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LIPID DISTRIBUTION IN THE MEAT OF JAU (*Zungaro jahu*) AND THE INFLUENCE OF STORAGE TEMPERATURE ON ITS FAT STABILITY

(*Distribuição de lipídeos na carne de jaú e a influência da temperatura de estocagem na estabilidade lipídica*)

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RESUMO: O objetivo deste estudo foi determinar o conteúdo total de lipídeos em nove diferentes regiões do corpo de jaú (*Zungaro jahu*) e avaliar a composição nutricional, valor energético e oxidação lipídica da carne de jaú durante 15 dias a 4°C, antes (T1) e após congelamento (T2) por 105 dias a –20°C. As regiões do corpo foram divididas em anterior-dorsal (P1), anterior-medial (P2), anterior-ventral (P3), central-dorsal (P4), central-medial (P5), central-ventral (P6), posterior-dorsal (P7), posterior-medial (P8), e posterior-ventral (P9). A carne de jaú apresentou elevado teor de proteína (20,17%), baixa quantidade de lipídeos (0,60%) e valor energético (88,36 kcal $100g^{-1}$). O aumento de malonaldeído (MDA) (0,2 – 2,5 mg MDA/kg) foi mais pronunciado (P<0,05) após o período de congelamento (T2). Dentre as regiões do corpo analisadas, as porções ventrais (P3, P6 e P9) apresentaram maior conteúdo total de lipídeos (P<0,05). Nosso estudo revelou que o teor total de lipídeos varia dependendo das regiões do corpo. Além disso, a oxidação lipídica ocorreu em ambas as condições de estocagem (refrigeração e congelamento), sendo mais pronunciada após os 105 dias de congelamento.
Palavras-chave: bagre; composição centesimal; oxidação lipídica.

ABSTRACT: The aim of this study was to determine the total lipid content in nine different body regions of jau catfish (*Zungaro jahu*), and evaluate the nutritional composition, energy value and lipid oxidation of jau meat during 15 days at 4°C, before (T1) and after freezing (T2) for 105 days at –20°C. The body regions were divided into anterior-dorsal (P1), anterior-medial (P2), anterior-ventral (P3), central-dorsal (P4), central-medial (P5), central-ventral (P6), posterior-dorsal (P7), posterior-medial (P8), and posterior-ventral (P9). Jau catfish contained high protein (20.17%), low lipid (0.60%) and low energy value (88.36 kcal $100g^{-1}$).The increase of malondialdehyde - MDA (0.2 to 2.5 mg MDA/kg) was more pronounced (P<0.05) after freezing period (T2).Among all body regions analyzed, ventral portions (P3, P6 and P9) presented highest total lipid content (P<0.05). Our study revealed that total lipid varies depending on body regions. Moreover, lipid oxidation occurs in both refrigerated and frozen storage, and it was more pronounced after 105 days of freezing.
Keywords: catfish; lipid oxidation; proximate composition.

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INTRODUCTION

World fish production has grown steadily throughout the last years. From 2011 to 2012, it increased by 1.5%, from an average of 155.7 million to 158.0 million tons. Brazil's large contribution significantly improved its global ranking among the top fish producing countries in recent years. In 2012, Brazil was ranked 10th for capture and 12th for farmed fish production, contributing 266.042 and 707.461 million tons, respectively (FAO, 2014).

Fish species of the genus *Zungaro* (Siluriformes, Pimelodidae), popularly known as "jau" in Brazil, are characterized as leather fish and are among the largest species with migratory behavior. They reach up to 150 kg in weight and 144 cm in length. These catfish are piscivorous and usually inhabit deep holes of lotic environments. Furthermore, jau species are of great importance for commercial fishing and their meat is highly appreciated by consumers (Agostinho et al., 2003).

Fish are a valuable source of nutrients for balanced nutrition and good health, mainly due to their high lipid quality (Calder and Yagoob, 2009). Nevertheless, lipid content varies among body regions of fish, which was previously described for some species such as salmon (Katikouet al., 2001), trout (Fjellangeret al., 2001) and European seabass (Testiet al., 2006). In general, total lipid content varies depending on exogenous (catching, season, environmental conditions, feed) and endogenous factors (species-specific physiological characteristics such as spawning and migration) (Boran and Karaçam, 2011). Furthermore, fish lipids contain a high amount of unsaturated fatty acids, which are more prone to oxidation due to the instability of double bonds (Mapiye et al., 2012; Tacon and Metian, 2013).

