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FATTY ACID PROFILE OF FROZEN FILLETS OF COBIA (*Rachycentron canadum*) STUNNED BY ELECTRONARCOSIS

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ABSTRACT

The objective of this research was to evaluate the effect of desensitisation by electronarcosis on the changes to the fatty acid profile of cobia (*Rachycentron canadum*) fillets stored at low sub-zero temperature. For stunning, 50, 100 and 150 V were used for 120 s and then exsanguination was performed, followed by storage at –18 °C for 180 days. A total of 47 fatty acids were detected in cobia fillet samples, and most of the quantified fatty acids differed ($p < 0.05$) between treatments and storage times. The n6/n3 ratio did not differ ($p > 0.05$) among treatments; however, the n6/n3 ratio and Σhypocholesterolaemic fatty acids/Σhypercholesterolaemic fatty acids ratio were significantly affected by the storage times and their outcomes. In general, the electronarcosis intensities used to numb cobia did not promote differences during the frozen storage of the fillets for most of the analysed variables but a significant effect of the storage time was noted within the treatments, with meat quality loss observed over time.

Key words: electric shock; storage; meat quality; *Rachycentron canadum*

INSENSIBILIZAÇÃO DO BIJUPIRÁ (*Rachycentron canadum*) POR ELETRONARCOSE: EFEITOS SOBRE O PERFIL DE ÁCIDOS GRAXOS EM FILÉS CONGELADOS

RESUMO

O objetivo desta pesquisa foi avaliar o efeito da insensibilização por eletronarcose em bijupirás (*Rachycentron canadum*) sobre o perfil de ácidos graxos em filés armazenados em congelamento. Foram utilizadas as voltagens de 50, 100 e 150 volts por 120 segundos, e após a insensibilização foi realizada a sangria e o armazenamento a -18 °C durante 180 dias. Foram analisados 47 ácidos graxos em amostras de filé do bijupirá. Ocorreram diferenças significativas ($p<0,05$) entre os tratamentos para os ácidos graxos e foram observadas diferenças no tempo de estocagem para a maioria dos ácidos graxos quantificados. A relação n6/n3 não apresentou diferença ($p>0,05$) entre os tratamentos, no entanto para os tempos de estocagem e seus desdobramentos foram observadas diferenças significativas. Para a razão H/H (Σ ácidos graxos hipocolesterolêmicos/Σ ácidos graxos hipercolesterolêmicos), ocorreram variações, mas não foram observadas diferenças ($p>0,05$), mas sim entre os tempos de estocagem e seus desdobramentos. De maneira geral, as intensidades de choque elétrico utilizadas para insensibilização do bijupirá não promoveram diferenças durante a estocagem congelada dos filés, na maioria das variáveis analisadas, no entanto, a avaliação do tempo de estocagem dentro dos tratamentos utilizados foi significativa, notando-se perda de qualidade da carne com o passar do tempo.

Palavras-chave: choque elétrico; armazenamento; qualidade da carne; *Rachycentron canadum*

INTRODUCTION

The cobia *Rachycentron canadum* is a species of pelagic, migratory fish found in tropical and subtropical seas. In the western Atlantic, it is found from southern Canada to Argentina. In Brazil, it is distributed throughout all coasts (from Amapá to Rio Grande do Sul) (Shaffer and Nakamura, 1989). *Rachycentron canadum* has a preference for water temperatures between 20 and 30 °C, migrating from the southern to the northern hemisphere in search of warmer water during autumn and winter. In nature, it can tolerate salinities between 8 and 44.5 ppm (Shaffer and Nakamura, 1989). In commercial fish farms, sexually mature females can reach a weight above 8 kg in 18 months of culture. Males reach sexual maturity at 1 year when the fish weighs about 7 kg (Su et al., 2000). Several cultivations of this species have recently been initiated in Brazil, and its adaptation capacity to net tanks has been a success.

