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Calidad de filetes de yaque Leiarius marmoratus durante el almacenamiento en congelación

Qualidade de filetes do judiá *Leiarius marmoratus* durante o armazenamento congelado

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Abstract

The objective of this research is to establish the variation of the physicochemical, microbiological and sensory properties of vacuum packed fillets of catfish *Leiarius marmoratus* from wild and farmed, after 120 days of storage at -18°C.It was observed that the meat from the two sources presents protein content between 19.8±0.2 and 20±1.1% and lipid content between 1.5±0.3 and 4.6±0.3%. The maximum values of aerobic mesophilic and total coliforms were 5.2±0.1 log cfu/g and 9±2 NMP/g, respectively, with significant variation ($p < 0.05$) over time. The aerobic psychrophilic count was less than ten, the fecal coliforms less than 3 MPN/g, the *S. aureus coagulasa*below100 cfu/g,and the *Salmonellasp*and *Vibrio sp* undetected. The pH reported in the range 6.5±0 to 7.1±0.2; the maximum valueof TVB-N were 15.3±0.2 mg of VBN/100 g, and the TBA was lower than 0.1 mg of MDA/kg with significant differences ($p<0.05$) during the 120 days of storage. The sensory analysis and texture had no significant differences ($p>0.05$) during storage. These results infer that catfish meat obtained from wild and farmed under the evaluated storage conditions have a shelf life greater than 120 days.

Key words: Fish meat,microbiological analysis, physicochemical analysis, sensory analysis, shelf life.

Resumen

El objetivo fue establecer la variación de las propiedades fisicoquímicas, microbiológicas y sensoriales de filetes de yaque *Leiarius marmoratus*, silvestres y de cultivo, empacados al vacío y almacenados durante 120 días a -18 º C. Se observó que la carne de las dos fuentes, presenta contenidos de proteína entre 19.8 ± 0.2 y 20 ± 1.1 % y de lípidos entre 1.5 ± 0.3 y 4.6 ± 0.3 %. Los valores máximos de *coliformes* y *mesófilos aerobios* totales fueron de9±2 NMP/g y 5.2 ± 0.1 log ufc/g, respectivamente; variando significativamente ($p<0.05$) en el tiempo. El recuento de psicrófilos aeróbicos fue menor de 10, los coliformes fecales menos de 3 NMP/g, el*S. aureus coagulasa* estuvo por debajo de 100 ufc/g y la *Salmonella sp* y el *Vibrio sp*por debajo de los niveles detectables. El pH varió entre 6.5 ± 0 y 7.1 ± 0.2; los valores máximos

de TVB-N fueron 15.3 ± 0.2 mg de VBN/100 g, y el TBA fue inferior a 0.1 mg de MDA/kg, con diferencias significativas ($p < 0.05$) durante los 120 días de almacenamiento. El análisis sensorial y la textura no presentaron diferencias significativas ($p>0.05$) durante el almacenamiento. Estos resultados permiten inferir que la carne de yaque silvestre y de cultivo, bajo las condiciones de almacenamiento evaluadas, pueden tener una vida útil superior a 120 días.

Palabras clave: Análisis fisicoquímicos, análisis microbiológico, análisis sensorial, carne de pescado, vida útil.

