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Full Length Research Paper

The changes of fatty acid composition in sun dried, oven dried and frozen hake (*Merluccius merluccius*) and sardinella (*Sardinella aurita*)

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The fatty acid composition and fat quality alteration of the round sardinella (*Sardinella aurita*) and the European hake (*Merluccius merluccius*) fillets during the frozen storage (-30°C), sun drying and controlled oven drying (temperature = 60°C, air velocity = 2 m/s and relative humidity = 20%) were investigated. Results show that the fresh fillets of the *S. aurita* and *M. merluccius* were particularly rich in polyunsaturated fatty acid mainly the Docosahexaenoic Acid (DHA) and eicosapentaenoic acid (EPA). Changes in the saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), n-3 polyunsaturated fatty acids (n-3PUFA), n3/n-6 ratio, atherogenic (AI), thrombogenic (TI) and polyene indices (PI) revealed that both freezing and drying (solar and oven) processes affected the lipid nutritional quality at different degrees in the two studied species. The frozen storage induced a high alteration of the sardinella fillet fat; however, the hake was more susceptible to the oven drying treatment.

Key words: Hake, sardinella, fatty acid, frozen storage, solar dry, oven dry.

INTRODUCTION

The round sardinella *Sardinella aurita* and the European hake *Merluccius merluccius* are important economic seafood resources in the Mediterranean Sea. These fish species constitute a considerable source of low-cost dietary protein and Polyunsaturated Fatty Acids (PUFA) (Özogul and Özogul, 2007; Pacetti et al., 2010). The nutritional benefits of PUFA for human health are well described in the literature (Uauy and Valenzuela, 2000; Holub and Holub, 2004). One of the major problems with the commercialization of those species is their high susceptibility to deterioration. To retain fish sensory and nutritional properties, several storage methods have been widely used. Besides salting and sun drying which are two ancient practices used by many cultures to preserve food (Clack and Goldblith, 1974; Rodrigo et al., 1998), freezing and oven drying techniques are largely emplo-yed (Saldanha et al., 2008; Akinwumi et al., 2011). Nevertheless, during processing and storage, fish quality may decline as a result of several factors. One of the most important concerns is the oxidation of the highly unsatu-rated lipids (Ackman, 1989). According to Devasagayam et al. (2004), lipids are highly prone to free radical da-mage resulting in lipid peroxidation that can lead to adverse alterations. Furthermore, Bagchi et al. (2000) reported that free radicals have been implicated in over a hundred disease conditions in humans, including arthritis, hemorrhagic shock, atherosclerosis, advancing age, is-chemia and reperfusion injury of many organs, Alzheimer

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Table 1. The average weights and lengths of the analyzed specimens of *Sardinella aurita* and *Merluccius merluccius.*

Specie	Average total weight (g)	Average total length (cm)
S. aurita	43.5 ± 2.7	18 ± 1.4
M. merluccius	53.5 ± 3.1	20 ± 2.8

and Parkinson‟s disease, gastrointestinal dysfunctions, tumor promotion and carcinogenesis.

This study aims to investigating the changes in the fatty acid composition of the fillets of two different fish species: *S*. *aurita* and *M*. *merluccius* after freezing storage and drying processing.

MATERIALS AND METHODS

Fish sampling

A total of 144 fresh samples of *S. aurita* and *M. merluccius* from the Tunisian coasts were purchased in a local harbor and transferred to the laboratory in polystyrene ice-filled boxes. The average weights and lengths of the sampled specimens were given in Table 1.

Sample preparation

The raw samples were washed properly and subsequently filleted. The fillets of each species were divided into four groups; the first lot was immediately analyzed to serve as the control group. The second lot was stored under a freezing temperature of -30°C for 1 month. The third one was salted and sun dried according to the methods described by Maas-van Berkel et al. (2005) and the last group was dried under a controlled oven method. The controlled drying trial was undertaken through a convective hot air drying processing system. Temperature, air velocity and relative humidity inside the vein were adjusted and controlled using an automated regulation system. The drying temperature was fixed at 60°C, air velocity at 2 m/s and relative humidity at 20%. Drying experiments were run in triplicate. The measurement sensors and the data recording and controlling system were connected to a computer. Hot air was vertically orientated on the samples to ensure optimum conditions for air-product contact.

