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IMPACT OF ECTO AND BLOOD-SUCKING PARASITES INFECTION ON THE CHEMICAL COMPOSITION OF MUSCLES IN WILD *Mugil cephalus* AND *Scomber scombrus* FROM SYRIAN COASTS (EASTERN MEDITERRANEAN)

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. Authors SG, MH and AD designed the study. Author SG performed the methodological part and the statistical analysis and wrote the first draft of the manuscript. Authors MH and AD managed the analyses of the study and contributed to the writing of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The present study aimed at isolating ectoparasite species and blood-sucking parasite- affecting wild *Mugil cephalus* and *Scomber scombrus*, and evaluating the impact of infection on the chemical composition of their muscles. A total of 238 individuals of *M. cephalus* and 224 of *S. scombrus* were captured from Syrian marine waters (Eastern Mediterranean) through two years, from April 2020 to April 2022. Fish samples were examined for infection, and parasites were isolated according to the wet smears method and identified at species level. Chemical composition: proteins, fats, moisture and ash contents of muscle of two species studied were determined. Variations of these different components in the infected and non-infected samples, and according to months or season, age and sex were assessed. Results showed the infection of *M. cephalus* by *Ligophorus mediterraneus*, *Ergenstrema* sp. (Monogenea) and *Caligus pageti* (Copepoda), whereas, only one ectoparasite species: *Kuhnia scombri* (Monogenea) was identified from *S. scombrus*. This is actually the first record of *Ergenstrema* sp; *C. pageti* and *K. scombri* in the two species studied in Syrian marine waters. This is also the first record of *Ergenstrema* sp. in wild *M. cephalus* in the world. No significant differences in the content of moisture, protein and ash were observed between the infected and non-infected fish. Nevertheless, fat content has showed a significant (*P*-value <0.05) decrease in the samples infected by the blood-sucking parasites- (i.e. *C. pageti* and *K. scombri*) in both species studied. In addition, significant differences of the chemical composition according to season and age were also found, but not between females and males.

Keywords: Ectoparasites; blood-sucking parasites; chemical composition; fish muscles; *Mugil cephalus*; *Scomber scombrus*; Syrian marine waters; Eastern Mediterranean.

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1. INTRODUCTION

The knowledge of the chemical composition of marine species is of fundamental importance in estimating the quality of the raw material [1-2], and that of fish flesh is regarded as a reliable predictor of the fish's quality, nutritional value, physiological state and habitat [3]. It was reported that 96%−98% of the body composition of fish is constituted by moisture, protein, fat and ash [4]. The evaluation of such components is known as the ‘proximate composition' of fish [5]. This composition varies significantly among species and from an individual to another, depending on age, sex, size and season [6-11]. Many other factors such as food availability and feeding rate, diet composition, habitat, genetic features, maturity stage, spawning and migration may all play a role in determining the chemical composition of fish species [12-15].

Many studies focusing on the chemical composition of fish species have been carried out; for example, [16] indicated that this composition differs among species according to the location where the biochemical constituents are stored. Changes in the chemical composition in response to the geographical variation, season and sex have been also documented [17-19].

It has been suggested that other exogenous variables including water temperature and salinity, health status and infection of fish by parasites could also affect their composition [20]. Fish parasite communities are dynamic across the geographical range of host species, and all wild caught seawater and freshwater fish must be considered at risk of containing any viable parasites of human health concern if these products are to be eaten raw or almost raw [21].

Actually, parasites affect fish health through mechanical, physical and reproductive damage. These changes can reduce growth, fecundity and survival, change behavior and sexual characteristics, and result in many other maladaptive alterations of the infected host [22].

Parasitofaunas comprise species with different life strategies, which are grouped mainly as ectoparasites or endoparasites [23].

Fish are exposed to infection by ectoparasites that could affect the quality (deformation of fish's shape, making it undesirable in the market) and the spoiling of fish, and cause losses in pisciculture [24]. In [25] is distinguished a decrease in fat content in the muscle of *Belone belone* fish because of the infection by the blood-sucking parasite- *Mothocya belone* (Malacostraca: Cymothoidae).

The flathead grey mullet *Mugil cephalus*, is one of the most important and widespread species of Mugilidae family, due to its biological behavior, adaptability in different conditions (i.e. fresh or hyperhaline waters, sandy or muddy habitats, within a wide range of dissolved oxygen levels), and its good nutritional quality [26]. This species constitutes about 50% of mullet production, for both wild and aquaculture fisheries [27]. It is a catadromous fish, usually found in estuaries and freshwater along the coasts. Due to its rapid growth, *M. cephalus* is one of the most cultivated fish around the world [28].

