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Experimental and statistical investigations of the global chemical composition of six trawling fish of the Gulf of Gabès (Mediterranean Sea)

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*The aim of this work is to study the variation of the global chemical composition of six fish species (*Lithognathus mormyrus, Mullus barbatus, Mullus surmuletus, Pagellus erythrinus, Pagrus caeruleostictus *and* Dentex maroccanus*) caught by the trawl of the Gulf of Gabès (Mediterranean Sea). The variations of the chemical contents of the fish as a function of size, sex, organs and parts of the muscle were examined between December 2005 and May 2006. ANOVA indicated that the global chemical composition was significantly affected by two factors: species and body locations (parts of the muscle). The correlation matrix established between the chemical contents showed two highly significant correlations (fat–moisture and protein–ash). The discriminant analysis allowed the distribution in the space of fish species into five groups according to their moisture, proteins, fat and ash contents. The analysis of the fat content in the parts of the fish body revealed the presence of a concentration gradient.*

Keywords: fish, trawling catch, chemical composition, discriminant analysis

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INTRODUCTION

The fishery sector plays an important role in the economy of coastal countries. In Tunisia, the national contribution of the trawling catch during the first eight months of 2008 was equal to 12,382 tons against 11,052 tons for the same period of 2007 (DGPA, 2008), thus increasing by 12%. The Gulf of Gabès constitutes one of the most productive zones of Tunisia and the Mediterranean Sea. It extends from the short-nap cloth Kapoudia (Chebba) to the Libyan border. The length of the coast of this area is estimated to be 750 km (Bradai *et al.*, 1995). This continental shelf is characterized by a soft slope and an average sea temperature of 13°C in winter and 26°C in summer (Ktari-Chakroun & Azouz, 1971). Considering the particular morphological and hydrological characteristics of the Gulf of Gabès, it has the aspect of a zone which supports the reproduction and development of small marine species. Ben Othmen (1971) noted the existence of 208 marine species in this area, at depths between 0 and 300 m, for this reason, several traditional and recent catch techniques are used in this area, such as coastal, small pelagic and shell fishing in addition to sponge fishing and the trawl.

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Sea products form a very nutritious part of man's diet. In fact, fish are rich in vitamins and contain a selection of valuable minerals and hydro-soluble vitamins. Besides, fish proteins contain all the essential amino acids and fish fat contains the n-3 highly unsaturated fatty acids, such as omega-3 and omega-6 (Uauy-Dagach & Valenzuela, 1996). These acids have beneficial effects on bone formation and metabolism, and the prevention of cardiovascular disease (Lauritzen *et al.*, 2000; Su *et al.*, 2003; Watkins *et al.*, 2003).

The aim of the present work is to examine experimentally and statistically the global chemical composition of six fish species caught by the trawl (*Lithognatus mormyrus, Mullus barbatus, Mullus surmilitus, Pagellus erythrinus, Pagrus caeruleostictus* and *Dentex maroccanus*) of the Gulf of Gabès (Mediterranean Sea).

MATERIALS AND METHODS

Biological material

Among the most selected edible groups by the benthic exploitation of the Gulf of Gabès, six fish species caught by the trawl were examined: four species belong to the Sparidae family (*Lithognatus mormyrus* Linnaeus, 1758, *Pagellus erythrinus* Linnaeus, 1758, *Pagrus caeruleostictus* Valenciennes, 1830 and *Dentex maroccanus* Linnaeus, 1758) and the two other species to the Mullidae family (*Mullus barbatus* Linnaeus, 1758 and *Mullus surmilitus* Linnaeus, 1758). Fish samples were bought from the fish market of Sfax (Tunisia) and transported in ice to the laboratory for chemical analyses.

Experimental procedure

Fish having different sizes corresponding to the lengths summarized in Table 1 were examined.

All fish species were examined in the period between December 2005 and May 2006. According to the literature (Gharbi & Ktari, 1981; FAO, 1987; Bradai, 2000), in this period, all the species are in the same physiological state (out sexual activity).

