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Research Article

Nutritional and Biochemical Quality of Fresh and Cold-Smoked Rudd (*Scardinius erythrophthalmus*) Fillets during Refrigerated Storage

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Abstract: Biochemicals and nutritional parameters of fresh and cold-smoked fillets of freshwater rudd (*Scardinius erythrophtalmus*) during refrigerated storage were investigated. Based on biochemical analysis, several indices were used to monitor the product quality over 9 weeks of refrigerated storage at 2±1°C. The results revealed the highest value for moisture and the lowest values for ASH content, carbohydrate, lipids, total volatile basic nitrogen (TVB-N) content, trimethylamine (TMA-N), and thiobarbituric acid concentrations (TBARS) in fresh fillets.

During refrigerated storage, the results showed that an increase in microbial load was accompanied by a concomitant rise in volatile basic nitrogen (TVB-N), trimethylamine (TMA-N), and thiobarbituric acid concentrations (TBARS). However, these values were much lower than the acceptable limits for smoked fish products. Microbiological analysis indicated that cold-smoked rudd fillets had a shelf life of up to 9 weeks of refrigerated storage. Low levels of biogenic amines (BAs) were observed in fresh and smoked fillets throughout the entire storage period, except for agmatine.

The indices of atherogenicity (IA) and thrombogenicity (IT), with values of 1.54 and 1.59, respectively, did not show a significant change during 35 days of storage.
These results showed that the cold smoking treatment led to an extension of the shelf life of the smoked net of the rudd up to 63 days of the refrigerated storage and presents potential advantages for the processing industry.

Keywords: *Scardinius erythrophthalmus*; cold-smoking; keeping quality; extended shelf life; biochemical analysis, microbiological analysis; biogenic amines; fatty acids, nutritive value.

1. Introduction

Over the past twenty years, global freshwater fish production has increased from 9.3 million tons in 2000 to 11.3 million tons in 2022 (FAO, 2024). In Tunisia, freshwater fish production is 216.670 tons in 2024 (DGPA, 2024).

This freshwater fish production includes various species such as pike-perch, mullet, carp, tilapia, and rudd.

However, this production faces marketing challenges both nationally and internationally. In Tunisia, the sale of these products remains limited due to consumer reluctance towards freshwater fish. For example, rudd (*Scardinius erythrophthalmus*) (Linnaeus, 1758), is a cyprinid that has been introduced into Tunisian dams as a forage fish. Widely distributed, it is grown extensively in dams and hill lakes in Tunisia (Mili et al., 2016), it is an under-exploited species, with low market value and sometimes it is discarded after fishing.

To address this situation, one solution would be to promote the commercial expansion of freshwater fish by lifting export restrictions. This requires access to health and nutritional information on the fish of interest to facilitate negotiations for favorable amendments to existing agreements. Another avenue for adding value would be to incorporate biotechnological processes such as smoking to generate new products that would be accepted by Tunisian consumers. These innovative products, meeting superior quality standards, would generate added value and could also access international markets.

For centuries, smoking has been a popular method of preserving fish. The application of salt and smoke in certain products imparts a characteristic texture and flavor that is appreciated worldwide. In addition to these organoleptic qualities, smoking provides significant nutritional value to the fish. The key is to ensure the product's preservation without altering its composition, thus maintaining all its nutritional qualities. Then, a distinctive flavor is imparted by the smoky infuse.

In this regard, three objectives have been established: quality control, product knowledge, and enhancement through cold smoking. This study addresses these objectives by investigating the influence of cold smoking on preserving the biochemical, microbiological, and nutritional quality of rudd (*Scardinius erythrophtalmus*) fillets during refrigerated storage.

2. Materials and Methods

2.1. Fish samples

10 kg of the samples of rudd (*Scardinius erythrophthalmus)* (400-500g) were sampled in winter from the dam of “Abid” in northwest Tunisia. After capture, the samples were immediately stored in ice in polystyrene boxes and delivered to the company “Horchani”. The fish were subsequently gutted, washed, headed, and filleted. For biochemical analysis, samples (n=6 different fillets) were taken at day 0 from fresh fillets, and following smoking, samples (n = 30 different fillets) were taken after 1 day, 7 days, 21 days, 35 days, 47 days, and 63 days of refrigerated storage at 2 ± 1°C (6 fillets at each time). For fresh fillets, tissue sampling was performed in the laboratory within 10 h of fish transport in an icebox. Samples of tissues were immediately stored at -80°C until analysis.