As a member of Scombridae family, the Atlantic mackerel *Scomber scombrus* is one of the abundant and widely distributed marine fish species worldwide, and one of the predominant species in the North Atlantic Ocean and the Mediterranean region [29,30]. It is characterized by a high percentage of DHA and EPA [31].

In the late 70’s, it was indicated that the chemical composition of *M. cephalus* varies according to season, age and sex [32]. *S. scombrus* was the subject of several studies, which also reported that the chemical composition of its muscle varies according to season [17-19].

In Syria, *M. cephalus* and *S. scombrus* are among the most important and desired fish for human consumption. Notwithstanding their importance, no studies concerning the effect of ectoparasites infection on the chemical composition of fish muscle have been achieved in Syria. Therefore, in this first study, we isolated and identified the ectoparasite and blood-sucking parasite- species affecting wild *M. cephalus* and *S. scombrus*, and evaluated the impact of infection on the chemical composition of muscle of these two species.

2. MATERIALS AND METHODS

2.1 Fish Sampling

Fish samples were captured from Lattakia marine waters (Syria: 35.5407° N, 35.7953° E), through two successive years, from April 2020 to April 2022. A total of 238 individuals of *M. cephalus* and 224 of *S. scombrus* were collected. Fish samples were kept in plastic bags containing ice and transported to the Laboratory of Parasitology at the Higher Institute for Environmental Research (Tishreen University). Total length, standard length, body depth, head length and weight for each sample were measured. Age was determined according to the method described by [33]; and sex was identified.

M. cephalus samples comprised 88 males and 150 females. Total length of individuals was16.5-39.9 cm, standard length 13.5-36.8 cm, body depth 2.9-5.2 cm, head length 3.2-6.9 cm, and weight 45.2-393.2 g. Fish age ranged between less than one year and three years.

The samples of *S. scombrus*, were composed of 85 males and 139 females. Total length ranged between 13.2-30.1 cm, standard length 10.6-27.2 cm, body depth 2.6-5.4 cm, head length 3.2-4.4 cm, and weight 40.9-151.3 g. Samples age ranged between less than one year and two years. Mean morphometric measurements (cm), weights (g) and sex of samples of two species studied were summarized in Table 1.

2.2 Ectoparasite Examination

Gills, buccal cavity, skin and fins of all samples of two species studied were examined for parasites infection. The parasites species were isolated according to the wet smears method using fine needles. Then, they placed in a drop of water on a glass slide, and preserved in formaldehyde 5% [34,35]. Isolated parasites were identified at species level according to specific taxonomic keys for Monogenea species [36-41], and for Copepoda species [42]. Extensity or infection rate (number of infected fish/ total examined fish x 100) and intensity (number of ectoparasites/number of infected fish) of identified parasites were also determined according to [43].

2.3 Chemical Composition Analysis of Fish Muscles

The analysis of chemical composition was carried out at Animal Nutrition Laboratory, Faculty of Agriculture, Tishreen University. The percentage of contents of moisture, protein, fat and ash were determined. A total of 76 individuals of *M. cephalus* and 64 of *S. scombrus* were analyzed. Of those, 33 individuals of *M. cephalus* and 21 of *S. scombrus* were chosen according to their high infection severity, and 43 non-infected (healthy) individuals of each species.

For the moisture content, a portion of 40 g of muscle was dried at 105°C for 24 h, according to the standard procedure detailed by [44; Method # 925.09]. Protein was determined as nitrogen contents using Kjeldahl method, as described by [44, (Method # 920.152], and the crude protein was then calculated: (N × 6.25). Fat content was determined using Soxhlet according to the method described by [44, Method # 920.85]**.** Fat content (%) was calculated: $F\ (\%) = \frac{W}{X} \times 100$, where: w = fat weight, x= weight of muscle sample. For ash content (%), 5 g of the dried sample were placed in a silica dish at 600 °C for 6 h, using the method described by [44, Method # 923.03]**.**

2.4 Data Analysis

Mean values of moisture, ash, protein and fat contents were assessed and compared between the infected and non-infected samples. Comparisons according to months or season, age and sex were also done. All statistical analysis were performed using R version 3.3.2 [45]. One-way ANOVA was performed to assess the effect of different variables on the chemical composition. Tukey test was then used for mean pair-wise multiple comparisons. Differences at $P = 0.05$ were considered as significant.