Male and female samples were analysed separately. The fish were eviscerated and their organs (head, gonads, liver and viscera) weighed. The muscles were divided into six parts: three dorsal parts (P1, P2 and P3) and three ventral parts (P4, P5 and P6) as shown in Figure 1.

Chemical analysis

Moisture, protein, fat and ash analyses were performed for the parts of the muscle and head. The moisture content of the organs (head, liver, gonads and viscera) was also determined.

The measurements of protein, fat and ash contents were performed in triplicate, whereas moisture measurement was repeated 10 to 12 times. Results were expressed as mean value (g/100 g fresh muscle) ± repeatability standard deviation.

MOISTURE CONTENT

Moisture content was determined by dehydration of fresh samples at 105°C for 48 hours (AOAC, 1990). After moisture content determination, the dry matter was mixed and homogenized in a food blender (Moulinex ®). Then it was divided into different portions for further analysis.

FAT CONTENT

Fat content was determined by using the Soxhlet method (6 extractors). A sample of ≈3 g of dry fish powder was used. Extraction (≈6 hours) was made by using 120 ml of chloroform (AOAC, 1990).

PROTEIN CONTENT

A sample of ≈2 g of dried fish powder was used. Sulphuric acid (≈10 ml) was used for the determination of total nitrogen by using the Kjeldahl method (AOAC, 1975). Crude protein was deduced by multiplying total nitrogen content by the universal factor 6.25.

Table 1. Lengths of different fish species.

Abbreviations	Latin names of fish	Fish length (cm)
E1	*Lithognatus mormyrus*	13.80–19.20
E2	*Mullus barbatus*	13.00–16.50
E3	*Mullus surmilitus*	14.00–17.60
E4	*Pagellus erythrinus*	14.90–20.20
E5	*Pagrus caeruleostictus*	14.30–14.90
E6	*Dentex maroccanus*	17.00–19.00

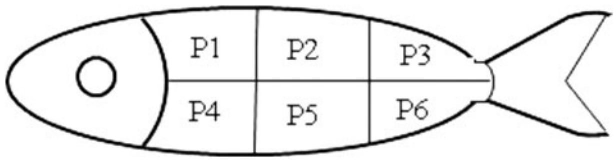

Fig. 1. Illustration of the six muscle parts localization in the fish body: three dorsal parts (P1, P2, P3) and three ventral parts (P4, P5, P6).

ASH CONTENT

Ash content was determined by incinerating the fish powder in a muffle furnace at 650°C for 3 hours (AOAC, 1984).

Statistical analysis

Statistical analysis was conducted by using SPSS (13.0) Software ®. Three statistical tests were performed on experimental data. The ANOVA was made on moisture, protein, fat and ash contents of the fish muscles in order to study the effects of the factors: size, sex, fish species and parts of the muscle on the global chemical composition of the muscle. Correlation matrices were established between quantitative variables (moisture, protein, fat and ash contents) measured on the fish muscle. The discriminant analysis was also performed in order to classify the examined fish into homogeneous groups according to their global chemical composition. For all statistical analysis, the level of significance was fixed at 5%. Every factor presenting a *P* value (*P*) inferior to 0.05 was considered significant.

RESULTS AND DISCUSSION

Proximate composition of fish muscles

The average global chemical composition (moisture, protein, fat and ash contents) of the muscles of the six fish species are shown in Table 2 (mean size and combination of sexes). The proximate global chemical composition of the examined fish muscle was in the same order of magnitude as that reported for fish by other authors (Oehlenschläger & Rehbein, 1982; Jhaveri *et al.*, 1984; Güner *et al.*, 1988; Oehlenschläger, 1990; Karakoltsidis *et al.*, 1995; Rossano *et al.*, 2005).

The fish muscles were characterized by a high content of protein and a low to moderate fat content. In fact, for all fish species, the protein content varied from 18.17±0.04% (*Pagrus caeruleostictus*) to 20.27±0.06% (*Mullus barbatus*). The fat content of fish muscles ranged from 2.05±0.17% (*Lithognatus mormyrus*) to 6.05±0.1% (*Mullus barbatus*). According to Silva & Chamul (2000), fish are usually classified as fatty (>10% fat), moderately fat (5–10%) and lean (<5%). Considering the last classification, all examined fish species are considered as lean fish with the exception of *Mullus barbatus* which is considered to be a moderately fat fish. The protein content of fish muscles remained high (>18%). This was consistent with the fact that the lean fish muscle is characterized by high protein content (Vareltzis, 1997).