Freezing is a technique used for long-term preservation of fish, allowing the maintenance of organoleptic and nutritional characteristics, by minimising enzymatic and microbial activities (Alizadeh et al., 2007). Nonetheless, the freezing method, which can be fast or slow, is a variable that interferes with the quality of the fish. Slow freezing causes the formation of intracellular ice crystals that cause cell disruption, increasing water loss, enhancing enzymatic activity and damaging the texture of the fillets (Alizadeh et al., 2007).

Electrical stunning (electronarcosis) is regarded as an appropriate method for fish desensitisation, without changing fish quality (Lines et al., 2003; Roth et al., 2012). However, the need for observations on the behaviour and welfare of fish during breeding and at the time of slaughter have been emphasised (Lines et al., 2003). In some countries, such as the UK, electronarcosis is utilised as the main method for paralysing fish, despite a lack of consensus among the scientific community and regulators.

According to Suárez-Mahecha et al. (2002), it is increasingly important to know the concentrations of fatty acids in fish from the natural environment and in culture, considering society's constant search for healthier foods. Fish is particularly enriched with long-chain fatty acids (C14–C22), which can be saturated fatty acids (SFA) or unsaturated fatty acids (USFA). The fatty acid composition varies according to the animal species, food habit, season, water temperature, diet, habitat and maturation physiological state (Ogawa and Maia, 1999; Mohanty et al., 2019).

Freezing is a technique used for long-term preservation of fish, allowing the maintenance of organoleptic and nutritional characteristics, by minimising enzymatic and microbial activities (Alizadeh et al., 2007; Sone et al., 2019). Nonetheless, the freezing method, which can be fast or slow, is a variable that interferes with the quality of the fish affecting the lipid stability due the oxidative processes that are not avoided by the low negative temperature of storage (Secci and Parisi, 2016). Slow freezing causes the formation of intracellular ice crystals that cause cell disruption, increasing water loss, enhancing enzymatic activity and damaging the texture of the fillets (Alizadeh et al., 2007; Sone et al., 2019).

The objective of the present study was to evaluate the effect of different voltages of electric shock applied to cobia fillets (*R. canadum*) as a method of desensitisation on the fatty acid profile and its changes during frozen storage of the fillets for 180 days.

MATERIAL AND METHODS

The experiment was carried out in Ubatuba (São Paulo, SP, Brazil), at the Clarimundo de Jesus base, belonging to the Oceanographic Institute of the University of São Paulo (Brazil), and at the Aquaculture Laboratory of the Department of Animal Science of the Faculty of Animal Science and Food Engineering (FZEA) of the University of São Paulo (USP), Pirassununga Campus (SP, Brazil). The specimens, obtained from a commercial production farm in the municipality of Ubatuba (SP, Brazil) had an average weight of approximately 2 kg.

To evaluate the effect of electronarcosis on the quality of cobia meat kept frozen for 180 days, the fish were submitted to the following three treatments: 50, 100 and 150 V, respectively, using alternating current, for 120 s. For each treatment, 120 fish were used, which were placed in a 120-L plastic box, in which the electrical conductivity of water was adjusted to 700 µS, for the correct application of the electricity. After the desensitisation, the fish were slaughtered, by cutting the branchial arches and then submerged in cold water for 3 min, for exsanguination.

Before and after the desensitisation, the water quality parameters were measured with the aid of a U-10 multi-parameter probe (Horiba, Ubatuba, SP, Brazil). The behaviour of the animals was observed during the exposure to electric shock, and the desensitisation time was considered as starting from the moment of electric current application until the complete unconsciousness, which was determined by the absence of reflexes to lateral line stimulation, and the absence of opercular movements and rotation of the eyes.

A 4×3 factorial scheme was used, with four assessment points (0, 60, 120 or 180 days at –18 °C after slaughtering) and three electric shock voltages (50, 100 or 150 V), according to the following statistical model:

$$Y_{ij} = m + \alpha_i + \beta_j + \alpha\beta_{ij} + e_{ij} \quad (1)$$

where

$\boldsymbol{Y_{ij}}$ = the observed value relative to time ***i*** at voltage ***j***;

$\boldsymbol{m}$ = the general average of the variable;

α = the effect of treatment ***i*** (storage days);

βj = the effect of treatment ***j*** (voltages of the current);

and $\boldsymbol{e_{ij}}$ = the contribution of chance associated with the effect of time ***i*** on voltage ***j***.