Biochemical analysis of the samples

Lipids were extracted according to the Folch et al. (1957) method with the solvent mixture chloroform–methanol (2:1, v/v) containing 0.01% butylated hydroxytoluene (BHT) as the antioxidant. Lipid extracts were trans-esterified according to the method of Cecchi et al. (1985). Methyl nonadecanoate C19:0 (Sigma) was added as internal standard. Separation of FAMEs was carried out on a HP 6890 gas chromatograph with a split/splitless injector equipped with a flame ionization detector at 275°C, and a 30 m HP Innowax capillary column with an internal diameter of 250 lm and a 0.25 lm film thickness. Injector temperature was held at 250°C. The oven was programmed to rise from 50 to 180°C at a rate of 4°C/min, from 180 to 220°C at 1.33°C/min and to stabilize at 220°C for 7 min. Nitrogen was the carrier gas. Identification of FAMEs was based on the comparison of their retention times with those of a mixture of methyl esters (SUPELCO PUFA-3). Fatty acid peaks were integrated and analyzed using the HP chemstation software. All chemical analyses were performed in triplicate. Fatty acid contents were expressed as percentages of total fatty acids. Data is presented as the mean value ± standard deviation.

Lipid quality indices

From the data on the fatty acid composition, lipid quality indices, that is, atherogenic index (AI) and thrombogenic index (TI) were determined according to Ulbricht and Southgate (1991). The following equations were applied:

$$AI = 12{:}0 + 4 \times 14{:}0 + 16{:}0 \ /[\sum MUFAs + PUFA\ n6 + PUFA\ n3] \quad TI = (14{:}0 + 16{:}0 + 18{:}0)/[\ 0.5 \times \sum MUFAs + 0.5 \times PUFA\ n6 + 3 \times PUFA\ n{-}3 + PUFA\ n3/\ PUFA\ n6]$$

The polyene index (PI) which is a good indicator to determine lipid oxidation (Sahari et al., 2009; Nazemroaya et al., 2009; Pirestani et al., 2010) was calculated according to the following formula:

$$DHA\ PI = EPA + C16{:}\ 0$$

Statistical analysis

Data was analyzed using the software "R". To assess significant differences between means, the one way analysis of variance (ANOVA) followed by the Duncan test was applied. Differences were considered significant when $P < 0.05$.

RESULTS

Changes in fatty acid composition and lipid indices of the round sardinella

Table 2 shows the proximate fatty acid composition of raw and processed *S*. *aurita* fillet. Results revealed that lipids of fresh sardinella were composed of 49.17% of saturated fatty acid (SFA), 12.03% of monounsaturated fatty acid (MUFA) and 38.80% of polyunsaturated fatty acid (PUFA). Among SFAs, those occurring in the highest proportions were palmitic (C16:0) and stearic (C18:0) acids. Oleic acid (C18:1n-9) was the main fatty acid among the MUFAs. A high level of n-3 PUFAs was recorded in raw *S. aurita* (34% of total fatty acid) due to the substantial proportions of the docosahexaenoic acid (C20:5n-3; DHA) and the eicosapentaenoic acid (C22:6n-3; EPA), which represent the predominant PUFA with 8.48 and 23.10%, respectively. One month of freezing storage of the sardinella fillet caused increase (p>0.05) of the SFA and MUFA amounts while PUFA decreased (from 38.80 to 31.39%; p<0.05). Same trends were recorded in oven

Table 2. Changes in fatty acid composition of the *Sardinella aurita* fillet at different conditions.