Variation of fat content in the fish body

Figure 2 shows the variation of the fish fat content according to different body locations (the head, the dorsal parts and the ventral parts of the muscle).

Table 2. Proximate muscle composition (g/100 g fresh muscle) of the studied fish species (mean size and combined sexes).

Fish species	Moisture (%)	Fat (%)	Protein (%)	Ash (%)
Lithognatus mormyrus	75.18 ± 0.96	2.05 ± 0.17	18.92 ± 0.05	2.41 ± 0.05
Mullus barbatus	70.92 ± 1.20	6.05 ± 0.10	20.27 ± 0.06	1.62 ± 0.09
Mullus surmilitus	73.53 ± 1.15	4.65 ± 0.15	19.57 ± 0.08	1.41 ± 0.08
Pagellus erythrinus	72.87 ± 1.10	3.18 ± 0.20	19.52 ± 0.08	3.08 ± 0.08
Pagrus caeruleostictus	73.83 ± 1.05	2.92 ± 0.09	18.17 ± 0.04	2.86 ± 0.07
Dentex maroccanus	73.64 ± 0.87	2.33 ± 0.08	19.39 ± 0.05	3.60 ± 0.04

A decreasing gradient of fat content was observed throughout the fish body. The head of the fish contained higher amounts of fat (≈9.38 ± 0.2 g/100 g) than the muscle (≈3.42 ± 0.1 g/100 g). Besides, fat content of the muscle varied with the fish body location. The highest fat content was located in the anterior region of the ventral parts of the muscle (≈5.01 ± 0.17 g/100 g) and the lowest fat content was in the tail region parts (≈2.63 ± 0.15 g/100 g). The last observation is in agreement with previous studies. Bell *et al.* (1998) reported that for farmed Atlantic salmon, the highest fat level was located in the region immediately in front of the dorsal fin and the lowest fat level was in the tail region. In the same way, Thakur *et al.* (2002) documented a large variation of fat content in the body of yellowtail (*Seriola quinqueradiata*). Therefore, for the eventual valorization of fish species, it is advisable to use the dorsal parts characterized by a high content of proteins and a low fat content. On the other hand, for the oil extraction from fish, it is more interesting to use the fatty meat ventral parts. Moreover, the large variation of muscle fat content according to the muscle location indicates a promising scope for the dietary manipulation of fish meat in order to produce different fish parts with consumer-desired lipid levels.

ANOVA of fish muscle composition

The moisture, protein, fat and ash contents of the fish muscle were examined according to the factors: size, species, sex and the six parts of the fish muscles. Table 3 recapitulates the result of ANOVA.

The global chemical composition (moisture, protein, fat and ash) of the muscle was significantly affected by both fish species and the location in the fish muscle (*P* value <0.05, R^2 ranging from 0.92 for moisture to 0.99 for ash). The variation of the global chemical composition of the fish according to the muscle location was also reported by many authors (Bell *et al.*, 1998; Thakur *et al.*, 2002).

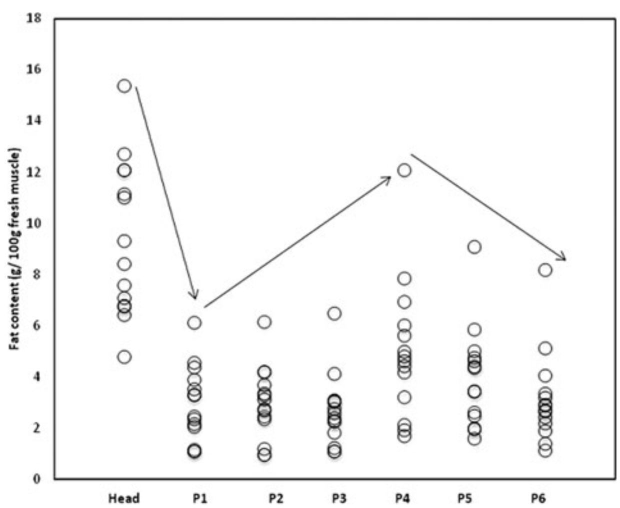

Fig. 2. Variations of fat content (g/100 g fresh muscle) according to the dorsal and ventral parts of the muscles and the head of the fish species (combination of fish species) P1, P2, P3: the dorsal muscle parts P4, P5, P6: the ventral muscle parts.

