and without viscera were measured in order to select homogenous samples. Red and white muscles were analysed separately. The number of samples used for this study was 35.

31.32 % of the fishes were indeterminate that sex was indefinite, females and males were about 23.83 % and 44.84 % respectively.

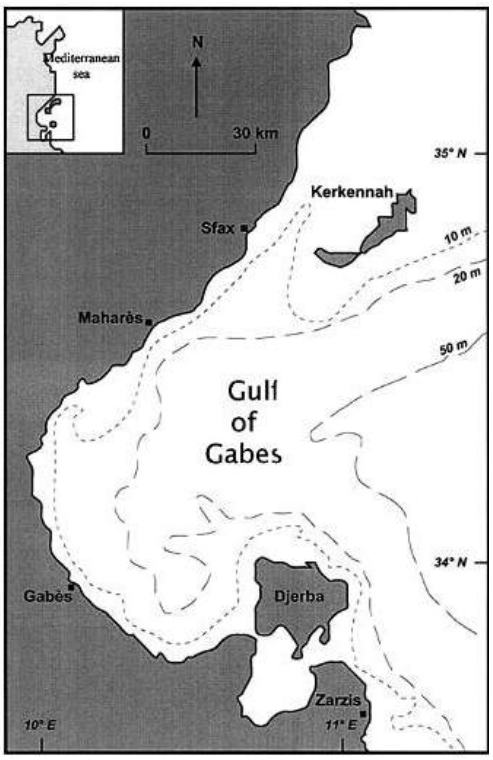

Figure 1: Chart of the Gulf of Gabes.

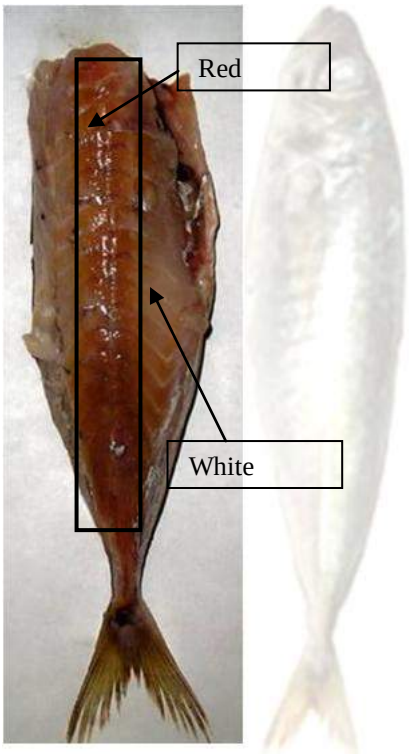

Figure 2: Eviscerated *Trachurus mediterraneus* and corresponding red and white muscles.

2. Global chemical analysis

Global chemical analysis was performed according to AOAC (2000) [14]. Males and females were analyzed separately (8 females and 8 males). Moisture content was measured by samples dehydration in an oven to a constant weight (48 hours) at 105°C. The samples weight was determined by using a precision scale 10^{-4} g (Sauter). The dry fish powders were crushed by a Moulinex® blender and then divided into 3 lots for determining protein, fat and ash contents.

Crude protein was calculated from nitrogen content (N × 6.25) by using the Kjeldahl method (The mineralisator BUCHI : K- 424, the Scrubber BUCHI : B- 414 and the distillator BUCHI : B-324, Labortechnik AG, CH-9230 Flawil , Switzerland) [15-14]. This method is based on digesting 0.2 g of dry sample by 10 ml of sulfuric acid.

Fat was extracted by Soxhlet apparatus in series (Electrotermal.ME heater, United Kingdom) using chloroform as solvent. A sample of 3 g of dry matter was extracted by 120 ml of chloroform for every extraction [9].

Ash was determined by incinerating 0.5 g of dry sample at 550°C for 4 hours until constant weight [14].

The mineral elements contents (calcium: Ca, sodium: Na, magnesium: Mg and iron: Ir) were determined for eviscerated fish. An amount of 4 g of weighed fish samples incinerated in a muffle at 550° C until complete mineralization (≈ 4 h) was used. The dry fish powder was treated with 15 ml of nitric acid diluted (1: 4) with demineralized pure water. Mineralize is filtered and adjusted at 100 ml in demineralized pure water [14]. The mineral element concentrations of Ca, Na, Mg and Ir in the solution were measured using a Z6100 polarized Zieman Atomic Absorption Spectrophotometer (Hitachi, Japan).