2.2. Smoking procedure

The fish used for the cold smoking were manually filleted, the fillets were dry salted on grids for 30 min using refined NaCl. When the dry salting was completed, the excess salt was removed by careful rinsing of the fillets with water (12°C). All fillets were then smoked using Raucher FV. V2 HEIZUNG smoking cabinet for 4 h at 22-23°C.The relative humidity of the smokehouse was sat at 65%. After cooling to 0°C within 12 h, The smoked fillets were then vacuum-packed using a “Multivac” model and finally stored at 2 ± 1°C for 9 weeks.

2.3. Proximate composition

Moisture was determined according to the AOAC method (1990). Ash content was

determined according to the AOAC method (1990). Total lipids were extracted according to the method of Folch et al. (1957) by chloroform/methanol proportion (2:1). The aliquot of the chloroform layer was evaporated to dryness under nitrogen, and the lipids were quantified gravimetrically. Carbohydrates were determined according to the method of Dubois et al. (1956).

2.4. Microbiological analyses

Microbiological counts were made (in triplicate) on fresh fillets and smoked fillets after 1 day, 30 days, and 60 days of storage. Ten grams of the sample were taken aseptically into a sterile blender containing sterile Ringer's solution and blended for 2 min at low speed. Volumes of 0.1 ml of decimal dilutions of these homogenates were incubated in the culture of Plate Count Agar (Biokar Diagnostics, Beauvais, France). Mesophilic counts were determined after incubation for 48 h at 30°C, and psychrophilic counts were determined after incubation for 10 days at 5°C. All microbial counts were converted to base-10 logarithms of colony-forming units per g (log CFU/g).

2.5. Biochemical analyses

For the following tests, 1 g of minced fish fillets (n=6) was homogenized (DI-25, IKA, Germany) on ice in 2 ml of ultra-pure water for 1 min, 0.250 ml of 6% (v:v) perchloric acid was added, and the extract was homogenized for a further 2 min. Homogenates were centrifuged at 12,000 x g for 15 min, and the supernatants were used for the determination of total volatile basic nitrogen (TVB-N) and trimethylamine (TMA-N).

2.5.1. Determination of total volatile basic nitrogen

The total volatile base (TVB-N) was determined by flow injection analysis according to the method of Ruiz-Capillas & Horner (1999).

2.5.2. Determination of total volatile basic nitrogen

The total volatile base (TVB-N) was determined by flow injection analysis according to the method of Ruiz-Capillas & Horner (1999).

2.5.3. Determination of trimethylamine

The trimethylamine (TMA-N) was determined by flow injection analysis according to the method of Sadok et al. (1996).

2.5.4. Determination of TBARS

The 2-thiobarbituric acid (TBARS) assay, as an index for lipid oxidation, was carried out according to the procedure of Genot et al. (1996).

The absorbance was measured at 532 nm by using a UV-vis spectrophotometer (model UV-1200, Shimadzu, Japan). TBA value was expressed as mg malonaldehyde (MA) per kg of fish sample.

2.5.5. Biogenic amines

Histamine (HIS), cadaverine (CAD), agmatine (SPD), and spermine (SPM) were purchased from Sigma Chemical Co. (St Louis, MO, USA). The standard amines were dissolved in Deionized Distilled Water (DDW) with a concentration of 100 mg/100 ml and used as the working solution.

Biogenic amine determination followed the method of Moret et al. (2005). The sample was then extracted twice with a 1 ml aliquot of diethyl ether. The combined extracts were dried under nitrogen flow, and the residue was re-dissolved in acetonitrile.

The samples were then filtered with a 0.45 µm PTFE filter (Sartorius, Göttingen, Germany) and injected into the HPLC system (Knauer Smartline, Berlin, Germany). It consists of a quaternary pump (Knauer, model 1000) and a UV-vis detector (Knauer, model 2000) set at 254 nm. The column was an RP C18 (Eurospher, 100-5), and the mobile phase

was composed of 350 ml of water and 650 ml of acetonitrile.