Table 3. Variance analysis of the fish muscles composition according to the factors size, sex, fish species, parts of the muscle and their interactions.

Factor	Multivariate ANOVA	Fisher number	*P* value	Coefficient of variation (R^2)
Size	Moisture	7.336	0.014^{*}	0.920
	Protein	4.942	0.038^{*}	0.958
	Fat	9.861	0.055^{NS}	0.976
	Ash	3.801	0.065^{NS}	0.996
Fish species	Moisture	12.367	$<10^{-3***}$	0.920
	Protein	4.441	0.007^{**}	0.958
	Fat	43.833	$<10^{-3***}$	0.976
	Ash	178.265	$<10^{-3***}$	0.996
Sex	Moisture	0.055	0.817^{NS}	0.920
	Protein	1.074	0.312^{NS}	0.958
	Fat	0.208	0.653^{NS}	0.976
	Ash	4.681	0.043^{*}	0.996
Muscle parts	Moisture	15.213	$<10^{-3***}$	0.920
	Protein	50.208	$<10^{-3***}$	0.958
	Fat	63.140	$<10^{-3***}$	0.976
	Ash	45.351	$<10^{-3***}$	0.996
Interaction fish species × sex	Moisture	11.763	$<10^{-3***}$	0.920
	Protein	7.475	0.001^{**}	0.958
	Fat	21.500	$<10^{-3***}$	0.976
	Ash	2.833	0.052^{NS}	0.996
Interaction fish species × muscle parts	Moisture	0.205	1.000^{NS}	0.920
	Protein	0.892	0.620^{NS}	0.958
	Fat	1.369	0.234^{NS}	0.976
	Ash	7.295	$<10^{-3***}$	0.996
Interaction sex × muscle parts	Moisture	0.243	0.957^{NS}	0.920
	Protein	0.330	0.913^{NS}	0.958
	Fat	0.413	0.861^{NS}	0.976
	Ash	2.204	0.086^{NS}	0.996
Interaction fish species × sex × muscle parts	Moisture	0.143	1.000^{NS}	0.920
	Protein	0.306	0.997^{NS}	0.958
	Fat	0.514	0.940^{NS}	0.976
	Ash	2.963	0.008^{**}	0.996

*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$; NS, not significant at 95%.

The effect of fish species on the variation of the global chemical composition is largely documented in the literature (El-Faer *et al.*, 1991; Karahadian *et al.*, 1995; Güner *et al.*, 1998). Synnes *et al.* (2006) studied the chemical composition of five deep-sea fish species. The authors showed that the main differences between fish species concerned moisture, protein, fat and ash contents. In fact, *Macrourus berglax* had the overall lowest protein and ash contents. Moisture content was higher compared to *Mora moro, Centroscyllium fabricil, Centrophorus squamosus* and *Centroscymnus coelolepis*. However, no significant effects ($P > 0.05$) were observed for sex and for fish size on the global chemical composition of the fish muscles. Thus, for the next analysis the size factor was considered as a co-variable. The insignificant effect of the sex on the global chemical composition of the studied fish is in agreement with the studies of Bariziza & Gatlin (2000) and Amin (1984).

Correlation matrices between different analysed compounds

Global correlation matrices (combination of fish species; Table 4) and individual correlation matrices (for each fish species; Table 5) were established between the four quantitative measured variables (moisture, protein, fat and ash contents). Statistical parameters (*P* value and correlation coefficient) obtained for the different correlations are summarized in Tables 4 & 5.