Fatty acid (%)	Raw	Frozen	Solar dried	Oven dried
C14:0	2.95±0.62^{a}	4.26±1.22^{ab}	7.21±1.53^{b}	6.84±2.35^{b}
C14:1	0.19±0.06^{a}	0.79±0.67^{b}	0.31±0.01^{a}	0.70±0.03^{b}
C15:0	0.86±0.18^{a}	1.35±0.4^{ab}	1.55±0.32^{bc}	1.46±0.40^{b}
C15:1	0.37±0.28^{a}	0.66±0.2^{b}	0.18±0.01^{c}	0.40±0.12^{a}
C16:0	32.80±3.10^{a}	30.07±2.61^{a}	35.22±3.17^{a}	35.68±3.37^{a}
C16:1n-9	3.60±0.67^{a}	3.69±0.56^{a}	6.76±0.64 ^{b}	4.61±2.21^{ab}
C16:1n-7	0.77±0.35^{a}	0.54±0.05^{a}	0.43±0.12^{a}	0.68±0.24^{a}
C16:2n-4	0.97±0.10^{a}	1.26±0.28^{a}	1.40±0.49^{a}	1.66±0.59^{a}
C16:3n-4	0.38±0.01^{a}	0.52±0.10^{ab}	0.57±0.04^{ab}	0.71±0.18^{b}
C16:4	0.43±0.11^{a}	0.43±0.12^{a}	0.60±0.11^{a}	0.79±0.34^{a}
C18:0	12.46±2.82^{a}	17.33±6.17^{a}	5.17±1.58^{b}	14.05±1.56^{a}
C18:1n-9	3.70±0.32^{a}	5.20±0.22^{a}	6.96±3.01^{a}	5.28±1.45^{a}
C18:1n-7	2.24±0.14^{ab}	1.50±0.15^{b}	2.49±0.64^{ac}	2.61±0.72^{ac}
C18:2n-6	1.41±0.01^{a}	1.62±0.10^{a}	1.63±0.36^{a}	1.98±0.72^{a}
C18:3n-4	0.13±0.03^{a}	0.10±0.01^{a}	0.22±0.08^{ab}	0.41±0.27^{b}
C18:3n-3	0.73±0.04^{a}	6.84±0.82^{b}	1.42±0.41^{a}	0.88±0.22^{a}
C18:4n-3	0.87±0.34^{a}	0.92±0.40^{a}	2.73±0.85^{b}	1.00±0.09^{a}
C20:1n-9	0.81±0.24^{a}	0.62±0.19^{a}	0.19±0.03^{b}	0.52±0.04^{a}
C20:1n-7	0.10±0.01^{a}	0.95±0.02^{b}	0.01±0.00^{c}	0.16±0.06^{a}
C20:2n-6	0.23±0.1^{a}	0.51±0.34^{a}	0.49±0.25^{a}	0.44±0.05^{a}
C20:4n-6	1.02±0.47^{a}	0.82±0.05^{a}	0.64±0.23^{a}	0.71±0.31^{a}
C20:4n-3	0.52±0.09^{a}	2.99±0.54^{b}	0.73±0.35^{a}	2.53±0.57^{bc}
C20:5n-3	8.48±0.98^{a}	3.00±0.62^{b}	7.74±1.00^{a}	3.81±1.04^{b}
C22:0	0.10±0.05^{a}	0.41±0.08^{b}	0.16±0.03^{a}	0.46±0.14^{b}
C22:1	0.25±0.06^{a}	1.23±0.23^{b}	0.27±0.06^{a}	0.66±0.03^{c}
C22:5n-3	0.52±0.16^{a}	1.33±0.08^{b}	0.41±0.06^{a}	0.69±0.33^{a}
C22:6n-3	23.10±4.78^{a}	11.04±2.08^{b}	14.50±3.54^{b}	10.29±0.46^{b}
SFA	49.17±3.94^{a}	53.43±4.78^{ab}	49.31±3.10^{a}	58.49±5.04^{b}
MUFA	12.03±1.15^{a}	15.19±1.56^{ab}	17.60±4.12^{b}	15.62±0.06^{b}
PUFA	38.80±2.31^{a}	31.39±2.08^{b}	33.09±1.43^{b}	25.90±4.30^{c}
n-3PUFA	34.23±3.11^{a}	26.12±3.88^{bc}	27.53±2.15^{b}	19.20±2.63^{c}
n-6 PUFA	2.66±0.38^{a}	2.96±0.35^{a}	2.76±0.59^{a}	3.13±0.97^{a}
n-3/n-6	12.87±1.39^{a}	8.83±0.87^{bc}	9.98±1.47^{b}	6.14±1.84^{c}
EPA/DHA	0.37±0.04^{ab}	0.27±0.12^{a}	0.53±0.18^{b}	0.37±0.11^{ab}