2.6. Fatty Acids Analysis and Indexes of Lipid Quality

2.6.1. Fatty Acids Analysis

Fatty acid methyl esters (FAMEs) were obtained by the method described by Metcalfe et al. (1966). The resulting methyl esters were analysed by gas chromatography using an Agilent Technologies chromatograph 6890 N (Agilent Technologies, Palo Alto, CA) equipped with a flame ionization detector, a split less injector and a polar Innowax 30M silica capillary column (0.25 mm i.d * 30m length * 0.25 µm film thickness, Agilent Technologies, J&W Scientific, Folsom, CA). The temperature of the injector and detector was 220°C and 275°C, respectively. Helium was used as a carrier gas with a flow rate of 1.5 mL/min. Peaks were identified by comparing their retention times with FAMEs standards (Supelco, Bellafonte, PA). The sequences of fatty acids were ranged according to their chromatographic retention times, and the values were given as percentages of the total FAMEs.

2.6.2 Indexes of Lipid Quality

Indexes of atherogenicity (IA) and thrombogenicity (IT) were calculated from the data on fatty acid composition according to the Senso et al. (2006) and Ulbricht & Southgate (1991) methods, respectively:

- Index of atherogenicity (IA): indicates the relationship between the sum of the main saturated and unsaturated fatty acid classes. The following equation was applied:

$$IA = [(4\times C14:0) + C16:0 + C18:0]/ [\sum MUFA + \sum PUFA\text{-}n6 + \sum PUFA\text{-}n3]$$

- Index of thrombogenicity (IT): This is defined as the relationship between the pro-thrombogenetic (saturated) and the anti-thrombogenetic fatty acids (MUFAs, PUFAs-n6 and PUFAs-n3).

The following equation was applied:

$$IT = (C14:0 + C16:0 + C18:0)/ (0.50\times MUFA\text{-}n6 + 3\times PUFA\text{-}n3 + PUFA\text{-}n3/PUFA\text{-}n6)$$

2.7. Statistical analysis

For each lot and at each sampling time, the results are presented as mean ± standard deviation (SD) of (n) fillets. The values relatives to the chemical composition of the fresh and smoked fillets at different times of storage were compared by one-way ANOVA. If significant differences ($P < 0.05$) between means were obtained, Tukey's honest significant test was used to differentiate between means. Statistics were performed using SPSS software for windows (SPSS Inc., Chicago, IL, USA).

3. Results and discussion

3.1. Proximate analysis

Initially, the mean moisture content measured in fresh fillets (81.12 ± 0.36%) (Table 1) was higher than the values (77.1 ± 0.39) reported by Bouzgarrou et al., (2020) for Tilapia (*Oerochromis niloticus*) and the value (72.65 %) reported by Monirul Islam and Sultana for the same species (2025).

Smoking process resulted in a significant decrease ($P<0.05$) of moisture content reaching a value of (72.216 ± 0.75%) (Table 1). Throughout storage, moisture content remained unchanged up to 63 days.

The initial ash content is 0.89 ± 0.15 mg/100 g. This value is slightly lower than the value of tilapia *(Oerochromis niloticus)* (Bouzgarrou et al., 2020). This may be due to the difference in diet of two species.

A significant difference in the ash content between fresh and smoked fillets of rudd has been reported ($p < 0.05$).

For carbohydrate content, the initial carbohydrate content was 0.52 ± 0.08 mg/100 g in fresh fillets. This content is lower than the content of tilapia *O. niloticus* (Bouzgarrou et al., 2020). Such value

increased to (1.69 ± 0.24 mg/100 g) immediately after the smoking process due to flesh dehydration. This increase is due to flesh dehydration.

During storage the carbohydrate content decreased significantly, probably due to the hydrolysis of glucose by endogenous and/or bacteria exogenous enzymes.

Table 1: Determination of the moisture, Ash, carbohydrates, and fat in the flesh and cold smoked fillets of *S. erythrophthalmus*

	Fresh fillets		**Smoked fillets**			
Days of storage	0	7	21	35	49	63
Moisture (%)	81.12 ± 0.36 (a)	72.21 ± 0.75 (b)	70.99 ± 0.94 (b)	69.39 ± 0.28 (b)	71.23 ± 0.9 (b)	71.82 ± 0.85 (b)
ASH (%)	0.89 ± 0.15 (a)	4.75 ± 0.03 (b)	4.70 ± 0.31 (b)	5.20 ± 0.29 (c)	5.53 ± 0.14 (d)	4.26 ±0.21 (e)
Carbohydrates (mg/100g)	0.52±0.077 (a)	1.11±0.01 (b)	0.51±0.088 (b)	0.38±0.06 (b)	0.32±0.03 (b)	0.66±0.05 (c)
Total lipid (mg/100g)	0.61±0.024 (a)	1.04±0.14 (b)	0.83±0.027 (c)	0.66±0.072 (c)	0.65±0.037 (c)	0.53±0.088 (d)

The lipid contents in fresh fillets were low (0.61± 0.024 mg/100 g). After cold smoking a significant increase ($p < 0.05$) in the lipid content (7 days) was noted, also due to the dehydration of the flesh following the salting and smoking process. During refrigerated storage, a significant decrease in lipid content was found after 21 days of storage, indicating the onset of lipid oxidation.