The results presented in Table 4 reveal four negative correlations: moisture–fat, moisture–ash, protein–fat and protein–ash and two positive correlations: moisture–protein and fat–ash. The six correlations were highly significant (*P* value $< 10^{-3}$). In fact, the correlation coefficients obtained for moisture–fat and protein–ash correlations were respectively equal to −0.900 and to −0.732. Moisture content was inversely related to fat content. The same relationship was observed between moisture and ash contents. Similar correlations have been reported by Tzikas *et al.* (2005).

Table 4. Global correlation matrix established for moisture, protein, fat and ash contents (combination of all fish species).

		Moisture	Protein	Fat	Ash
Moisture	R	1	0.361	−0.900	−0.514
	P value		$<10^{-3***}$	$<10^{-3***}$	$<10^{-3***}$
	number of samples	98	98	98	98
Protein	R	0.361	1	−0.507	−0.732
	P value	$<10^{-3***}$		$<10^{-3***}$	$<10^{-3***}$
	number of samples	98	98	98	98
Fat	R	−0.900	−0.507	1	0.418
	P value	$<10^{-3***}$	$<10^{-3***}$		$<10^{-3***}$
	number of samples	98	98	98	98
Ash	R	−0.514	−0.732	0.418	1
	P value	$<10^{-3***}$	$<10^{-3***}$	$<10^{-3***}$	
	number of samples	98	98	98	98

R, correlation coefficient; ***, $P < 0.001$.

The analysis of each fish species separately (Table 5) allowed the improvement of the values of statistical parameters. Indeed, the R value obtained for a fixed fish species, analysed separately was higher than the R value obtained for the global correlation matrices (combination of all the fish species). In addition, the quality of the statistical parameters varied according to the fish species. For example, for protein–fat correlation, *Mullus surmilitus* and *Pagrus caeruleostictus* presented higher R values (R values are respectively −0.806 and −0.937) than those obtained for *Mullus barbatus* and *Dentex maroccanus* (R values are respectively −0.579 and −0.558). Thus, it could be concluded that the analysis of all fish species together masks the inter-species variability. However, the correlation type (positive or negative) did not change if all fish species were analysed one by one or together (global matrix; Table 4). It could be noted that moisture–fat, protein–ash and fat–ash correlations were the most significant ones for all fish species. The negative moisture–fat correlation is well known in literature and was observed in numerous fish products (Pėrez-Villareal & Pozo, 1990; Méndez & González, 1997; Thakur *et al.*, 2002; Grigorakis *et al.*, 2002; Tzikas *et al.*, 2005). A positive correlation in rainbow trout has been reported between fat and dry matter in fish muscle (Tveranger, 1985; Asgard, 1987). Moisture–protein correlation was also reported by many authors: Groves (1970) and Love (1970, 1980). Love (1970, 1980) showed that the dry matter content of fish tissues was related to protein content in lean fish.

The expressions of fat–moisture and protein–ash correlations were established for the fish muscles (regardless of the fish species). Their equations of correlation were respectively:

$$\text{Fat} = 68.190 - 0.877 \times \text{Moisture}; \quad (N = 98; R = -0.900)$$

$$\text{Protein} = 21.140 - 0.751 \times \text{Ash}; \quad (N = 98; R = -0.730)$$

where fat, moisture and protein contents were expressed as g/100 g fresh muscle; N, number of fish samples and R, correlation coefficient.

These expressions could have practical use. In fact, the fat–moisture equation allows a rapid estimation of the fat content from the moisture content, which could be determined by a cheap and free solvent analysis. In addition, the protein–ash equation allows the estimation of the protein contents by a simple measurement of the ash content.

Discriminant analysis of the fish muscle composition

Figure 3 shows the results of the discriminant analysis made on moisture, protein, fat and ash contents of the fish muscles. The first axis ash–fat explained 81.3% of the experimental data and was mostly marked by the variables fat (R = 0.340) and ash (R = −0.320), while the second axis moisture–protein explained only 13.1% of the experimental data and was mostly marked by the variables moisture (R = 0.660) and protein (R = −0.310). Thus both axes explained 94.4% of the whole experimental data. As shown in Figure 3, the discriminant analysis allows distinguishing five groups of fish according to their global chemical composition:

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Table 5. Statistical parameters of the individual correlation matrices established for each fish species separately.