Table 1. Mean morphometric measurements (cm) and weights (g) of *M. cephalus* and *S. scombrus*

	M. cephalus					***S. scombrus***				
Sex	**Total length**	**Standard length**	**Body depth**	**Head length**	**Weight**	**Total length**	**Standard length**	**Body depth**	**Head length**	**Weight**
Male	24.5	21. 1	4.7	4. 6	125.4	20.8	18. 1	3.8	4. 3	84. 9
Female	25.3	21.8	4.9	4. 7	133.2	19.3	16. 6	3.5	3.9	76. 1

3. RESULTS

3.1 Identification and Description of Ectoparasites Species

Four ectoparasites species were isolated and identified in the two fish species studied from Syrian marine waters. Three species: *Ligophorus mediterraneus*, *Ergenstrema* sp. and *Caligus pageti* were identified in *M. cephalus*, and only one species *Kuhnia scombri* in *S. scombrus.*

Ligophorus mediterraneus (Monogenea: Ancyrocephalidae):

This monogenean ectoparasite was isolated from the gills of *M. cephalus* through six months (March, April, May, June, July and September). Actually, it was the most frequent species during the study period, with an extensity of 17.2% and a total intensity of 15.2 parasite/fish. Nevertheless, the intensity in the samples analyzed for chemical composition was 43.6 parasites/fish. *L. mediterraneus* feeds mainly on mucus and desquamation cells of gills.

Ergenstrema sp. (Monogenea: Tetraonchidae):

This monogenean ectoparasite was also isolated from the gills of *M. cephalus,* but in very low frequency. It was only recorded in February with an extensity of 1.4% and a total intensity of 1.5 parasite/fish, whereas the intensity in the analyzed samples was 3 parasites/fish. *Ergenstrema* sp. feeds also on mucus and desquamation cells of the gills.

Caligus pageti (Cepopoda: Caligidae):

An ectoparasite of sea lice group. It was isolated from the caudal fin of *M. cephalus* only in October, with a low extensity and a total intensity of 2.1% and 1.2 parasite/fish respectively, but the intensity in the analyzed samples was 5.2 parasites/fish. *C. pageti* feeds on the host blood; so classified as blood-sucking parasite.

Kuhnia scombri (Monogenea: Mazocraeidae):

It was isolated from the gills of *S. scombrus,* in March, April, and June, with an extensity of 4.46% and a total intensity of 1.5 parasite/fish. Nevertheless, the intensity in the samples analyzed for chemical composition was 6.5 parasites/fish. *K. scombri* belongs also to the blood-sucking parasites (Table 2).

3.2 Ectoparasites Infection and Variations of Chemical Composition of Muscle

Contents of moisture, protein and ash showed no significant difference between the infected and non-infected samples of *M. cephalus*, whereas a significant difference was observed in fat content (*P*-value= 0.00012). Actually, the lowest value of fat 2.6%±0.4 was found in the samples infected by *C. pageti,* and the highest value 5.1%±0.6 was recorded in those infected by *Ergenstrema* sp., compared to the non-infected samples 4.9%±0.7, or those infected by *L. mediterraneus* 4.7%±0.7 (Table 3).

Similarly, contents of moisture, protein and ash in *S. scombrus,* were not significantly different between the samples infected by *K. scombri* and the non-infected ones. Nevertheless, there were significant differences in the percentage of fat (*P*-value= 0.000033) between the infected and non-infected samples, with values of 5.9%±0.6 and 8.1% ±0.7 respectively (Table 3).

3.3 Variations in Chemical Composition According to Months

Variations in the chemical composition of muscles of *M. cephalus* and *S. scombrus* during two successive years were tracked. Results showed significant differences in the content of moisture, protein and fat, but not for ash. In *M. cephalus*, the highest value of moisture 76. 6 %±2.1 was recorded in June and the lowest 72.9%±2.5 in October. The highest value of protein 20.4%±2.1 was significantly larger in November compared to June where the lowest value 17.2%±2.1was recorded. The highest value of fat content 5.2%±0.6 was recorded in December, and the lowest 3.8%±1.1in March.