This observation is in agreement with that reported by Espe et al. (2002).

3.2. Microbiological analysis

The changes in mesophilic and psychrophilic flora in the smoked fillets of rudd as a function of treatment and shelf life are shown in Figure 1. The initial loads of the mesophilic and psychrophilic flora were 4.04 and 3.95 log CFU/g, respectively (Figure 1 (A and B)). This indicates the good initial quality of the rudd fillets and is explained by respect for hygiene rules during the processing stages.

After treatment by cold smoking the loads of mesophilic bacteria (3.86 CFU/g) decreased significantly ($p<0.05$) This process has shown significant antimicrobial activity against mesophilic flora. Salan et al. (2006) agreed that smoking inhibits microbial growth in fish products.

During storage (30 and 63 days), the load of the mesophilic and psychrophilic flora of the smoked product increased significantly without reaching the upper limit of rejection of the product 10^7 cfu/g (ICMSF, 1986).

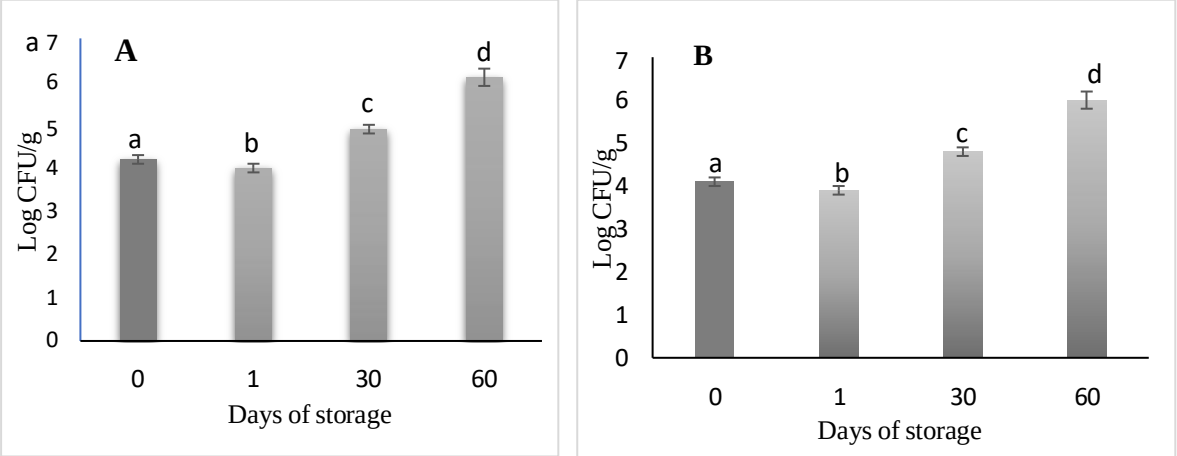

Figure 1: Changes in mesophilic (A) and psychrophilic (B) counts of *Scardinius erythrophthalmus* fillet before and after cold smoking during the refrigerated storage (2 ± 1°C). Data means ± standard deviation, n = 6. Means within the same row, with different superscripts, are significantly different ($p < 0.05$).

3.3. Biochemical analyses

3.3.1. Variation of nitrogen indicators

Table 2 shows the results of the chemical analysis relating to certain quality indicators such as total volatile bases (TVB-N) and trimethylamine (TMA-N). Monitoring was conducted on fresh and smoked fillets during refrigerated storage.

Table 2: Evolution of the TVB-N, TMA-N, and TBARS content in the fresh and smoked fillets of *S. erythrophthalmus* during the refrigerated storage (2 ± 1°C).