Fish species	Statistical parameters	Correlations					
		M–P	M–F	M–C	P–F	P–A	F–A
Lithognatus mormyrus (N = 32)	*P* value	0.020*	$<10^{-3}$***	$<10^{-3}$***	$<10^{-3}$***	$<10^{-3}$***	$<10^{-3}$***
	R	0.436	−0.932	−0.696	−0.629	−0.863	0.829
Mullus barbatus (N = 18)	*P* value	0.223^NS^	$<10^{-3}$***	$<10^{-3}$***	0.030*	$<10^{-3}$***	0.003**
	R	0.348	−0.964	−0.542	−0.579	−0.935	0.733
Mullus surmilitus (N = 18)	*P* value	0.170^NS^	$<10^{-3}$***	0.041*	0.001**	$<10^{-3}$***	0.003**
	R	0.623	−0.953	−0.552	−0.806	−0.911	0.726
Pagellus erythrinus (N = 30)	*P* value	$<10^{-3}$***	$<10^{-3}$***	$<10^{-3}$***	$<10^{-3}$***	$<10^{-3}$***	$<10^{-3}$***
	R	0.790	−0.899	−0.894	−0.777	−0.940	0.820
Pagrus caeruleostictus (N = 9)	*P* value	0.002**	$<10^{-3}$***	$<10^{-3}$***	0.002**	0.003**	$<10^{-3}$***
	R	0.936	−0.981	−0.984	−0.937	−0.921	0.977
Dentex maroccanus (N = 8)	*P* value	0.070^NS^	$<10^{-3}$***	$<10^{-3}$***	0.038*	0.002**	$<10^{-3}$***
	R	0.499	−0.962	−0.862	−0.558	−0.740	0.826

N, number of samples; R, coefficient of correlation; M, moisture; P, protein; F, fat; A, ash;
*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$; NS, not significant at 95%.

The first group comprises *Pagellus erythrinus* and *Pagrus caeruleostictus*. These fish were characterized by lower levels of fat compared to *Mullus barbatus* and *Mullus surmilitus*.

The second group contains *Mullus surmilitus*. This species had lower fat content and higher moisture content than *Mullus barbatus*. Comparing the data of fat and moisture contents, the variation of moisture content was inversely proportional to that of fat content and a highly negative correlation (R = −0.900) was observed. This result is in agreement with the previous statistical analysis (correlation matrix). The reverse linear relationship between fat and moisture contents was obviously observed in the organs and the muscles of *Siganus rivilatus* (Amin, 1984). This negative correlation between fat and moisture can be explained by the hydrophobic character of fat. Indeed the moisture contents in different tissues result from the oxidation of fat during its metabolism. Consequently, the most humid tissue is poor in fat and vice versa.

The third group comprises *Mullus barbatus*. This fish showed the highest fat and protein amounts.

The fourth group is constituted by *Lithognatus mormyrus* fish. It had lower fat content and higher moisture content than the *Mullus* species.

The fifth group contains *Dentex maroccanus*. This species had higher protein content than *Lithognatus mormyrus* and *Mullus surmilitus* and a lower level of fat than the *Mullus* species (*barbatus* and *surmilitus*).

The discriminant analysis result is in agreement with the previous classification of fish species according to their fat content (proximate composition of fish muscles). Indeed, *Mullus barbatus* is considered as a moderately fat fish while the other species (*Lithognathus mormyrus, Mullus surmuletus, Pagellus erythrinus, Pagrus caeruleostictus* and *Dentex maroccanus*) are considered as lean fish.

Moisture content of fish organs

The moisture content of fish organs (head, gonads, liver and viscera) was examined according to the factors: species, organs and the interaction between these factors. The results of ANOVA indicated that the moisture content was significantly affected by organs and fish species factors (*P* value < 0.05).

Figure 4 shows the variation of the average moisture content of the organs (head, gonads, liver and viscera) according to the examined fish species.