Lipid oxidation results in secondary compounds, for example malondialdehyde, which are harmful to human health (Chaijan, 2008; Zakiet al., 2014) due to their mutagenic and carcinogenic properties (Duthieet al., 2013). However, more substantiated studies on the behavior of lipid molecules in fish are needed, because they are considered an important source of fatty acids for humans. The lipid oxidation behavior for each fish species can be influenced by endogenous factors (fish species and chemical composition), as well as by processing and storage conditions that affects lipid composition (Taheriet al., 2012). Nevertheless, studies evaluating lipid content of different body regions, and lipid oxidation of jau (*Zungaro jahu*) meat are still limited.

Therefore, the objective of this study was to evaluate total lipid content in nine different body regions of jau catfish, and determine the nutritional composition and evolution of the lipid oxidation in jau meat during 15 days at 4 ± 1°C, before and after freezing (105 days at –20 ± 2°C).

MATERIAL AND METHODS

Experimental design

A total of 25 jau catfish (*Zungaro jahu*), with an average length of 85 cm, weight ranging from 7 to 9 kg, without distinction of sex, and fed with fish and commercial feed, were obtained from a fish industry located in the State of Goiás, Brazil. Fishes were slaughtered in an ice bath, headed, gutted and submitted to fast freezing (–20°C) in the processing area. Samples were transported in isothermal box to the laboratory in Rio de Janeiro, Brazil. The transportation period did not exceed three hours.

Under laboratory conditions, fish samples were randomly divided into two

batches. Group one was used to determine total lipid content in nine different body regions. In addition, chemical composition, energy value, and thiobarbituric acid reactive substances (TBARS) were evaluated during refrigerated storage (15 days at 4 ± 1°C) using pooled muscle tissue of fish samples from this group. This pooled sample was obtained by combining subsamples from all sampled body regions. Fish samples from group two were immediately packed and frozen. After 105 days of freezing at –20 ± 2°C, samples were thawed overnight in a refrigerator (4 ± 1°C), and pooled muscle tissue was obtained as described previously. Thereafter, fish samples were stored at 4 ± 1°C for 15 days for TBARS determination. Samples were refrigerated and thawed in a household refrigerator (RDE30, Electrolux, Rio de Janeiro, Brazil) equipped with a static cooling system and freezing compartment without quick freeze function. In relation to freezing, samples were frozen during 105 days in horizontal freezer (CHB53CB, Consul, Rio de Janeiro, Brazil) equipped with quick freeze function. The refrigerator and freezer worked without interruption and temperatures were monitored throughout all experiment. An internal digital thermometer (TH 439, Equitherm, Rio de Janeiro, Brazil) with scale ranging from -10°C to 50°C was used for monitoring the refrigerated temperature, while the frozen temperature was monitored by an infrared thermometer (H811-002, Mod. 406, HOMIS, São Paulo, Brazil) with scale ranging from -50°C to 550°C. All experiments were repeated twice.

Total lipid content of different body regions

Each fish sampled in group one was divided into three regions: anterior, central and posterior, and then subdivided into three areas (dorsal, medial and ventral), totaling nine regions: P1 (anterior-dorsal), P2 (anterior-medial), P3 (anterior-ventral), P4 (central-dorsal), P5 (central-medial), P6 (central-ventral), P7 (posterior-dorsal), P8 (posterior-medial), and P9 (posterior-ventral) (Figure 1). Total lipid content was determined by the gravimetric method using petroleum ether as organic solvent (AOAC, 2012). All analyses were performed in duplicate.