Moisture analyses were repeated 8 times. Protein, fat, ash and the Ca, Na, Mg and Ir contents analyses were repeated three times. The moisture, protein, fat and ash measurements were performed for the eviscerated fish and for the red and the white muscles.

3. Determination of red and white fractions

The red and white muscle fractions (% RM and % WhM) were calculated:

- according to the weight of the total muscle as follows:

$$\%WhM_{TM} = \frac{W_{WhM}}{W_{TM}} \times 100 \text{ and } \%RM_{TM} = \frac{W_{RM}}{W_{TM}} \times 100 \quad (1)$$

where W: the weight (g); TM, WhM and RM are the total muscle, the white muscle and the red muscle respectively.

- according to the weight of the eviscerated fish as follows:

$$\%RM_{ev} = \frac{W_{RM}}{W_{ev}} \times 100 \text{ and } \%WhM_{ev} = \frac{W_{WhM}}{W_{ev}} \times 100, \quad (2)$$

where W_{ev}: weight of the eviscerated *Trachurus mediterraneus.*

Equation 1 was used to determine the fractions of red and white muscles in the total muscle of males and females. Whereas, equation 2 was used to determine the fractions of red and white muscles in the males and females eviscerated fish.

4. Determination of hepato-somatic index

The hepato-somatic index, HSI, was calculated as follows:

$$HSI = \frac{W_h}{W_{ev}} \times 100, \quad (3)$$

where W_h is the liver weight and W_{ev} is the eviscerated fish weight.

5. Statistical analysis

Moisture, protein, fat and ash contents are presented as mean values, MV, (g / 100g fresh fish) ± error deviation (E D). The coefficient of variation (CV) is calculated as follows:

$$CV = \frac{ED}{MV} \times 100 \quad (4)$$

All statistical analysis were performed using SPSS software® version 11.0 (Statistical Package for Social Sciences). Two statistical tests have been performed on the experimental data:

- In order to determine the main factors of variation of the global chemical composition (sex, muscle type); an analysis of variance was performed for moisture, protein, fat and ash contents measured in the eviscerated fish, red and white muscles.
- Correlation matrixes were established between different component contents (moisture, protein, fat and ash) measured in the both muscles (red and white) and in the eviscerated fish.

Every factor presenting a p-value (p) inferior to 0.05 was considered significant.

RESULTS

The variation coefficients values of moisture, protein, fat and ash measurements (g/100 g of fresh fish) determined for the white and red muscles and the eviscerated fish were inferior to 5 %.

1. Composition of the eviscerated fish

Table 1 shows the experimental data of the chemical composition of the eviscerated mediterranean horse mackerel and red and white muscles according to sex.

Table I: Global chemical compositions (g/100g of fresh weight) of the eviscerated fish, red and white muscles of the fish according to sex. (MC: moisture content, PC: protein content, FC: fat content, AC: ash content, Fe: female, Ma: male, MV ± ED: mean value ± error deviation, F_{ev}: eviscerated fish, WhM: white muscle and RM: red muscle)

	MC		PC		FC		AC	
	Ma	**Fe**	**Ma**	**Fe**	**Ma**	**Fe**	**Ma**	**Fe**
F_{ev}[a]	70.47 ± 1.05	74.87 ± 2.43	19.98 ± 0.34	18.34 ± 0.22	2.16 ± 0.01	1.61 ± 0.01	2.00 ± 0.04	2.36 ± 0.07
WhM[b]	74.15 ± 0.63	73.71 ± 0.70	24.92 ± 0.01	24.64 ± 0.01	2.05 ± 0.01	2.17 ± 0.01	1.22 ± 0.01	1.24 ± 0.01
RM[c]	68.44 ± 1.64	67.98 ± 0.88	21.15 ± 0.01	22.64 ± 0.10	9.86 ± 0.01	9.87 ± 0.01	1.26 ± 0.01	1.32 ± 0.09

(a): contents expressed in g / 100 g of eviscerated fish
(b) and **(c):** contents expressed in g / 100 g of white or red muscles respectively

The highest moisture content was located in the female eviscerated fish (74.87 ± 2.43 % against 70.47 ± 1.05 % for males). The corresponding fat contents are (2.16 ± 0.01 % for males against 1.61 ± 0.01 % for females). The males of the eviscerated fish present the greater proportion in protein content (≈19.98 ± 0.34 %). Females are richer in ash 2.36 ± 0.07 % than the males of eviscerated mackerel (2 ± 0.04 %).