	Fresh fillets	**Smoked fillets**				
Days of storage	0	7	21	35	49	63
TVB-N (mg/100g)	0.79 ± 0.07 (a)	0.92 ± 0.09 (b)	1.33 ± 0.048 (b)	1.21 ± 0.068 (b)	1.6 ± 0.13 (c)	1.56 ± 0.16 (c)
TMA-N (mg/100g)	0.3 ± 0.029 (a)	0.6 ± 0.051 (b)	0.84 ± 0.15 (b)	1.18 ± 0.13 (b)	1.47 ± 0.15 (c)	1.37 ±0.046 (c)
TBA-rs (mg MDA/kg)	0.13±0.0026 (a)	0.227±0.0036 (b)	0.161±0.006 (c)	0.141±0.015 (c)	0.18±0.013 (c)	0.172±0.005 (c)

The concentration of initial TVB-N was 0.79 ± 0.07 mg/100 g. This low TVB-N value is due to the fact that the rudd is a lean fish with low lipid content and the diet of this species. Previous study of Bouzgarrou et al. (2015) on fatty freshwater fish from the same site, "Abid Dam," namely *Mugil cephalus*, have shown higher TVB-N levels. Other study of Bouzgarrou et al. (2020) on tilapia showed higher value of TVB-N May be due to diet of this specie whose farming method is intensive.

Throughout the refrigerated storage period, the TVB-N content in the smoked fillets showed a small increase. After 63 days of storage, the TVB-N values in the smoked samples remained significantly lower (1.48 ± 0.12 mg/100g) at the 30-35 mg/100g alteration threshold.

Variations of trimethylamine (TMA-N) in fresh and smoked/stored fillets are shown in Table 2. The initial TMA-N level in the fresh fillets was 0.3 ± 0.029 mg/100 g. This

result is indicative of the coolness of the samples and the freshwater origin of the rudd, which generally has a low concentration of TMA-N, which may also be absent. This concentration is slightly lower than that found in the fresh fillets of tilapia *(Oerochromis niloticus*) raised in our geothermal waters, which is 0.4 ± 0.03 mg/100 g. However, Horsfall et al. (2006) demonstrated the absence of trimethylamine in the fresh fillets of tilapia. This difference in TMA-N levels is a function of species, age, year, type of muscle, and fish diet (Reddy, 2000).

Immediately after smoking, no significant difference in TMA-N concentration ($p<0.05$) was reported. This observation agrees with the results reported by Leroi & Joffraud (2000) for smoked salmon. During storage, there was a significant increase in TMA content. After 60 days of storage, the TMA-N levels of the smoked fillets did not exceed the legal limit of 12 mg N / 100 g set by the EU for fish, indicating the conservative effect of cold smoking.

3.3.2. *Variation of thiobarbituric acid*

The variations of 2-thiobarbituric acid for fresh and smoked fillets of rudd are presented in Table 2. The initial TBA value of the fresh fillets of rudd has been 0.13 ± 0.002 mg/kg. This low level of TBA may be due to the flesh of the fish, which is a white-fleshed fish and therefore of low lipid content and subsequently less sensitive to lipid oxidation.

This value doubled after cold smoking. This increase can be attributed to partial dehydration of fish and oxidation of unsaturated fatty acids as a result of smoking. Indeed, during smoking, the nets are exposed to atmospheric oxygen; this factor can accelerate the lipid oxidation of fish, resulting in an increase in TBA.

During refrigerated storage, no statistically significant difference ($p < 0.05$) in TBA values was observed. The final TBA value is 0.172 ± 0.005 mg/kg.

This value has not exceeded the value of 1-2 mg/kg, which is generally considered to be the limit beyond which the fish will normally develop an unpleasant smell and taste (Connell, 1995).

The maintenance of this low level of TBA may be due to the deposition of the phenolic constituents on the smoked fillets. Among the components of smoke, phenols have the highest antioxidant activity (Doe, 1998).

3.3.3. *Variation of biogenic amines*

Biogenic amines (BAs) are used to estimate the freshness or degree of spoilage of fresh fish; they are found at low concentrations but are associated with bacterial spoilage (Veciana-Nogues, 1997).

In the present study, four biogenic amines were detected and quantified, namely agmatine, cadaverine, histamine, and spermine (Table 3).