The whole experiment was performed with three replicates, with one fillet per replicate that were analysed immediately after death (0 Time) and after storage at low negative temperature (-18 °C), at different storage time (60, 120 and 180 days). At the different storage times, the fillets were submitted to the lyophilization to stabilize the matrix before the fatty acid profile analysis.

The total lipid content of the fish samples was analysed according to the method of Folch et al. (1957). Accordingly, 2 g of fresh

sample was reconstituted from the lyophilised sample, by the addition of 1.5 mL of distilled water per 0.5 g (average) of the lyophilised sample. The extract was filtered through filter paper into a test tube. To maintain a constant chloroform:methanol:water ratio of 8:4:3 (v/v/v), as suggested in the original method, 9.8 mL (11.3–1.5 mL) of 0.88% (w/w) aqueous KCl solution was added to the extract (30.3:15.1:11.3). The blends were held overnight at refrigerated temperature to allow separation of the two phases. Then, the solvents were removed by vacuum evaporation (Buchi Rotavapor RE111) until only the fat remained at the bottom of the tube. The fat was dried under pressurised nitrogen and dissolved in 5 mL chloroform. Another 1 mL of chloroform solution was added before methylation of the fatty acids for analysis by gas chromatography (GC).

The fatty acids were methylated, as described by Morrison and Smith (1964). For saponification, 5 mL of 0.5 M of methanolic KOH was added, and the tubes were then placed in a 90 °C water bath for 40 min, with stirring every 10 min, and finally cooled. A mixture of potassium carboxylates and glycerol was formed. One mL of distilled water and 2.5 mL of 2 M HCl were added to the saponified fatty acids. A 2.5-mL aliquot of petroleum ether (40–60 °C) was added, and the tubes were stirred to favour the extraction of fatty acids by the solvent. The ether phase was transferred twice, and the two phases were separated by the addition of 2.5 mL petroleum ether. Then, the petroleum ether containing the dissolved fatty acids was evaporated.

Esterification was carried out according to the modified method of Morrison and Smith (1964). Cyclohexane (0.5 mL) and 2 mL of 14% BF_3–methanol were added. The samples were placed in a water bath at 90 °C for 3 min, cooled in a water bath, and 2.5 mL of distilled water and 2.5 mL petroleum ether were added. Themethylated fatty acids were extracted twice by the addition of 2.5 mL petroleum ether, the solvent was distilled, and the methylated fatty acids were dissolved in 1 mL hexane.

Each sample was transferred to a vial and sealed. GC analysis was performed using a Varian 430 gas chromatograph equipped with a Supelco Omegawax 320 capillary column (30 m × 0.32 mm i.d., 0.25 mm film thickness) and a flame ionisation detector (FID). The GC conditions were set as follows: injection volume, 1 µL; carrier gas (He) flow rate, 1.5 mL min^{-1}; injector temperature, 220 °C; detector temperature, 300 °C; split ratio, 1:20. The flows of He, air and H_2 to the FID were 25, 300 and 30 mL min^{-1}, respectively.

The atherogenicity index (AI) and thrombogenicity index (TI), according to Ulbricht and Southgate (1991) and hypocholesterolemic/hypercholesterolemic FA ratio (h/H), according to Santos-Silva et al. (2002) were also calculated as follows:

- AI = [C12:0 + (4 × C14:0) + C16:0] / (Σn3 PUFA + Σn6 PUFA + ΣMUFA)
- TI = (C14:0 + C16:0 + C18:0) / [(0.5 × ΣMUFA) + (0.5 × Σn6 PUFA) + (3 × Σn3 PUFA) + (Σn3 PUFA / Σn6 PUFA)]

h/H = (C18:1n9 + C18:2n6 + C20:4n6 + C18:3n3 + C20:5n3 + C22:5n3 + C22:6n3) / (C14:0 + C16:0).