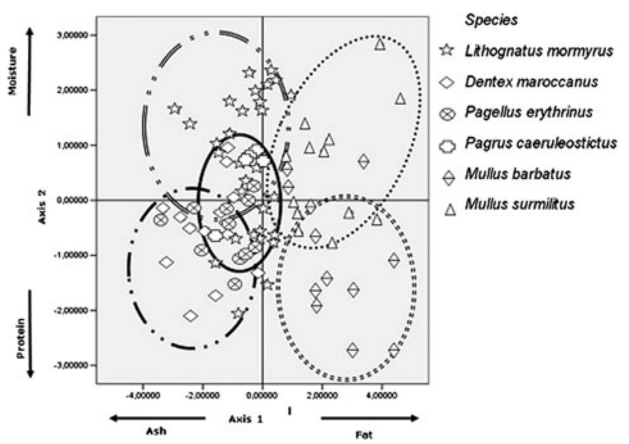

Fig. 3. Discriminant analysis according to moisture, protein, fat and ash contents of the fish muscles (combination of all fish species regardless the sex and size).

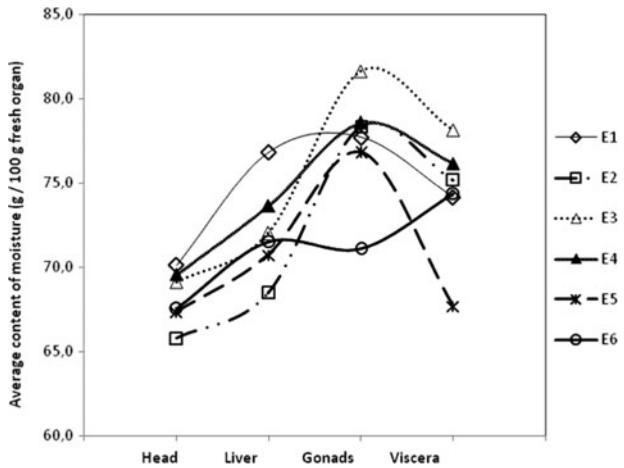

Fig. 4. Average moisture content of the different fish species organs E1:, E2:, E3:, E4:, E5:, E6: *Lithognathus mormyrus, Mullus barbatus, Mullus surmuletus, Pagellus erythrinus, Pagrus caerulestictus* and *Dentex maroccanus*.

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The moisture content of the studied fish ranged from a low (65.78%) to a high (81.64%) content. This result is in agreement with the literature (Oehlenschläger, 1990). The fish heads had the overall lowest moisture content. While the highest moisture content of the fish species (*Lithognatus mormyrus*, *Mullus barbatus*, *Mullus surmilitus*, *Pagellus erythrinus* and *Pagrus caeruleostictus*) was obtained for the gonads. Similar results were observed in the gonads of *Chaenocephalus aceratus* (Oehlenschläger, 1990). The average moisture content varied from one species to another. In fact, the average moisture content in the fish head varied from 65.78% for *Mullus barbatus* to 70.13% for *Lithognatus mormyrus*.

CONCLUSION

The ANOVA indicated that the proximate composition (moisture, protein, fat and ash) was significantly affected by the factors fish species organs and part location in the muscle. The correlation matrices established between the quantitative variables (moisture, protein, fat and ash contents), showed six significant correlations (moisture–fat, moisture–ash, protein–fat, protein–ash, moisture–protein and fat–ash), in which the fat–moisture correlation was the most significant (P value $< 10^{-3}$ and $R = -0{,}900$). The discriminant analysis allowed the distribution in the space of five fish groups according to moisture, proteins, fat and ash contents. The analysis of the fat content in different fish body locations revealed the presence of a concentration gradient. Indeed, the fat content decreased from the head to the tail of the fish. For all studied fish species, the moisture content of the liver was never below $68.49 \pm 1.28\%$ and the highest moisture level was obtained in the gonads of *Mullus surmilitus* ($81.64 \pm 2.21\%$). The head of *Mullus barbatus* had the overall lowest moisture content ($65.78 \pm 1.28\%$).

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