SFA, Saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid. Different letters indicate significantly different values (Duncan"s $p<0.05$) between treatments.

dried specimens with $p < 0.05$ for all fatty acid groups. However, the solar drying treatment induced increase of MUFA and decrease of PUFA ($p < 0.05$) while SFA remained statistically invariable ($p>0.05$). In all treated groups, there was a tendency towards a significantly lower level of the n-3 series in comparison with the control group. However, slight variations were recorded for the n-6 series ($p>0.05$). Hence, the decrease in the n-3/n-6 ratio from 12.87 in the raw fillet to 8.83, 9.98 and 6.14 in frozen, sun dried and oven dried *S. aurita* fillet, were recorded respectively.

Frozen and drying conditions caused a considerable decrease ($p<0.05$) of the most important n-3 fatty acids in *S. aurita* fillet, EPA and DHA. The exception was the EPA in the solar dried fillet which remained invariable ($p > 0.05$). According to the relative contents of particular groups of fatty acids, the oven dry process induced a significant elevation of the atherogenic index (AI) and thrombogenic index (TI) of the sardinella fillet in compa-rison to the raw ones (Table 3). The (EPA + DHA)/C16:0 ratio (PI) of the raw sardinella fillet (0.96) was significantly higher than those in frozen (0.47), in sun dried (0.63) and

Table 3. Changes in lipid quality indices of the *Sardinella aurita* fillet at different conditions.

Lipid index	Raw	Frozen	Solar dried	Oven dried
AI	0.91±0.18^{a}	1.06±0.29^{a}	1.34±0.26^{ab}	1.66±0.18^{bc}
TI	0.39±0.15^{a}	0.54±0.14^{a}	0.46±0.13^{a}	0.77±0.02^{b}
PI	0 .96±0.19^{a}	0.47±0.09^{bc}	0 .63±0.05^{b}	0.39±0.03^{c}

AI, Atherogenic index; TI, thrombogenic index; PI, polyene index. Different letters indicate significantly different values (Duncan"s $p<0.05$) between treatments.

in oven dried fillet (0.39) (Table 3).

Changes in fatty acid composition and lipid indices of the European hake

Table 4 gives data on the effects of freezing and drying on the percentage of different fatty acids (FA) identified in the fillet of the European hake *M. merluccius*. In raw hake fillet, our results revealed that SFA amounting to 45.88% of total fatty acids are prevalent over the PUFA (40.53%) and MUFA (13.59%). Among them, those occurring in the highest proportions were palmitic acid (C16:0), stearic acid (C18:0), oleic acid (C18:1n9), EPA and DHA. The content of SFAs in the raw hake fillet remained insignificantly different in oven dried (42.63%) and sun dried fillet (47.71%). We also noted that the drying treatments induced the increase of the MUFA ($p<0.05$). Concerning the PUFA group, we recorded that the solar drying has induced a significant decrease. However, one month of freezing storage was found to induce the increase of SFAs (59.57%) and the decrease of PUFAs (22.75%) with $p<0.05$. Losses of the n-3 series (mainly the DHA) in frozen fish were higher than those dried by other method. Hence, the frozen hake fillet showed the lowest n-3/n-6 ratio and PI index (5.88 and 0.42, respectively) and the highest EPA/DHA ratio (0.37), AI and TI indices (1.09 and 0.84, respectively) (Table 5).