A moderate level of agmatine (60 mg/kg) and a low level of cadaverine (11.1 mg/kg) were detected, while histamine and spermine were not detected in fresh fillets. Agmatine was the dominant biogenic amine in the fresh and smoked fillets. Agmatine, a polyamine precursor, is formed by the decarboxylation of L-arginine by arginine decarboxylase and exerts a wide range of biological activities in brain, where it has been proposed to act as a neurotransmitter (Reis and Regunathan, 2000). Agmatine has also antiepileptic activity (Bence et al, 2003), This moderate level of agmatine may be due to the role of fish diet in the profile and levels of amines in the muscle. In fact, fish trophic levels can affect the microbial flora of fish skin and gut (Liu et al, 2016). Further studies are needed to ascertain the role of fish diet in the profile and levels of amines in the muscle.

Agmatine and histamine were the main ABs formed in terms of concentration after cold smoking treatment, showing an increasing trend with storage time.

Polyamine, spermine, was absent in fresh and smoked fillets during refrigerated storage. During refrigerated storage the level of agmatine increased considerably (133 mg/kg).

In this study, low concentrations of cadaverine were observed. In addition, cadaverine values were kept below the upper limit (< 10 mg/kg) in smoked fillets during storage (Yamanaka, 1989).

An earlier study of the relationship between biogenic amines and dominant alteration bacteria showed that cadaverine is highly correlated (r = 0.92) with the dominant alteration microflora, *Pseudomonas sp* (Yamanaka, 1989).

Histamine is considered the most important indicator of the freshness of marine fish. The current level of histamine remained low after 63 days (10.54 mg/kg) of storage, well below the upper allowable limit of histamine (100 mg/kg) (EC, 2005).

Table 3: Determination of biogenic amines in the fresh and cold-smoked filets of *S. erythrophthalmus*.

	Biogenic amines (mg/kg)				
	Days of storage	**Agmatine**	**Cadaverine**	**Histamine**	**Spermine**
Fresh fillets	0	60 ± 3.9 (a)	11.1 ± 2.3 (b)	ND	ND
Smoked fillets	7	80 ± 5.6 (b)	6 ± 0.3 (b)	ND	ND
	35	82.±6.4 (b)	0.57±0.2 (b)	3.16±0.22 (b)	ND
	63	133±4.8 (c)	6.7±0.58 (c)	10.94±2.7 (c)	ND

3.3.3. *Determination of fatty acid composition*

The fatty acid (FA) composition of the total lipids of the fresh and smoked fillets is presented in Table 4.

In the fresh fillets of rudd, saturated fatty acids (SFA) account for the majority of the total identified for FA (53.13%), followed by monounsaturated fatty acids (MUFA) (23.98%) and polyunsaturated fatty acids (PUFA) (20.23%). The work of Citil et al. (2014), however, reported a lower percentage of SFA (33.52%) and higher in MUFA (34.98%) and PUFA (30.73%).
This difference can be attributed to seasonal and environmental variation (Ben Khemis et al, 2015).

The main fatty acids are palmitic acid (C16:0 = 41.54%), palmitoleic acid (C16:1 w7 = 10.28), and oleic acid (C18 :1 w9 = 14.16),

respectively (Table 4). Similarly, the work of Citil et al. (2014) reported high levels of oleic acid (16.01%).

The profile of the composition of the fresh fillets of rudd is also characterized by a high level of branched-chain (C15: 0, C16: 0 and C18: 2) fatty acids (48.24%) in the fresh fillets of rudd. These SFA have a significant advantage because of their high temperature stability.

A moderate value of eicosapentaenoic acid (EPA: C20:5n-3) and docosahexaenoic acid (DHA: C22:6 n-3) has been detected. Similarly, Kamler et al. (2008) reported similar results for these three PUFA. However, Citil et al. (2014) reported lower values of EPA and DHA. This difference may be due to the origin of fish with different environmental conditions, including salinity and temperature (Khériji, 2003).

As a result of smoking, the sum of the SFA of the fish fillets has remained stable, while the sum of the PUFAs has increased significantly; this increase may be due to dehydration. Cold smoking thus has a conservative effect on the polyunsaturated fatty acids of the nets of the rudd.

The cold smoking step allowed the storage of PUFAs during refrigerated storage. It also has a positive effect on EPA and DHA, which have a preventive action against cardiovascular diseases; it also allows the preservation of these fatty acids for 2 months.

In this study, the effect of cold smoking on lipid stability appears at the end of refrigerated storage, which is revealed by the stability of the levels of SFA, PUFA, and MUFA.