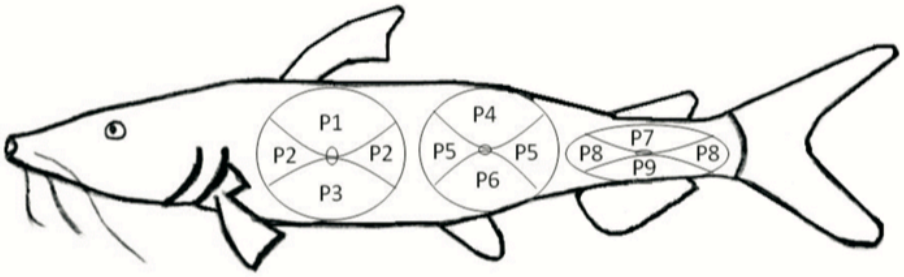

Figure 1 - Different region points of Jau catfish (*Zungaro jahu*). P1 (anterior-dorsal), P2 (anterior-medial), P3 (anterior-ventral), P4 (central-dorsal), P5 (central-medial), P6 (central-ventral), P7 (posterior-dorsal), P8 (posterior-medial), and P9 (posterior-ventral).

Chemical composition

Moisture, protein, ash, and lipid content were determined according to AOAC (2012). Moisture was determined by drying the sample at 100–105°C until constant weight. Protein content was estimated by the Kjeldahl method with a conversion factor of N × 6.25. Ash content was determined after incineration at 550°C in a muffle furnace. Lipid content was obtained by petroleum ether extraction using a Soxhlet apparatus. The percentage of carbohydrates was calculated by the equation % carbohydrates = 100% − (% protein + % lipid + % moisture + % ash). Energy value was determined following the equation energy value (kcal) = (4 x % protein+ 9 x % lipid + 4 x % carbohydrate). Both carbohydrate and energy values were obtained according to Merrill and Watt (1973). All analyses were performed in duplicate.

Lipid oxidation

Thiobarbituric acid reactive substances (TBARS) content was determined using the distillation method described by Monteiro et al. (2012). Oxidative rancidity was measured, every other day, during refrigerated storage of 15 days at 4 ± 1°C in two different groups: in fresh fish (T1) and in thawed fish after freezing for 105 days at –20°C (T2). Results were expressed as milligram of malondialdehyde per kilogram sample (mg MDA/kg). All analyses were performed in duplicate.

Statistical Analysis

Significant differences between mean values of total lipid content from different body regions and TBARS from different storage days were evaluated by one-way ANOVA with Tukey's test at a 95% confidence level ($P<0.05$). These analyses were performed with the software XLSTAT, version 2012.6.08 (Addinsoft, Paris, France).

RESULTS AND DISCUSSION

Total lipid content of different body regions

The total lipid content of nine different body regions is listed in Table 1. Considering the anterior and posterior areas, total lipid content did not differ between dorsal (P1 and P7) and medial (P2 and P8) regions ($P>0.05$). Total lipid content was highest in P3 and P9 (0.57% and 0.96%, respectively), of the anterior and posterior areas ($P<0.05$). In the central regions, the highest total lipid content was found ventrally (P6), followed by medial (P5) and dorsal (P4) areas ($P<0.05$). Total lipid content was higher in ventral regions (0.57 – 1.91%) than in dorsal (0.13 – 0.32%) and medial (0.13 – 0.42%) regions ($P<0.05$). From ventral regions, the highest total lipid content was found in P6 (1.91%) ($P<0.05$). Our results indicate that total lipid content of jau catfish tended to increase in the dorsal-ventral direction ($P<0.05$).

Our results are in agreement with Thammapat et al. (2010), who observed a similar tendency in total lipid content of different body regions of Asian catfish (*Pangasius bocourti*). In addition, total lipid content tended to increase significantly in the dorsal-ventral direction in rainbow trouts (*Oncorhynchus mykiss*) (Fjellanger et al., 2001; Testi et al., 2006), Nile tilapia (*Oreochromis niloticus*) and broadhead catfish (*Clarias macrocephalus*) (Yarnpakdee et al., 2014). Chaijan et al. (2010) also observed that lipid content was lower in the dorsal region (0.54%) than in the ventral region (4.52%) in giant catfish (*Pangasianodon gigas*). The increase of lipid content in the dorsal-ventral direction can be explained by close proximity to the visceral region, which has higher lipid content than muscle portions. Thammapat et al. (2010) observed that viscera of Asian catfish had higher lipid content (93.32%)

than ventral (4.79 – 57.51%) and dorsal body regions (2.95 – 5.54%). Zhong et al. (2007) found that viscera of steelhead trout (*Oncorhynchus mykiss*) (40.2%) had higher lipid content than muscle. Similar findings were reported by Duan et al. (2014) for yellow croaker (*Larmichthys crocea*), with mean values for total lipid content in muscle and viscera of 14.32% and 24.55%, respectively.