DISCUSSION

In the current study, data referring to the fatty acid compositions of the raw fillets of *S. aurita* and *M. merluccius* revealed that within the group of main fatty acids identified, the total content of SFA, MUFA and PUFA were similar in both species ($p>0.05$). FA contents in the two species of fish followed a pattern with SFA >PUFA > MUFA. Same tendencies were recorded in *Sardinella* sp (Steiner-Asiedu et al., 1991) and in sardine *Sardinella gibbosa* (Chaijan et al., 2006). We recorded high percentages of EPA and DHA, in both studied fish species within the PUFA group. Our results are consistent with those that characterize several fish species (Soriguer et al., 1997; Garcıa-Arias et al., 2003). In fact, compared to other animal fat, fat fish are particularly rich in EPA and DHA derived from algae and plankton (Nichols et al., 1989). It is known that freezing and frozen storage are widely used to keep nutritional and sensory properties of fish (Erickson, 1997). However, fish quality decreases during frozen storage as a result of increasing time and temperature of storage as some authors demonstrate (Sotelo et al., 1995; Aubourg, 1999). Our results showed that the frozen storage at -30°C for one month induced a significant reduction in PUFAs, mainly the omega-3 in both studied species. We noted that DHA and EPA dropped markedly with respect to T_0. The losses of EPA and DHA varied between 64.63 and 52.21% in raw sardines and between 59.19 and 66.38% in raw hake, respectively. These results are in agreement with those reported in several fish species (Saldanha et al., 2007; Chaijan et al., 2006; Pirestani et al., 2010).

According to Godwin and Prabhu (2006), the high degree of unsaturation in fish oils increase the vulnerability to lipid peroxidation. Furthermore, the degradation of the PUFAs group induced by auto-oxidation leads to the formation of volatile compounds that are associated with rancidity (Pazos et al., 2005). The findings of the present study suggest that, the decrease in the polyene index (PI) during the frozen storage indicated that the oxidation process was in progress in the fillets of sardinella and hake. These results agree with previous research findings and concord with those of Taheri et al. (2012) for the fillets of Cobia (*Rachycentron canadum*). In addition, the increase of the AI and TI indices and the decrease of the n-3/n-6 ratio denoted a deterioration of the flesh lipid quality mainly in *M. merluccius.* In rural areas, the traditional sun drying method remains the predominant processing method to conserve fish (Akinola et al., 2006). Nevertheless, according to some authors, the lipid of traditional salted, sun-dried fish is highly susceptible to oxidation during processing and storage (Smith and Hole, 1991). Our results demonstrated that sun drying induced a significant reduction of PUFA groups including EPA (C20:5n-3) and DHA (C22:6n-3) in species, sardinella and hake. This finding suggests that in addition to salting, which induce oxidation of the highly unsaturated lipids as reported by Aubourg and Ugliano (2002); the exposure to light and oxygen enhanced dehydration of fish and caused considerable loss of fatty acids. Similar results are reported for the Mackerel (Goulas and Kontominas, 2005) and for catfish (Smith and Hole, 1991). In the present study, we noted that the decrease of the availability of n-3PUFAs reduced the n-3/n-6 ratio and negatively affected the AI and TI indices in the two studied species.

Table 4. Changes in fatty acid composition of the European hake *M. merluccius* fillet at different conditions.