Furthermore, PUFAn3/PUFAn6 (n6/n3 ratio) and C18:2n6/C18:3n3 (LA/ALA ratio) were also calculated.

RESULTS

Fatty acid profile

Due to the expected similar content in total lipids (4.52 ±1.15/100 g fillet), as expected since the cobia submitted to the different stunning methods were of the same group and were similarly fed before the treatment, the fatty acid profile was expressed in percentage of each fatty acid in relation to the total fatty acid content. As it is known, the quantitative expression of fatty acids poses some incertitude, from an analytical point of view, and this expression can be appropriate in the case of matrix with different lipid contents.

Table 1. Saturated fatty acids in frozen (–18 °C) fillets of cobia desensitised with electronarcosis at different voltages, according to storage time.

Fatty acid	Treatment (V)			Time (days)				CV (%)	*p*-value		
	50	100	150	0	60	120	180		Volts	Time	Interaction
C12:0	1.23a	1.29a	1.22a	1.70a	1.18b	1.12b	1.14b	7.25	0.2146	0.0001	0.0886
C13:0	0.64a	0.67a	0.64a	0.89a	0.62b	0.58b	0.60b	7.22	0.1920	0.0001	0.0916
C14:0	3.46a	3.30a	3.60a	4.32a	3.27b	3.11b	3.41b	9.75	0.1409	0.0001	0.3572
C15:0	1.00a	1.04a	1.02a	1.31a	0.95b	0.95b	0.97b	6.07	0.3383	0.0001	0.1910
C16:0	17.42a	18.16a	18.48a	21.56a	16.98b	17.95b	16.78b	6.63	0.1260	0.0001	0.2936
C17:0	0.98a	1.01a	0.98a	1.24a	0.92b	0.93b	0.95b	5.73	0.3032	0.0001	0.1604
C18:0	5.75a	5.85a	5.83a	6.76a	5,59b	5.67b	5.55b	6.81	0.8266	0.0001	0.3100
C20:0	0.89b	0.85a	0.83a	1.10a	0.80b	0.77b	0.76b	5.78	0.4441	0.0001	0.0729
C21:0	0.09a	0.09a	0.10a	0.16a	0.08b	0.05b	0.10b	38.91	0.9636	0.0001	0.5367
C22:0	0.20a	0.20a	0.19a	0.31a	0.19b	0.13b	0.19b	28.96	0.9442	0.0001	0.1986
C24:0	0.14a	0.13a	0.12a	0.19a	0.13b	0.01b	0.13b	21.68	0.2838	0.0001	0.0940

Within criterium (Treatment or Time), different letters indicate significant statistical differences ($p < 0.05$).

The profiles of the SFA (Table 1), monounsaturated (MUFA; Table 2) and polyunsaturated fatty acids (PUFA; Table 3) of cobia fillets submitted to different electric shock voltages indicated that docosadienoic (C22:2 n6), docosapentaenoic (DPA, C22:5 n3 and C22:5 n6) and docosahexaenoic (DHA, C22:6 n3) fatty acids were significantly affected by the different treatments ($p < 0.05$). Differences due to the storage time were also observed for most of the fatty acids quantified, except for octadecadienoic acid (C18:2 n4), eicosadienoic acid (C20:2 n6) and for C22:2 n6.

Table 2. Monounsaturated fatty acids in frozen (–18 °C) fillets of cobia desensitised by electronarcosis at different voltages, according to storage time.