Table 1 - Total lipid content of the 9 region points of jau catfish (*Zungaro jahu*).

Region points[1]	Lipid content (%)
P1	$0.28^{ab} \pm 0.13$
P2	$0.13^{a} \pm 0.04$
P3	$0.57^{c} \pm 0.14$
P4	$0.13^{a} \pm 0.03$
P5	$0.44^{bc} \pm 0.01$
P6	$1.91^{e} \pm 0.01$
P7	$0.32^{abc} \pm 0.09$
P8	$0.42^{bc} \pm 0.15$
P9	$0.96^{d} \pm 0.21$

[1]P1 (anterior-dorsal), P2 (anterior-medial), P3 (anterior-ventral), P4 (central-dorsal), P5 (central-medial), P6 (central-ventral), P7 (posterior-dorsal), P8 (posterior-medial) and P9 (posterior-ventral). Values are mean ± standard derivation (n=2).
[a,b,c,d,e] means in a row without common superscripts are significantly different (P<0.05).

Chemical composition

Jau catfish consisted on average of 20.17 ± 1.40% protein, 0.60 ± 0.27% lipids, 77.71 ± 3.62% moisture, 0.96 ± 0.05% ash, 0.56 ± 0.23% carbohydrates and 88.36 kcal $100g^{-1}$ energy value. The results are in agreement with the chemical composition is similar in catfish (*Pseudoplatystoma faciatum*) from Colombia (Perea et al., 2008) and in African catfish (*Clarias gariepinus*) (Foline et al., 2011), however, the protein content reported by the latter was low (16.24%). On the other hand, our results are in partial disagreement with previous studies of other fishes such as sutchi catfish (*Pangasius hypophthalmus*) (Orban et al., 2008), silver catfish (*Rhamdia quelen*) (Weberet al., 2008) and African catfish (*Clarias gariepinus*) (Ersoy and Özeren, 2009; Ibhadonet al., 2015). These studies reported protein, lipid and moisture contents between 11.40 – 16.20%, 1.84 – 5.02%, and 69.30 – 83.57%, respectively. Nevertheless, in accordance with our data, these authors reported similar values of ash content (0.83 – 1.25%). Carbohydrate values were higher in African catfish (*Clarias gariepinus*) (Chukwu and Shaba, 2009; Foline et al., 2011; Ibhadon et al., 2015).

The high variability of chemical composition in fish depends on species, catching season, environment, diet, age, and sex (Boran and Karaçam, 2011; Li et al., 2012). Lipid and protein are the most variable components in fish (Yeganehet al., 2012) leading to variation in moisture content due to the inverse relationship between lipid and moisture (Katikou et al., 2001). Our study suggests that jau catfish has high nutritional value due to high protein content and low total lipid content resulting in the lowest energy value among catfish species.

Lipid oxidation

Malondialdehyde (MDA) values are commonly used as an indicator of the degree of lipid oxidation in fish muscle. MDA determination is very important due to its ability to negatively influence the human health with loss of sensory properties of foods (Guimarães et al., 2016). In fresh fish (T1), MDA values increased (P<0.05) from day 6 (0.1 mg MDA/kg) to day 15 (0.6 mg MDA/kg) of refrigerated storage (Figure 2). After a freezing period (T2), MDA values remained constant until day 8 of refrigerated storage, except on days 4 and 5 where MDA increased (3.4 mg MDA/kg) (P<0.05). After day 8, MDA values decreased (2.3 mg MDA/kg)

(P<0.05) and remained constant until the end of the storage period (Figure 2). Nevertheless, the increase of MDA values was more pronounced after a freezing period (0.2 mg MDA/kg observed on day 0 in fresh fish (T1) and 2.5 mg MDA/kg on day 0 in thawed fish (T2) P<0.05)).