Table 2. Ectoparasites species identified in wild *Mugil cephalus* and *Scomber scombrus* from Syrian marine waters

Class	Species: Family	Host	Infected site	Host order: family	Extensity	Intensity	Infection period
Monogenea	*Ligophorus mediterraneus*: Ancyrocephalidae	*Mugil cephalus*	Gills	Mugiliformes: Mugilidae	17.2%	15.2	March, April, May, June, July, September
Monogenea	*Ergenstrema* sp.: Tetraonchidae	*M. cephalus*	Gills	Mugiliformes: Mugilidae	1.4%	1.5	February
Copepoda	*Caligus pageti*: Caligidae	*M. cephalus*	Caudal fin	Mugiliformes: Mugilidae	2.1%	1.2	October
Monogenea	*Kuhnia scombri*: Mazocraeidae	*Scomber scombrus*	Gills	Scombriformes: Scombridae	4.5%	1.5	March, April, June

Table 3. Variations of chemical composition components in *M. cephalus* and *S. scombrus* related to ectoparasites infection in Syrian marine waters (x̄ ± SD). The letters a, b indicate a significant difference in the same raw

Fish species		*Mugil cephalus*					*Scomber scombrus*		
Parasite species	***L. mediterraneus***		***C. pageti***	***Ergenstrema* sp**	**Non-infected**	***P*-value**	***K. scombri***	**Non-infected**	***P*-value**
Chemical composition	**%moisture**	74.9±2.6	74.2±3.1	72.8±3.6	74.7±2.8	0.65	71.6±2.1	70.3±2.2	0.05
	%protein	18.9±2.3	21.4±2.6	20.5±2.9	18.9±2.4	0.126	20.7±1.8	20.3±1.9	0.46
	%fat	4.7 a±0.7	2.6 b±0.4	5.1 a±0.6	4.9 *a*±0.7	0.00012	5.9 *b*±0.6	8.1 a±0.7	0.000023
	%ash	1.5±0.3	1.8±0.4	1.6±0.4	1.5±0.3	0.158	1.7 *a*±0.4	1.5 *b*±0.3	0.14

Table 4. Variations of chemical composition components in *M. cephalus* and *S. scombrus* according to months (x̄ ± SD). The letters a, b indicate a significant difference in the same column

Fish species	*Mugil cephalus*				*Scomber scombrus*			
Month	**%moisture**	**%protein**	**%fat**	**%ash**	**%moisture**	**%protein**	**%fat**	**%ash**
January	75.1 ab±2.4	20.1ab±3.1	5.1a±0.7	1.6±0.2	71.7a±1. 1	19. 1c±0.1	6.6b±0.5	1.4±0.2
February	74.6 ab±2.9	18.9ab±2.6	4.8a±0.6	1.6±0.2	71.3a±1.5	19.4c±1.4	6.3b±0.5	1.5±0.3
March	73.4 ab±3.5	20.1ab±2.7	3.8b±1.1	1.5±0.3	65.5d±1.1	19.6b±1.9	7.3b±1.6	1.5±0.3
April	75.4 ab±1.3	18.5ab±1.2	4.6ab±0.5	1.5±0.2	70.5ab±1.1	20.3a±0.9	7.7b±0.8	1.5±0.4
May	75.3 ab±2.4	18.8ab±2.2	4.6a±0.7	1.4±0.3	66.2cd±1.3	23.1ab±1.1	8.9ab±0.6	1.9±0.4
June	76.6 a±2. 1	17.2b±2.1	4.6a±0.5	1.5±0.3	70.4ab±1.5	20.9a±1.4	7.2b±0.8	1.6±0.3
July	76.5 a±1.1	17.3b±1.3	4.8ab±0.7	1.5±0.3	69.1bc±1.6	21.3a±2.1	7.9b±0.7	1.7±0.4
August	75.5 ab±2.2	18.2ab±2.3	4.9a±0.5	1.5±0.3	70. 5ab±1.3	20.1a±1.6	7.9b±0.7	1.5±0.4
September	73.3 ab±3.6	18.4ab±2.6	5.1a±0.6	1.5±0.1	71.7a±1.8	24.1a±0.8	9.1a±0.6	1.4±0.3
October	72.9 b±2.5	20.1ab±2.2	5.1a±0.8	1.5±0.3	70. 7cd±0.9	20.1cb±0.9	7.7b±0.5	1.5±0.3
November	74.7 ab±2.1	20.4a±2.1	5.2a±0.6	1.5±0.3	71.5a±1.1	19.1c±1.1	8.1ab±0.8	1.3±0.2
December	73.2 ab±3.4	20.1ab±3.3	5.2a±0.63	1.5±0.3	71.3a±1. 1	19.3c±0.8	6.9b±0.6	1.6±0.3
P-value	**0.00701**	**0.0092**	**0.015**	0.195	**0.000000022**	**0.000000034**	**0.0014**	0.227