Fatty acid	Treatment (V)			Time (days)				CV (%)	*p*-value		
	50	100	150	0	60	120	180		Volts	Time	Interaction
14:1 n5	0.66a	0.69a	0.65a	0.90a	0.64b	0.60b	0.61b	7.25	0.2234	0.0001	0.0533
16:1 n7	4.44a	4.61a	4.70a	5.14a	4.36b	4.64b	4.34b	6.73	0.1583	0.0004	0.5146
16:1 n9	0.84a	0.87a	0.85a	1.08a	0.81b	0.81b	0.79b	6.83	0.5328	0.0001	0.1384
17:1	0.56a	0.53a	0.55a	0.76a	0.54b	0.43b	0.52b	6.73	0.1583	0.0004	0.5146
18:1 n9	19.12a	17.97a	19.91a	22.11a	19.12ab	17.52b	18.29b	14.41	0.2667	0.0286	0.6529
18:1 n7	3.54a	3.44a	3.27a	4.31a	3.05b	3.20b	3.42ab	20.18	0.6552	0.0139	0.4567
20:1 n7	0.45a	0.47a	0.45a	0.57a	0.43b	0.43b	0.44b	6.02	0.1517	0.0001	0.2693
20:1 n9	1.30a	1.25a	1.31a	1.72a	1.22b	1.13b	1.23b	20.40	0.8636	0.0022	0.8038
20:1 n11	0.43a	0.52a	0.44a	0.60a	0.42ab	0.49ab	0.40b	28.29	0.2660	0.0427	0.2701
22:1 n7	0.13a	0.13a	0.13a	0.17a	0.13b	0.10b	0.13b	17.97	0.5638	0.0002	0.5311
22:1 n9	0.30a	0.30a	0.25b	0.39a	0.27b	0.25b	0.27b	13.57	0.0075	0.0001	0.0120
22:1 n11	0.45a	0.45a	0.43a	0.51a	0.43b	0.43b	0.42b	8.01	0.2472	0.0003	0.0008

Within criterium (Treatment or Time), different letters indicate significant statistical differences (p <0.05).

Table 3. Polyunsaturated fatty acids in frozen (–18 °C) fillets of cobia desensitised by electronarcosis at different voltages, according to storage time.

Fatty acid	Treatment (V)			Time (days)				CV (%)	*p*-value		
	50	100	150	0	60	120	180		Volts	Time	Interaction
16:2 n4	0.99a	1.03a	0.97a	1.08a	0.94b	0.97b	1.07b	6.28	0.1266	0.0032	0.5878
16:3 n4	0.95a	0.97a	0.96a	1.10a	0.93b	0.92b	0.94b	7.02	0.7438	0.0003	0.2630
16:4 n1	0.62a	0.65a	0.61a	0.78a	0.60b	0.58b	0.59b	6.32	0.1151	0.0001	0.1040
18:2 n4	0.77a	0.71a	0.64a	0.80a	0.73a	0.60a	0.71a	28.26	0.4354	0.2823	0.2443
18:2 n6	8.05a	8.02a	8.06a	4.88b	8.78a	9.03a	8.44a	8.34	0.9849	0.0001	0.0891
18:3 n3	1.49a	1.52a	1.49a	1.02b	1.60a	1.65a	1.57a	7.00	0.7144	0.0001	0.1175
18:3 n4	0.62a	0.65a	0.61a	0.78a	0.60b	0.59b	0.56b	6.52	0.1349	0.0001	0.2297
18:3 n6	0.79a	0.83a	0.78a	0.90a	0.79b	0.78b	0.76b	5.68	0.0661	0.0001	0.2250
18:4 n1	0.51a	0.48a	0.50a	0.66a	0.50b	0.40b	0.48b	17.59	0.6496	0.0002	0.4539
18:4 n3	1.02a	1.06a	1.00a	0.82b	1.06a	1.10a	1.07a	7.19	0.2469	0.0001	0.4388
20:2 n6	0.54a	0.55a	0.53a	0.55a	0.55a	0.53a	0.54a	7.06	0.4025	0.8292	0.5404
20:3 n3	0.36a	0.34a	0.32a	0.43a	0.32ab	0.29b	0.35ab	25.37	0.6118	0.0323	0.3359
20:3 n6	0.49a	0.50a	0.48a	0.52a	0.50ab	0.49ab	0.46b	7.89	0.6814	0.0500	0.7568
20:4 n3	0.58a	0.59a	0.56a	0.49b	0.59a	0.60a	0.60a	6.35	0.1866	0.0001	0.5624
20:4 n6	1.58a	1.58a	1.44a	0.92b	1.63a	1.64a	1.73a	11,30	0.1087	0.0001	0.9325
20:5 n3	3.90a	4.00a	3.75a	1.58b	4.18a	4.64a	4.37a	9.53	0.2998	0.0001	0.2099
22:2 n6	0.94a	0.96a	0.81a	0.74a	0.63a	0.84a	0.14a	35.61	0.7319	0.1117	0.6991
22:4 n6	0.30a	0.28a	0.28a	0.20c	0.32ab	0.23bc	0.37a	22.97	0.7270	0.0002	0.6840
22:5 n3	1.88a	1.87a	1.68b	0.56b	2.03a	2.10a	2.14a	8.22	0.0057	0.0001	0.2882
22:5 n6	0.44a	0.44a	0.39b	0.24b	0.45a	0.47a	0.49a	11.44	0.0192	0.0001	0.6381
22:6 n3	9.94a	9.96a	8.81b	3.74b	10.63a	10.84a	11.14a	10.44	0.0195	0.0001	0.4946