The variance analysis of moisture, protein, fat and ash contents according to the factors sex and type of muscle is presented in Table 2.

Table II: Variance analysis of moisture, protein, fat and ash contents according to the factors sex and fish body locality (NS = not significant p >0.05, S = significant for 0.01< p < 0.05, HS = highly significant, p < 0.001).

Locality	**Factors**	**Components**	**F (Fisher number)**	**p (p-value)**	**Significance level**
Eviscerated fish	**Sex**	**Moisture**	34.67	$<10^{-3}$	HS
		Protein	148.60	$<10^{-3}$	HS
		Fat	7840.63	$<10^{-3}$	HS
		Ash	8.85	0.01	S
Red Muscles	**Sex**	**Moisture**	4056	$<10^{-3}$	HS
		Protein	16537.5	$<10^{-3}$	HS
		Fat	6.25	0.06	NS
		Ash	54	0.002	HS
White Muscles	**Sex**	**Moisture**	19837.5	$<10^{-3}$	HS
		Protein	1176	$<10^{-3}$	HS
		Fat	216	$<10^{-3}$	HS
		Ash	6	0.07	NS
Total muscle [(a)]	**Sex**	**Moisture**	20916.75	$<10^{-3}$	HS
		Protein	4446.75	$<10^{-3}$	HS
		Fat	168.10	$<10^{-3}$	HS
		Ash	48	$<10^{-3}$	HS
	Type of muscle	**Moisture**	866718.8	$<10^{-3}$	HS
		Protein	289230.8	$<10^{-3}$	HS
		Fat	2166902	$<10^{-3}$	HS
		Ash	108	$<10^{-3}$	HS

Sex ×Type of muscle	**Moisture**	2976.75	$<10^{-3}$	HS
	Protein	13266.75	$<10^{-3}$	HS
	Fat	96.100	$<10^{-3}$	HS
	Ash	12	0.01	S

[a] Analysis made for calculated values of moisture, protein, fat and ash contents in total muscle (using equation 1).
HS: p value $\leq 10^{-3}$; S: 0.01 <p< 0.05; NS :p value > 0.05

For the eviscerated fish, moisture, protein, fat and ash contents varied significantly according to sex ($0.01 \leq p \leq 0.001$).

The mineral contents of Na, Ca Mg and Ir of eviscerated fish was determined for both sexes. Figure 3 shows the composition of Na, Ca, Mg and Ir (mg / 100 g of fresh whole eviscerated fish) of male (Ma) and female (Fe) of the Mediterranean horse mackerel.

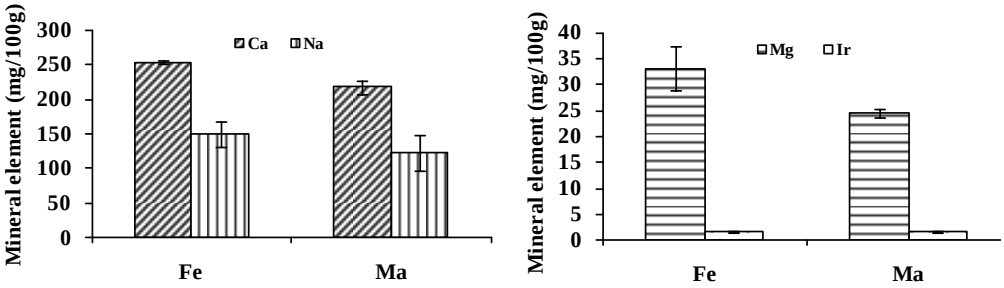

Figure 3: Composition of Na, Ca, Mg and Ir (mg / 100 g of fresh eviscerated fish) of both sexes of Mediterranean horse mackerel.

The rough content orders were: Calcium 〉 sodium 〉 magnesium 〉 iron. The variability between males and females concerning mineral elements is significant for calcium ($F=26.02$; $p<10^{-3}$) and magnesium ($F=8.05$; $p=0.04$). The females are richer in minerals than males. For calcium, females contain 258.70 ± 2.78 mg /100 g of fish against 216.80 ± 2.61mg / 100 g for males. Magnesium content represents 33 ± 0.87 mg /100 g for females and 21.50 ± 0.42 mg / 100 g for males. Sodium is about 149 mg / 100 g for females against 121.7 mg / 100 g for males. Finally, iron content is similar for both fish sexes 1.52 mg / 100 g for females and 1.35 mg / 100 g for males.