Table 5. Variations of chemical composition components in *M. cephalus* and *S. scombrus* according to season ($\bar{x}$ ± SD). The letters a, b indicate a significant difference in the same column

Fish species	***Mugil cephalus***				***Scomber scombrus***			
Season	**%moisture**	**%protein**	**%fat**	**%ash**	**%moisture**	**%protein**	**%fat**	**%ash**
Spring	73.63 b±0.95	19.63 a±1.08	5.13 a±0.06	1.50±0	71.30 a±0.53	21.10±2.65	8.30 a±0.72	1.40±0.1
Summer	74.70 ab±1.13	19.13 ab±0.85	4.33 b±0.46	1.47±0.06	67.40 b±2.71	21.02±1.85	7.97 ab±0.83	1.63±0.23
Autumn	76.20 a±0.61	17.57 b±0.55	4.77 ab±0.15	1.50±0	70.01 ab±0.78	20.77±0.61	7.67 ab±0.4	1.60±0.1
Winter	74.30 ab±0.61	19.70 a±0.69	5.03 a±0.21	1.57±0.06	71.43 a±0.23	19.27±0.15	6.60 b±0.3	1.50±0.1
P-value	**0.0304**	**0.0408**	**0.025**	0.0855	**0.029**	0.522	0.041	0.264

Table 6. Variations of chemical composition components in *M. cephalus* and *S. scombrus* according to age ($\bar{x}$ ± SD). The letters a, b indicate a significant difference in the same raw

Fish pecies	***Mugil cephalus***					***Scomber scombrus***			
Age	**< 1 year**	**1 year**	**2 year**	**3 year**	***P*-value**	**< 1 year**	**1 year**	**2 year**	***P*-value**
%moisture	75.8±1.9 a	75.4±2. 1 a	72.5±3. 1 b	70.4±1.1 c	**0.00000074**	71. 1 ±1.8 a	70.9 a	65.7 ±1.5 b	**0.000000022**
%protein	18.66 ±2.2 b	18.1 ±1.9 b	21.1 ±2.5 a	22.8 ±1.2 a	**0.0000014**	19.8 ±1.4 b	20.1 ±1.8 b	23.6 ±1.5 a	**0.000000022**
%fat	4.5±0.7 b	4.7±0.6 ab	4.9 ±1.1 ab	5.3±0.9 a	**0.0113***	7.5 ±0.8 c	7.8 ±0.7 b	9.1 ±0.5 a	**0.000019**
%ash	1.5±0.3	1.5±0.3	1.5±0.3	1.5±0.2	0.8	1.5±0.3	1.5±0.4	1.4±0.3	0.59

In *S. scombrus*, the highest value of moisture 71.7%±1.8 was recorded in September, and the lowest one 65.5%±1.1in March. The highest protein content 24.1%±0.8 was found in September and the lowest 19.1%±0.1 in January. The highest value of fat 9.1%±0.6 was found in September and the lowest 6.3%±0.5 in February (Table 4).

3.4 Variations in Chemical Composition According to Season

Seasonal variations in the chemical composition of muscles in the two fish species studied were pursued. In *M. cephalus,* significant differences in the content of moisture, protein and fat were found, but not for ash. The highest value of moisture 76.2% ±0.61 was recorded in autumn and the lowest one 73.63% ±0.95 in spring. The highest value of protein 19.7%±0.69 was significantly greater in winter compared to autumn where the lowest value 17.57% ±0.55 was recorded. The highest value of fat content 5.13% ±0.06 was recorded in spring and the lowest 4.33% ±0.46 in summer.

In *S. scombrus*, significant differences in the content of moisture and fat were found but not for protein and ash contents. The highest value of moisture 71.43% ±0.23 was recorded in winter and the lowest one 67.4% ±2.71 in summer. The highest protein content 21.1%±2.65 was found in spring and the lowest one 19.275±0.15 in winter. The highest value of fat 8.3% ±0.72 was found in spring and the lowest 6.6% ±0.3 in winter (Table 5).