Within criterium (Treatment or Time), different letters indicate significant statistical differences (p <0.05).

Evaluation of the fatty acid profile with storage time revealed significant differences in all the detectable fatty acids. The highest values were recorded on the first day of storage, which differentiated them from the other storage times. Furthermore, the USFA contents decreased over time, and the SFA contents increased proportionally, probably due to the progressive lipid oxidation in the fillets throughout storage.

H/H index

The Σhypocholesterolaemic fatty acids/Σhypercholesterolaemic fatty acid ratio (H/H index) is strictly related to cholesterol metabolism. In the present study, the H/H index decreased (Figure 1) during storage at –18 °C, with the treatments at 50 and 150 V associated with the largest variations in this parameter, mainly in the first 60 days.

Linoleic/alpha-linolenic acid ratio (LA/ALA)

Significant differences ($p < 0.05$) in the LA/ALA ratio among the treatments occurred during storage (Figure 2). It was possible to observe a sharp decrease in the LA/ALA ratio for the 50 and 150 V treatments, up to 60 days of storage, followed by a plateau, with no further changes throughout the experiment, in all the treatments studied.

Thrombogenic fatty acids

There were no significant differences in the thrombogenic fatty acids ($p > 0.05$) among the treatments (Figure 3). However, it was possible to observe significant differences related to storage time and their outcomes ($p < 0.05$), with an increase in the values of thrombogenic acids over storage time.

n6/n3 ratio

The evolution of the n6/n3 ratio in cobia fillets during storage is shown in Figure 4. Statistical differences due to the electronarcosis at different voltages were not found. Conversely, discrete variations in the n6/n3 fatty acid ratios occurred throughout storage.

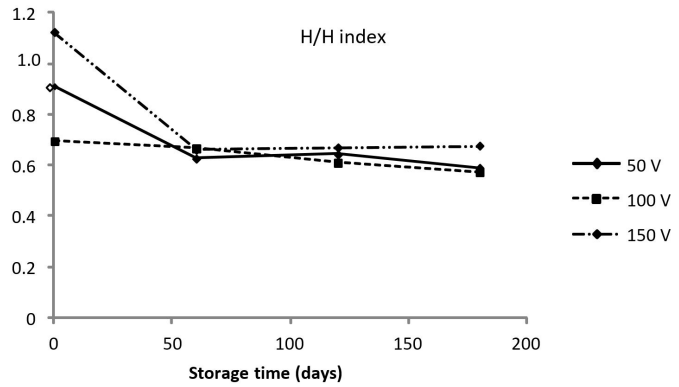

Figure 1. Σhypocholesterolaemic fatty acids/Σhypercholesterolaemic fatty acids (H/H) index in frozen (–18 °C, up to 180 days) fillets of cobia desensitised by electronarcosis at different voltages.