2. Composition of white and red muscles

Fat content differed not only from one muscle to another, but also inversely to moisture content. As shown in Table 1, the fat content ranged from a low content, 2.05 ± 0.01 % for male white muscles to a high content, 9.87 ± 0.01 % for female red muscles. Red muscles contained more fat than white muscles (4-5 times as much). Red muscles of this species contained the same fat content for both sexes. For the white muscles, moisture, protein and fat contents varied significantly according to sex ($p<0.001$). But, ash content presents insignificant difference according to sex ($p= 0.07$) (Table 2). For the red muscle moisture, protein and ash contents varied significantly according to sex ($p<0.001$). But, fat content presents insignificant difference according to sex ($p= 0.06$). When the moisture, protein, fat and ash contents in the total muscle, were estimated by using equation 1, the Anova analysis shows that the factor sex, type of the muscle and the interaction of both factors has significant effects on the global chemical composition of the Mediterranean horse mackerel muscle ($0.01 \leq p \leq 0.001$).

The proximate chemical composition of the fish muscles showed a high nutritional value. In fact, protein content varied from 18.34 ± 0.22 g / 100 g fresh fish (female eviscerated fish) to 24.92

± 0.01 g / 100 g fresh fish (male white muscle). The hepatosomatic index was 1.65 ± 0.05 % for males and 1.68 ± 0.11 % for females. Thus the liver represents about 2 % of the weight of eviscerated mackerel.

Table 3 shows the moisture content of the liver and the fractions of the white and red muscles of both sexes of *Trachurus mediterraneus*.

Table III: Moisture content of the liver and the fractions of red and white muscles (RM and WhM) of *Trachurus mediterraneus* according to sex (Ma or Fe), total muscle (TM) and eviscerated fish (ev).

Sex	Moisture content of the liver (%)	$\%RM_{TM}$	$\%WhM_{TM}$	$\%RM_{ev}$	$\%Wh_{ev}$
Ma	75.47 ± 0.41	11.42 ± 0.78	88.57 ± 0.78	6.14 ± 0.18	45.33 ± 1.91
Fe	72.36 ± 0.46	11.81 ± 0.78	88.18 ± 1.03	5.78 ± 0.68	43.74 ± 1.27

The moisture content measured in the liver revealed that males were more hydrated than females (75.47 ± 0.41 % and 72.36 ± 0.46 %, respectively). The lowest moisture content was recorded in red muscle (67.98 ± 0.88 % for females and 68.44 ± 1.64 % for males of the Mediterranean horse mackerel (**Table I**). Since the moisture content was inversely related to that of fat [8,9]. The muscle or organ more hydrated should had the lowest fat content, it could be concluded that in this period of analysis *Trachurus mediterraneus* stocked fat in red muscles and not in the liver.

3. Effect of the muscle type

The red muscles represent 11.42 ± 0.78 % of the total muscle for males and 11.81 ± 1.02 % for females. In the contrary, the white muscles represent 88.57 ± 0.78 % of the total muscle for males and 88.18 ± 1.02 % for females (Table 3). The fractions of red and white muscles according to total muscles present insignificant difference between both sexes. The high fractions of white and red muscles in the male eviscerated fish (45.33 ± 1.91 % and 6.14 ± 0.18 %) correspond to high protein and fat contents in male eviscerated fish (19.98 ± 0.34 % and 2.16 ± 0.01 %, Table I). The white muscle of both sexes contains mean values equal to 73.93 ± 0.22 % for moisture; 24.80 ± 0.14 % for proteins; 2.11 ± 0.06 % for fat and 1.23 ± 0.01 % for ash. The red muscle of both fish sexes presents an average composition equal to 68.22 ± 0.24 % for moisture, 21.67 ± 0.52 % for proteins, 9.86 ± 0.005 % for fat and 1.27 ± 0.015 % for ash. For both sexes the fraction of the red muscles is weak compared to that of the white muscles (≈ 11.62 % ± 0.19 against ≈ 88.38 % ± 1.30) with a relative richness of the red muscles in fat 9.86 ± 0.005 % and white muscles in protein 24.80 % ± 0.14.