The indices of atherogenicity (IA) and thrombogenicity (IT) have been identified among the various nutritional indices (Kalogeropoulos, 2008). In this study, the IA and IT indices (1.47 and 1.6, respectively, (Table 4) were significantly higher than those reported by Khemis et al for pike perch (*Sander lucioperca*) (Ben Khemis et al, 2015) and Bouzgarrou et al. (2016) for the freshwater mullet (*Mugil cephalus*). This may be due to the difference in diets between the two species. Our results also showed a stability of the IA index and a slight decrease in the IT index after cold smoking. Through 63 days of refrigerated storage, IA values remained stable in the smoked fillets.

In agreement with the results of Kumaran et al. (2012). This study showed that up to 63 days of refrigerated storage.
The smoked fillet still contains significant amounts of fatty acids beneficial to health.

Table 4: Changes in fatty acids composition (%) in fresh and smoked fillets of *S. erythrophthalmus* during refrigerated storage

DAYOF STORAGE	**FRESH FILLETS**		**SMOKED FILLETS**	
Days of storage	0	7	35	63
(C14:0)	4.14±0.23a	3.23±0.29b	3.21±0.18b	2.56±0.05c
(C15:0)	0.85±0.07a	0.65±0.04b	0.74±0.03b	0.62±0.01b
(C16:0)	41.54±0.54a	41.76±0.7a	42.82±0.75a	42.42±0.56a
(C18:0)	6.60±0.5a	8.48±0.16b	7.49±0.55b	7.39±0.4b
∑ SFA	**53.13±0.71a**	**54.11±0.65a**	**54.26±1.05a**	**52.79±0.71a**
(C16:1 w7)	10.28±1.22a	6.28±0.32b	7.14±0.29b	6.53±0.48b
(C18:1 w9)	14.16±1.22a	11.44±0.49b	12.70±1.29b	11.82±0.24b
(C18:1 w7)	0.00±0	0.00±0	0.00±0	0.00±0
(C20:1 w9)	0.00±0	0.00±0	0.00±0	0.00±0
∑ MUFA	**23.98±0.8a**	**19.83±0.18b**	**19.84±1.57b**	**18.35±0.24b**
(C16:2 w4)	0.00±0	0.00±0	0.00±0	0.00±0
(C16:3 w4)	1.19±0.26a	0.82±0.06a	1.02±0.06b	1.44±0.24b
(C18:2 w6)	5.85±0.2a	6.54±0.02a	7.94±0.72a	6.80±0.71a
(C18:3 w4)	0.00±0	0.00±0	0.00±0	0.00±0
(C18:3 w3)	4.22±0.27a	4.89±0.2a	4.85±0.31a	5.44±0.12a
(C18:4 w3)	0.00±0	0.00±0	0.00±0	0.00±0
(C20:4 w6)	4.96±0.27a	7.08±0.29b	5.83±0.8b	6.75±0.09b
(C20:4 w3)	0.00±0	0.00±±0	0.00±0	0.00±0
(C20:5 w3)	1.57±0.09a	2.11±0.09b	1.56±0.17c	1.99±0.02d
(C22:5 w3)	0.37±0.02a	0.42±0.01a	0.36±0.04a	0.45±0.01a
(C22:6 w3)	2.06±0.1a	3.17±0.11b	2.07±0.21c	2.52±0.07d
∑ PUFA	**20.23±0.87a**	**25.04±0.31b**	**23.62±0.4b**	**25.39±0.54b**
∑ FA	**97.81±0.11a**	**96.86±0.84a**	**97.72±0.18a**	**95.52±0.1b**
∑ n-3	**8.68±0.17a**	**10.60±0.37b**	**8.84±0.15c**	**10.40±0.16d**
∑ n-6	**11.09±0.47a**	**13.62±0.3b**	**13.77±0.28b**	**13.55±0.62b**
IA	**1.47±0.02a**	**1.54±0.04a**	**1.49±0.05a**	**1.42±0.01b**
IT	**1.60±0.01a**	**1.59±0.01a**	**1.58±0.01a**	**1.35±0.01b**

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4. Conclusion

The characteristics of the proximal composition and the biochemical and lipid quality indicators of cold-smoked fillets indicate excellent nutritional properties for rudd (*Scadinius erythrophtalmus*) produced in Tunisia, the consumption of which should be recommended. In addition to the nutritional value provided by this processing technology, smoking has extended the shelf life of rudd fillets to 63 days in refrigerated storage.

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