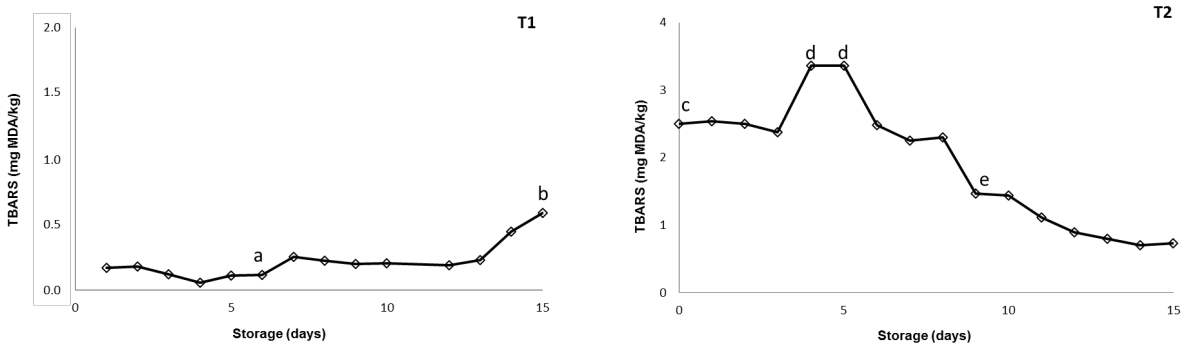

Figure 2 - TBARS expressed in mg MDA/kg sample of jau catfish stored for 15 days under refrigeration (T1) and 15 days under refrigeration after frozen for 105 days (T2). Different symbols indicate significant differences (P<0.05). [c]Difference between day 0 (T1) and day 0 (T2).

Several studies confirmed the increase of MDA during refrigerated and freezing storage of different fish species. Abreu et al. (2011) reported that the highest values of MDA (0.83 ± 0.07 mg MDA/kg) was obtained after 6 months of frozen storage in Atlantic halibut (*Hippoglossus hippoglossus*). In Nile tilapia fillets (*Oreochromis niloticus*) stored on recyclable ice for 9 days, Monteiro et al. (2012) observed an increase of MDA of 17.5%. Indergardet al. (2014) observed the highest lipid oxidation (14.04 mg MDA/kg) in salmon (*Salmo salar*) after 1 year of storage at −25 °C. The lipid oxidation of saithe (*Pollachius virens*) increased during storage period at −25 °C demonstrating the maximum value for MDA (approximately 20 µmol MDA/kg) at 18 months (Karlsdottir et al., 2014a). Karlsdottir et al. (2014b) reported that MDA values increased from 6 to 12 month of frozen storage in saithe (*Pollachius virens*) and hoki (*Macruronus novaezelandiae*). These authors also observed an increase more pronounced of MDA in dark muscles, which has higher lipid content than light muscles. Furthermore, Karlsdottir et al. (2014b) observed that the higher increase of MDA occurred in both fish species stored at −20 °C compared with those stored at −30 °C. Qiu et al. (2014) observed an increased from 0.4 to 1.7 mg MDA eq/kg in sea bass (*Lateolabrax japônicas*) stored at 4 °C for 12 days. During frozen storage, an increase of MDA is probably due to endogenous lipoxygenase activity at low temperatures (Abreu et al., 2010; Abreu et al., 2011). In the lipoxygenase pathway, oxidative reactions affecting the double bonds of unsaturated fatty acids produce a wide variety of degradation products and lead to hydroperoxide formation (Allen and Hamilton, 1994). On the other hand, a decrease in MDA can be attributed to a loss of secondary oxidation products by their volatility or by the ability of malondialdehyde to form covalent bonds with alkaline compounds from the degradation process (Monteiro et al., 2012; Intarasirisawatet al., 2014). In addition, oxidative rancidity can occur even in low-fat fishes depending on the lipid fraction (polyunsaturated fatty acids composition) (Sohn et al., 2005), which

may explain the results found for this species.

CONCLUSIONS

Our findings show that total lipid content differed between body regions, and that the highest lipid content was found in the ventral muscle. These results provide guidance to lipid researchers and sensorial food analysts in selecting representative fillet portions for their studies and fundamental importance on the application of different technological processes. Lipid oxidation increased during storage in both conventional storage methods, however it was more pronounced after 105 days of freezing (increase by more than 10 times), possibly due to action of enzymes such as lipoxygenase, which remains active at – 20°C. While lipid oxidation increased by more than 5 times over refrigerated storage, this parameter increased approximately 1.30 times during freezing. Furthermore, a conservation method in order to inactivate enzymes (lipoxygenase) warrants further research.

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