3.5 Variations in Chemical Composition According to Age and Sex

Chemical composition variations according to fish samples age of the two species studied were also investigated. Significant differences in the content of moisture, protein and fat were found, but not for ash.

Results are resumed in Table (6); in *M. cephalus*, the highest value of moisture 75.8%±1.9 was recorded in the samples of less one-year age class, and decreased to 70.4%±1.1in those of three-years class. Contrastingly, the highest value of protein content 22.8%±1.2 was found in the samples of three-years age class, and the lowest one 18.1% ±1.9 in the one-year age class. Fat content value 5.3%±0.9 was higher in the samples of three-years age class, compared to the lowest value 4.5%±0.7 in the less one-year class (Table 6).

Similarly, in *S. scombrus*, significant differences in moisture, protein and fat contents were found, but not for ash. The highest value of moisture 71.1%±1.8 was recorded in the samples of less one-year age class, whereas the lowest one 65.7% ±1.5 was found in those of two-years age class. The protein content had the highest value 23.6%±1.5 in the samples of two-years age class, whereas the lowest one 19.8% ±1.4 was found in the samples of less one-year age class. The highest value of fat 9.1% ±0.5 was recorded in the two-years age class, compared to the lowest one 7.5% ±0.8 in the less one-year age class (Table 6).

However, no significant differences in the chemical composition constituents between males and females were found in both studied species (Table 7).

4. DISCUSSION

We isolated and identified ectoparasites species affecting wild *M. cephalus* and *S. scombrus*, and evaluated how infection may have affected chemical composition of muscle in those species. Protein, fat, moisture and ash contents were determined. Variations of these different components in infected and non-infected samples according to months or season, age and sex were assessed.

Four ectoparasites were identified for the first time in the Syrian marine waters: two blood-sucking species *C. pageti* and *K. scombri* [46-47] and *L. mediterraneus* and *Ergenstrema* sp. that feed on mucus and desquamation cells of gills [48]. These are the first records of *C. pageti*, *K. scombri* and *Ergenstrema* sp. in the Syrian marine waters. This is also the first record of *Ergenstrema* sp. in wild *M. cephalus* in the world.

Table 7. Variations of chemical composition components in *M. cephalus* and *S. scombrus* according to fish sex ($\bar{x}$ ± SD)

Fish pecies	***Mugil cephalus***			***Scomber scombrus***		
Sex	**Male**	**Female**	***P-value***	**Male**	**Female**	***P-value***
%moisture	74.5±2.8	74.8±2.8	0.524	70.7±1.8	70.1±2.4	0.524
%protein	19.1±2.5	19. 1±2.5	0.771	20. 1±1.7	20.5±2. 1	0.087
%fat	4.9±0.7	4.7±0.8	0.126	7.8±0.8	7.9±0.9	0.637
%ash	1.5±0.3	1.5±0.3	0.56	1.5±0.3	1.5±0.3	0.204

Chemical composition of muscles in the two fish species was affected by ectoparasites infection particularly observed as a decrease in fat content. Moreover, significant differences according to months, season and age were found but not between sex.

Fat content in *S. scombrus* has decreased from 8.1% in the non-infected samples to 5.9% in those infected by *K. scombri*. This was also observed in *M. cephalus* where the fat content decreased from 4.9% to 2.6% in the samples infected by *C. pageti*. This decrease could be due to the feeding behavior of these two blood-sucking parasites that feed on the blood of their host. Hence, the amount of host blood decreases and the body uses its fat stores to gain energy. [49] also indicated that the infection of *Merlangius merlangus* gills by *Lernaeocera branchialis* have caused a significant decrease in body weight associated with a decrease in the fat content of liver as well as an increase in cholesterol rates, as this parasite feeds on blood through root-like attachment organs, which invade throughout host tissue [50-51]. Our results are also in agreement with those of [25] that showed; a decrease in fat content from 0.8 to 0.7% in the muscle of *Belone belone* due to the infection by the blood-sucking parasite *Mothocya belone*. Moreover, this parasite caused an increase in the proportion of unsaturated fatty acids and a decrease in saturated fatty acids, leading to think about a positive effect of this parasite on fat quality.

However, despite the difference in their prevalence, our results show that the infection of *M. cephalus* by *L. mediterraneus* or *Ergenstrema* sp. seem to be not affected the fat content, where the values were 4.7 and 5.1%, respectively.