4. Correlation between different chemical components

Correlation matrixes between moisture, protein, fat and ash contents of the eviscerated fish, white muscle, red muscle and total muscle are presented in Table 4, where R is the coefficient of correlation and p, is the p-value.

Table 4: Correlation matrixes of moisture, protein, fat and ash contents established for red and white muscles (separately and confounded) and in the eviscerated fish (A: Ash, P: Protein, F: Fat, M: Moisture and n: number of samples. R: correlation coefficient, p: p value determined at 95% of significance, significant for $p<0.05$).

Correlation	WhM (n=16)		RM (n=16)		Total muscle (n=32)		Fev (n=16)	
	R	**p**	**R**	**p**	**R**	**p**	**R**	**p**
P – M	0.990	$< 10^{-3}$	-0.990	$< 10^{-3}$	0.950	$< 10^{-3}$	-0.780	$< 10^{-3}$

F– M	-0.990	$< 10^{-3}$	-0.786	0.064	-0.990	$< 10^{-3}$	-0.840	$< 10^{-3}$
F – P	-0.980	0.001	0.778	0.069	-0.970	$< 10^{-3}$	0.950	$< 10^{-3}$
A – M	-0.770	0.071	-0.950	0.003	-0.830	0.001	0.590	0.016
A – P	-0.770	0.071	0.970	0.001	-0.640	0.024	-0.623	0.010
A – F	0.770	0.075	0.703	0.119	0.780	0.002	-0.610	0.011

A negative correlations for «fat-moisture», «fat-protein», «ash- moisture» and « ash-protein » contents and positive correlations for «fat-ash» and «protein - moisture» contents for the white muscle of *Trachurus mediterraneus* were showed. For the red muscle, «fat-protein», «ash-protein» and «fat-ash» present positive correlations and negative correlations were observed with «protein-moisture», «fat-moisture» and «ash- moisture». The eviscerated fish showed four negative correlations: « protein - moisture », «fat-moisture», «ash- protein» and «fat-ash» and positive correlations for «fat-protein» and «ash- moisture». The most significant negative correlation is «fat – moisture» obtained for white muscle, total muscle and for the eviscerated fish ($p < 10^{-3}$ and $-0.840 < R < -0.99$). « Protein - moisture » is also a strong correlation, but it is negative for red muscle ($R = -0.990$, $p < 10^{-3}$) and the eviscerated fish ($R = -0.780$, $p < 10^{-3}$); and positive for white muscle ($R = 0.990$, $p < 10^{-3}$) and the total muscle ($R = 0.950$, $p < 10^{-3}$).

The statistical parameters (correlation coefficient, R and p values) were improved if each muscle was examined separately (R increases and p decreases). On the other hand, the intensity of the correlations varied according to the type of the muscle. Indeed, white muscle showed a strong correlation «fat – moisture». Whereas, red muscle showed insignificant «fat – moisture» correlation. Furthermore, for white muscle and total muscle, all correlations are the same (negative or positive). This could be attributed to the fact that the total muscle was constituted essentially by white muscle (more than 88 % of the total muscle, Table 3). Besides, « ash - fat » correlation which was negative and significant in the eviscerated fish became positive and insignificant for white and red muscles. The expression of the relationship between fat and moisture contents obtained for the experimental data obtained of eviscerated fish, the red and the white muscles:

Fat content = $- 1.005 \times$ Moisture content + 77.82; ($R = - 0.952$; $p < 10^{-3}$, $n = 28$).

DISCUSSION

A major part of fat content of Mediterranean horse mackerel is stocked in red muscles (Table 1). This result is in relation with the period of pre-spawning during which the fishes stock their fat in red muscles or in liver for spending them during the maturation of the gonadic products. Red muscle represents an important part of muscle in terms of fat metabolism, and the main part of fish consumed is generally muscle. The white muscle contains low content of fat and is richer in protein than red muscle. The same result was shown by Njinkoué et al. [16] with *Sardinella aurita* and *Sardinella maderensis*. The source of energy producing ATP in the white muscle is glycogen whereas the red muscle can also use the fat in addition to protein. Another major difference between red and white muscles comes from the fact that the red muscle contains much more mitochondrion that the white muscle, thus enabling it to operate a significant aerobic metabolism of energy producing CO_2 and H_2O. The white muscle more generally produces energy by anaerobic metabolism and accumulates lactic acid which will have to be transported to the liver where it is metabolized. Moreover, the red muscle would have functions similar to those found in the liver [3]. In red muscle and liver, fat undergo more enzymatic activities than in white muscle, producing large amounts of free fatty acids in oils [17].