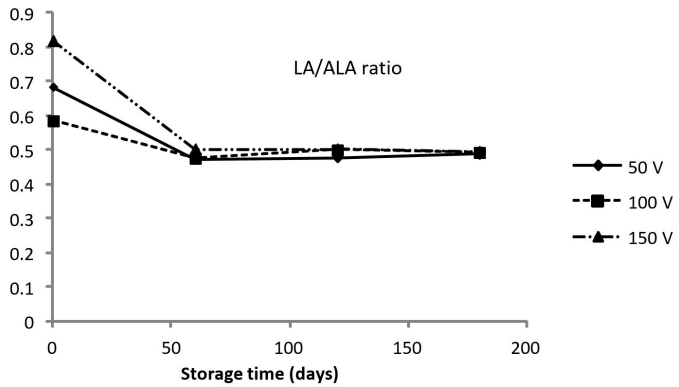

Figure 2. Linoleic/alpha-linolenic acid ratio (LA/ALA) in frozen (–18 °C, up to 180 days) fillets of cobia desensitised by electronarcosis at different voltages.

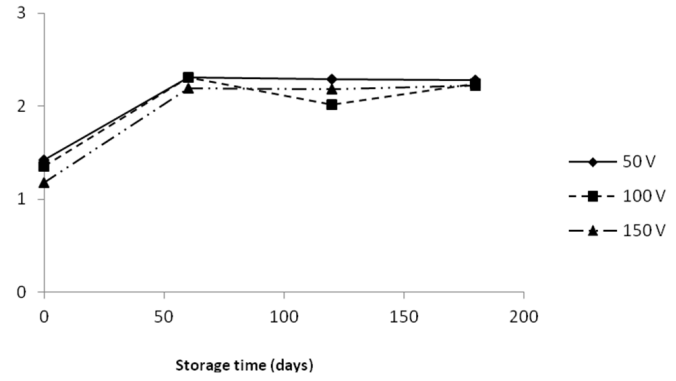

Figure 3. Thrombogenic fatty acids in frozen (–18 °C, up to 180 days) fillets of cobia desensitised by electronarcosis at different voltages.

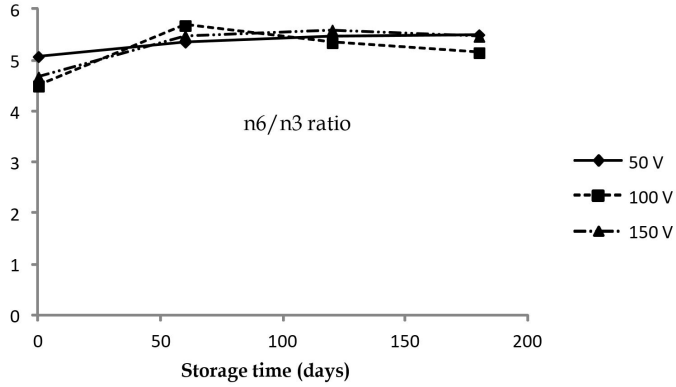

Figure 4. Omega-6/omega-3 fatty acids (n6/n3) ratio in frozen (–18 °C, up to 180 days) fillets of cobia desensitised by electronarcosis at different voltages.

DISCUSSION

Fatty acid profile

Nazemroaya et al. (2009) evaluated the effects of storage time at –18 °C for up to 6 months on the fatty acid composition of narrow-barred Spanish mackerel (*Scomberomorus commersoni*) and shark (*Carcharhinus dussumieri*). In both species, the main SFA and MUFA were palmitic acid (C16:0) and oleic acid (C18:1 n9), respectively. In both shark and mackerel, the total n6 PUFA mainly contained LA (C18:2 n6) and arachidonic acid (C20:4 n6), whereas eicosapentaenoic acid (EPA, C20:5 n3) and DHA (C22:6 n3) predominated the total n3 fatty acid fraction. During the storage, the PUFA (40.1 and 23.94%), n3 (48 and 42.83%), n3/n6 (41.36 and 50%), PUFA/SFA (56 and 42.23%) and EPA + DHA/C16 (55.55 and 46.66%) contents decreased in *S. commersoni* and *C. dussumieri*, respectively, whereas the free fatty acid levels increased significantly, as storage progressed.