Monthly variations of chemical composition were observed through the two study successive years. In *M. cephalus*, the moisture content had a highest value 76.6% in June, whereas the lowest one 72.9% was found in October. Nevertheless, [32] indicated this highest value 76.1% in May and the lowest one 71.9% in December in *M. cephalus*. This difference could be attributed to the peak season of spawning of *M. cephalus* in September and October in the eastern Mediterranean [52], and in December in the Indian Ocean [32]. Our results report a highest value of protein content 20.4% in November and the lowest one 17.2% in June. Yet again, [32] reported the highest protein value 18.6% in December and the lowest one 15.8% in April. We reported the highest value of fat content 5.2% in December, and the lowest one 3.8% in March. It is a bit different from the results of [32] who indicated a highest value 6 % in October and the lowest 2.1% in February. The beginning of spawning season in fish, according to [53] leading to fat decrease could be the cause of this variation in fat content. Actually, after the spawning season, fish enter in a wintering period, stop feeding and depend on fat stores, so, the fat level in the body decreases.

Our results also show significant variations in the chemical composition according to season in *S. scombrus*. The highest value of moisture 71.43 % has reported in winter, and the lowest one 67.40 % in summer. In Tunisia (Central Mediterranean), the highest value 72.5% was recorded in summer and the lowest one 70.6% in autumn [18]. This decrease in moisture content could be due to the entering of fish to the spawning period [54]. The highest value of protein content 21.10% was found in spring, and the lowest one 19.27% in winter, that are somehow different of those reported by [18], where the highest value of protein 24.1% was in spring and the lowest one 18.8% in autumn. Similarly, fat content of our samples has decreased from 8.3% in spring to 6.6% in winter, whereas it has been previously reported in spring 11.5% and in summer 4.4% [18]. This decrease of fat content in winter could be also because of the wintering period mentioned above. Our results are in agreement with those of [17] in Western English Channel that has indicated a decrease of fat levels in mackerel fish in winter because of stopping feeding and using fat stores as an energy source.

According to our results, no variation in ash content were reported according to months in both *M. cephalus* and *S. scombrus* during the study period. Nevertheless, [32] reported in *M. cephalus*, in Indian Ocean, a highest value of ash 5.7% in February, which decreased to 1.8% in August. This is also in disagreement with the results of [18] in Tunisia, where the highest ash value 2.3% and the lowest 1.8% have been reported in autumn and spring, respectively.

However, our results revealed no significant variations in chemical composition of muscles according to fish sex in both fish studied. Nonetheless, [55] argued the fish sex as a factor affecting the chemical composition of muscles of *S. scombrus*. They found significant variations in fat content and reported in spring, a highest value of 18.9% in males and 13.2% in females, and the lowest value in summer, 5.4% and 3.4% in males and females, respectively. Similarly, they found a highest value of moisture in summer, 72. 1% in females and 71.5% in males, and the lowest 66.03% in spring in males and in winter 66.9% in females. Contrastingly, they found no significant differences in protein and ash contents according to sex, and reported the highest protein value 22.1% in females and 22.1% in males, and the highest ash content in summer 2% in females and 1.3% in males, and the lowest value of 1% in spring in males, and in autumn in females.

Our results concerning ash content in *M. cephalus* are in disagreement with those of [32], where the highest value of 4.1% has been reported in females in March and 4.9% in males in February, compared to the lowest values reported in August 1.8% and 1.5% in males and females, respectively.

Finally, our results show significant variations in chemical composition according to fish age in both species studied. Indeed, the protein and fat contents increased with age, whereas the moisture content decreased. This could be explained by the fact that fish have attained their sexual maturity, associated with energy and nutrients required for gonads development, supposed to be 2 -3 years in *S. scombrus*, and two years for males and three years for females in *M. cephalus* [29,56].

5. CONCLUSION

The results of this study indicated the infection of *M. cephalus* by two monogeneans and one copepod, and *S. scombrus* by one monogenean. Variations of moisture, protein and ash contents between the infected and non-infected fish were not significant. Nevertheless, fat content in the muscle decreased significantly in the samples infected by the blood-sucking parasites *C. pageti* and *K. scombri* in both species studied. Significant variations in the chemical composition according to months or season and age were also found, but not between males and females. In consideration of the great importance of parasites associated with Pisciculture, further studies to identify the ecto and endoparasites in other fish species candidates, and studying their impact on survival and chemical composition, are needed.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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