The various metabolic diagrams found in the both types of muscles make that the white muscle is adapted perfectly to the significant but short efforts whereas the red muscle is planned for continuous motions but is lower. Virtually, every tissue in the body produces eicosanoids and it has a wide range of physiological actions, in blood clotting, the immune response, the inflammatory response, cardiovascular tone, renal function, neural function and reproduction [18].

The correlations matrixes between the different analysed compounds were also established for each muscle separately. The correlation type was not the same for white and red muscles; the intensity of the correlations determined for the muscles could be affected by the type of the muscle. The fish muscle composition showed a strong «fat – moisture» correlation, and a strong « protein - ash» correlation (Table IV). Moisture content is usually inversely related to fat content. This result is in agreement with literature [9,19-21]. This relationship has been observed in pelagic fish and reported as a consequence of the fish maintaining constant density [8, 22].

Tzikas et al. [8] found seasonal variations in the fat content of *T. mediterraneus* muscle of the coast of Greece. The fat content varied between 0.4 % in September to 2.8 % in April. This variation is obtained for total muscle containing the skin. The mean fat content obtained for *T. mediterraneus* muscle during the period of April - May was about 2.45 ± 0.35 % a value lower than that found in the present study (≈ 6 ± 0.03 %). This difference in fat content could be explained by the fact that skin has less fat concentration than red muscle. Njinkoué et al. [16] studied the red and white muscle composition of three species of fish: *Sardinella maderensis*, *Sardinella aurita* and *Cephalopholis taeniops*. The red muscles contain 21 ± 0.9 % for S. *maderensis* and 10 ± 0.9 % for S. *aurita*. Inversely, the fat contents were lower in white muscles (5 ± 0.7 for S. *maderensis* against 3.5 ± 0.4 for S. *aurita)*. Therefore, the red muscle appears to be the region of storage of fat content. Indeed, the highest fat content is located in the red muscles (9.86 %). However, the highest protein content was found in the white muscles (24.78 ± 0.14). In general, the males' muscles were more developed than females' muscles when the fractions of red and white muscles (determined according to the eviscerated fish) are greater for males than females.

The effect of sex depends on the type of fish sample and on the analysed compounds. It is significant for the moisture and protein of white and red muscles. Whereas, the effect of sex is insignificant for fat content of red muscle and ash content of white muscle. The effect of sex is also significant for the global chemical composition of the eviscerated fish. Therefore, the proportion of red and white muscles should be evaluated to differentiate between male's and female's compositions. Compared to the chemical composition of the eviscerated fish, the protein and fat contents are lower than those of the total muscle. But, the ash contents are higher for the eviscerated fish because it contains the carcass and the skeleton. The composition of Na, Ca, Mg and Ir (mg / 100 g of fresh whole eviscerated fish) of male (Ma) and female (Fe) of the Mediterranean horse mackerel shows the rough content orders: calcium 〉 sodium 〉 magnesium 〉 iron. The same sequences are already found [23-25].

According to literature, the calcium content analyzed in the edible parts of the fish is about 40 mg / 100g [26], but in this study the content, is 5 times higher (200 mg / 100g). This can be allotted to the fact that this analysis is carried out on the eviscerated fish containing the skeleton, the head and the fins which are rich in phosphorus and calcium. The magnesium, sodium and iron contents are similar to those reported in literature [26]. In fact these latter are present in muscle only. The last observation could be attributed to the richness of red muscle in haemoglobin which contains iron.

CONCLUSION

The variations of moisture, protein, fat and ash contents of the Mediterranean horse mackerel *Trachurus mediterraneus*, a coastal catch fish of the Gulf of Gabes is significant

according to the sex and the type of the muscle (white and red muscles). These variations are considerable for moisture and fat contents. The factor sex is significant for the global chemical composition of the eviscerated fish *Trachurus mediterraneus*. The fish contains considerable contents of calcium and sodium whereas iron and magnesium are presented in small quantities. The variability of calcium and magnesium is significant for both sexes of *Trachurus mediterraneus*. The fish muscle composition showed strong «fat – moisture» and « protein - ash» correlations. The factor type of the muscle is significant for the total muscle. The red muscles are richer in fat than white muscles. However, the white muscles are richer in moisture and protein than the red muscles.

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