H/H index

According to Santos-Silva et al. (2002) and Sousa Bentes et al. (2009), the higher the H/H index, the more adequate is the functional quality of the fish fat, and for meat products, the ideal value for this parameter is close to 2. Ramos Filho et al. (2008), studying four species of fish from the Pantanal region of Brazil, found H/H values of 1.75 for barred sorubim (*Pseudoplatystoma fasciatum*), 1.84 for spotted sorubim (*Pseudoplatystoma coruscans*), 1.66 for pacu (*Piaractus mesopotamicus*) and 1.49 for golden dorado (*Salminus maxillosus*), which were all higher than those found in the current study.

LA/ALA ratio

As stated by Price and Schweiggert (1976), reactions that occur in the live animal and after slaughter are similar, but it should be considered that after physiological death, the tissues are unable to eliminate certain metabolites. Hence, the variation in the LA/ALA ratio may be explained by the action of desaturase and elongase enzymes, which, in animals, convert LA and ALA into DPA (C22:5 n6) and DHA (C22:6 n3). As seen in Table 1, the decrease in the LA and ALA contents (also observed in Figure 2) was directly related to the increase in DPA and DHA.

In the study by Nazemroaya et al. (2009), a gradual increase in the LA/ALA ratio was observed between 0 and 5 months of frozen storage (from 1.6 to 4.5), whereas, from 5 to 6 months, this value almost doubled (from 4.5 to 9.3) for the narrow-barred Spanish mackerel samples (*S. commersoni*). In shark (*C. dussumieri*), the LA/ALA increased significantly between 0 and 2 months, from 3.3 to 34.8; after the fifth month, this index could no longer be measured because no more ALA could be detected.

Thrombogenic index

In the same study mentioned above, Nazemroaya et al. (2009) noted a gradual increase in the thrombogenicity index from 0 to 6 months of storage for both fish species (shark and mackerel), reflecting an increase in the thrombogenic fatty acids with increased storage. Although there is no ideal value for the thrombogenicity index, the lower this value, the better the nutritional/functional quality of the fat, due to the prevention of coronary diseases (Tonial et al., 2011). When working with tilapia supplemented with soybean oil, Tonial et al. (2011) found thrombogenicity values close to 0.98. Comparatively lower values were found in the current research, irrespective of the electric shock intensity.

n6/n3 ratio

Again, in the study performed by Nazemroaya et al. (2009), there was a gradual decrease in the n6/n3 ratio from 4.16 to 2.43 in narrow-barred Spanish mackerel (*S. commersoni*) and 2.03 to 1.01 in shark meat (*C. dussumieri*), during frozen storage for 6 months. The London Department of Health and Social Security (Leathard, 1994) advocates that for the human diet, an n6/n3 ratio below 4 is desirable for the prevention of cardiovascular diseases. In comparison, the values found in this research ranged from 4.45 and 6.32. Among the four species of fish (barred sorubim, spotted sorubim, pacu and golden dorado) investigated by Ramos Filho et al. (2008), pacu showed the highest n6/n3 ratio (3.65) whilst the spotted sorubim showed the lowest value (0.95), yet all values were indicative of a good nutritional quality.

CONCLUSIONS

The results of this study demonstrate that the three intensities of the electricity tested can be used for cobia desensitisation, but without further research, no conclusive effects on the fatty acid profile can be established.

The 150-V intensity exclusively reduced the levels of C22:1 n9, C22:2 n6, C22:5 n6, C22:5 n3 and C22:6 n3 fatty acids. The storage times did not modify the contents of C18:2 n4 and C20:2 n6.

At all the intensities tested, electronarcosis caused a decrease in the USFA and an increase in the SFA during storage of the cobia fillets times at sub-zero temperature.

Among the treatments, the 100-V intensity better stabilised the H/H index, maintaining the fillet quality.

The different currents applied did not modify the levels of the thrombogenic fatty acids and maintained the n6/n3 ratio, which was modified by the storage time.

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