Fatty acid (%)	Raw	Frozen	Solar dried	Oven dried
C14:0	1.39±0.29^{a}	3.57±1.16^{b}	1.81±0.71^{a}	1.37±0.47^{a}
C14:1	0.26±0.04^{a}	1.81±0.33^{b}	0.24±0.07^{a}	0.77±0.08^{c}
C15:0	0.54±0.11^{a}	1.31±0.39^{b}	0.77±0.06^{a}	1.42±0.21^{b}
C15:1	0.44±0.23^{a}	1.05±0.37^{b}	0.22±0.03^{a}	1.3±0.08^{b}
C16:0	27.54±2.02^{a}	26.44±2.53^{a}	29.57±1.32^{a}	25.62±3.80^{a}
C16:1n-9	1.73±0.31^{a}	2.97±0.92^{a}	3.13±1.02^{a}	4.98±0.61^{b}
C16:1n-7	0.31±0.03^{a}	0.51±0.13^{b}	0.35±0.08^{a}	0.78±0.03^{c}
C16:2n-4	1.52±0.28^{a}	1.5±0.16^{a}	1.46±0.30^{a}	1.64±0.41^{a}
C16:3n-4	0.5±0.06^{a}	0.54±0.17^{a}	0.74±0.12^{a}	1.53±0.30^{b}
C16:4	0.59±0.09^{a}	0.67±0.16^{a}	0.69±0.25^{a}	1.52±0.14^{b}
C18:0	16.29±6.85^{a}	26.04±5.51^{b}	15.25±6.21^{a}	13.15±3.81^{a}
C18:1n-9	8.03±1.40^{a}	5.81±1.86^{a}	12.77±2.77^{b}	8.14±2.54^{a}
C18:1n-7	2.03±0.54^{a}	1.23±0.45^{b}	2.23±0.27^{a}	1.56±0.21^{b}
C18:2n-6	1.09±0.19^{a}	1.06±0.42^{a}	1.11±0.17^{a}	2.10±0.49^{b}
C18:3n-4	0.08±0.01^{a}	0.24±0.12^{b}	0.07±0.01^{a}	1.02±0.15^{c}
C18:3n-3	0.5±0.28^{a}	1.22±0.49^{b}	0.50±0.14^{a}	1.55±0.19^{b}
C18:4n-3	1.26±0.33^{a}	2.67±0.46^{b}	0.46±0.05^{c}	1.84±0.33^{a}
C20:1n-9	0.4±0.04^{ab}	0.6±0.05^{a}	0.21±0.06^{b}	1.46±0.18^{c}
C20:1n-7	0.07±0.03^{ab}	0.14±0.02^{a}	0.02±0.00^{b}	1.00±0.08^{c}
C20:2n-6	0.44±0.13^{a}	1.08±0.09^{b}	0.51±0.04^{a}	0.59±0.05^{a}
C20:4n-6	1.58±0.26^{a}	0.74±0.08^{b}	1.52±0.61^{a}	1.04±0.10^{ab}
C20:4n-3	0.43±0.13^{a}	0.42±0.15^{a}	2.35±0.39^{b}	3.82±0.81^{c}
C20:5n-3	7.35±1.54^{a}	3.00±0.62^{b}	2.66±0.59^{b}	3.69±0.41^{b}
C22:0	0.12±0.04^{a}	2.21±0.98^{b}	0.31±0.11^{a}	1.07±0.06^{b}
C22:1	0.32±0.05^{a}	3.56±0.93^{b}	0.40±0.03^{a}	0.63±0.11^{a}
C22:5n-3	1.01±0.17^{a}	1.48±0.55^{a}	0.85±0.21^{a}	1.59±0.52^{a}
C22:6n-3	24.18±2.14^{a}	8.13±2.68^{b}	19.80±1.16^{c}	14.82±1.11^{a}
SFA	45.88±3.59^{a}	59.57±4.06^{b}	47.71±5.20^{a}	42.63±4.92^{a}
MUFA	13.59±2.12^{a}	17.68±4.68^{ab}	19.57±1.58^{b}	20.62±2.08^{b}
PUFA	40.53±3.1^{a}	22.75±4.55^{b}	32.72±2.06^{c}	36.75±6.21^{ac}
n-3	34.73±6.61^{a}	16.92±5.05^{b}	26.62±8.58^{ab}	27.31±4.21^{ab}
n-6	3.11±0.47^{a}	2.88±1.12^{a}	3.14±0.36^{a}	3.73±0.94^{a}
n-3/n-6	11.17±1.95^{a}	5.88±1.68^{b}	8.48±1.98^{ab}	7.32±1.76^{b}
EPA/DHA	0.3±0.03^{ab}	0.37±0.17^{a}	0.13±0.03^{b}	0.25±0.10^{ab}

SFA, Saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid. Different letters indicate significantly different values (Duncan"s $p<0.05$) between treatments.

Table 5. Changes in lipid quality indices of the European hake *M. merluccius* fillet at different conditions.

Lipid index	Raw	Frozen	Solar dried	Oven dried
AI	0.64±0.15^{a}	1.09±0.16^{b}	0.75±0.13^{a}	0.6±0.12^{a}
TI	0.36±0.10^{a}	0.84±0.07^{b}	0.47±0.18^{a}	0.4±0.09^{a}
PI	1.14±0.19^{a}	0.42±0.07^{b}	0.76±0.13^{c}	0 .72±0.10^{c}

AI, Atherogenic index; TI, thrombogenic index; PI, polyene index. Different letters indicate significantly different values (Duncan"s $p<0.05$) between treatments.

Furthermore, the assessment of the polyene index (PI) confirmed the increased oxidation of lipids.

Compared to sun - drying technique; the oven-drying method saves time, can be relatively controlled and ensures good quality of the product (Akinwum et al., 2011). According to our work, controlled oven drying con-

ditions (temperature at 60°C, air velocity at 2 m/s and relative humidity at 20%) induced different tendency of the fatty acids groups between sardinella and hake. We noted that in the sardinella *S. aurita*, oven drying has led to significant increase in the SFA and MUFA groups while PUFAs (mainly the n-3 series) dropped markedly. Similar findings are reported for roasted sardines (Bulla et al., 2011) and canned sardines (Tarley et al., 2004). Other authors have demonstrated that oven-baking procedures minimally affect the fatty acid content in the sardine *Sardina pilchardus* fillet (García-Arias et al., 2003). Nevertheless, Wu and Mao (2008) have shown that hot air and microwave drying entail a significant increase of PUFA (including DHA and EPA) against a decrease of MUFA and SFA in carp *Ctenopharyngodon idella*. In the hake *M. merluccius*, we noted that both SFA and PUFA contents insignificantly decreased, while MUFA fatty acids increased after drying ($p<0.05$). These results reveal that the effects of the drying process on the SFA, MUFA and PUFA were dependent on fish species, drying methods and fatty acid types.

Thermal oxidation was observed in both studied fish species. This is evidenced by the decreasing n-3/n-6 ratio and the (EPA + DHA)/C16:0 ratio (PI) and indicated an alteration of the nutritional index of fatty acid during the oven drying process. Findings regarding AI and TI, which indicate the global dietetic quality of lipids, showed more pronounced degradation of the nutritional value of *S. aurita* than *M. merluccius.* In fact, the latter showed no significant differences in these indices compared to row sample.

Conclusion

The row fillets of the *S. aurita* and *M. merluccius* revealed close values in terms of total n-3PUFAs group richness (particularly DHA and EPA). This showed the excellent nutritional quality as evidenced through the values of different lipid parameters. The observed variations in SFA, MUFA, PUFA, n3/n6 ratio, PI, AI and TI revealed that the fatty acid composition of the two studied fish spe-cies were susceptible to significant change during the frozen storage (-30°C) and/or during the drying processes. However, the preservation (freezing) and transformation (drying) methods did affect the nutritional quality at different de-grees according to the type of fish. In fact, our findings demonstrated that a lean fish such as hake was more susceptible to degradation when it is frozen. However, controlled drying induced less impact on its nutritional quality. For sardinella, a fat fish, it was more adequate to apply the solar drying method.

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