Resumo

O objetivo foi estabelecer a variação das propriedades físico - químicas microbiológicas e sensoriais dos filetes do yaque Leiarius marmoratus, selvagens e de criação, embaladas a vácuo e armazenadas por 120 dias a -18 ° C. Observou-se que a carne das duas fontes apresenta conteúdos de proteína entre 19.8 ± 0.2 e 20 ± 1.1 % e 20 ± 1.1 % e de lipídeos entre 1.5 ± 0.3 y 4.6 ± 0.3 %. Os valores máximos de *coliformes* e *mesófilos aeróbios* totais foram de 9 ± 2 NMP/g e 5.2 ± 0.1 log ufc/g, respectivamente; variando significantemente no tempo ($p < 0.05$). A contagem *aeróbia de Psicrofílicas* foi menor que dez, os coliformes fecais menos que 3 NMP/g, a *S. aureus coagulasa*sob 100 ufc/g, e a *Salmonella sp* e o *Vibrio sp*abaixo dos níveis detectáveis. O pH variou de 6.5 ± 0 e 7.1 ± 0.2; os valores máximos de TVB -N foram de 15.3 ± 0.2 mg de VBN/100 g e o TBA foi inferior a 0.1 mg do MDA/kg, com diferenças significantes ($p<0.05$) durante os 120 dias de armazenamento. O analise sensorial e da textura não apresentaram diferenças significantes ($p>0.05$) durante o armazenamento. Estes resultados permitem inferir que a carne de yaques silvestres e de criação, sob as condições de armazenamento avaliadas podem ter uma vida util superior aos 120 dias.

Palavras-chave: Análise físico-química, análise microbiológica, análise sensorial, a carne, a vida dos peixes.

Introduction

Fish meat has been positioning itself as a staple of a healthy diet because it is considered a source of high quality food (Suárez-Mahecha *et al.*, 2002), but the nutritional and physical characteristics can vary considerably between species and between individuals of the same species; and are related to the microbiological quality of the cultivation water, body size, temperature, hygiene during handling, harvest and slaughter methods, packaging, transport and storage, among others, which not only alter the characteristics of live fish, but also affect the shelf life of the final product (González *et al.*, 2009; Rodríguez *et al.*, 2009).

Catfish farming is a growing industry worldwide, with production in 2005 of over a million and a half tons of meat, mainly based on the cultivation of *Ictaluruspunctatus* and two species of *Pangasius spp* (*P. bocourtti* and *P. sutshii*) (FAO, 2011); in 2011, this amount was seen just with the production in Vietnam of *Pangasiusspp*, which was intended only for international markets (FAO, 2012). However, the quality of the meat of these catfish is now being questioned, not only in the context of nutrition specifically related to the content and ratio of fatty acids, but also the physical and chemical alterations caused by handling conditions used during production, processing and marketing.

In catfish meat, as in all meats, the deterioration process starts as soon as the fish dies, including the degradation of proteins and ATP, altered pH, fat oxidation and production of undesirable compounds such as trimethylamine (TMA-N) and volatile bases of low molecular weight (TVB-N), which are produced by bacterial action and generate changes in texture, color, odor and flavor (Li *et al.*, 2011). These changes can be classified as biochemical, physical and microbiological, and determine the degree of acceptance by consumers and, along with nutritional valuation, shelf life (McMillin, 2008). Thus, Colombian law, specifically the Colombian Technical Standard NTC 4348, has established maximum allowable limits to identify the acceptable quality level for some parameters, such as 400 CFU/g for *E. coli*, 1000 CFU/g for *S.aureus coagulasa* and absence of *Salmonella spp* and *Vibro cholera* in 25 g of meat. These rates apply to all species of fish, even disregarding the variability within and between species.

Leiariusmarmoratus, commonly known as yaque or black catfish, is a native siluridin the basins of the Amazon, Orinoco and Essequibo rivers; and has generated interest because it is specie that not only adapts to cultivation conditions, but also possesses characteristics similar to those of commercial catfish. Currently, trade in these species depends 100% on natural ex-

traction, but recent studies have identified the potential of these species for use in the process of diversification of aquaculture in Colombia (Cruz-Casallas *et al.,* 2011), but currently the quality of the meat has not been determined in order to establish processes that allow management to potentiate their qualities. Therefore, the objective of this research was to determine the chemical, physical, microbiological and sensory characteristics of yaque meat, both for wild and farmed over a period of 120 days of storage under freezing conditions at -18 °C.

Materials and methods

15 specimens of yaque catfish (*Leiariusmarmoratus*) were used, captured from the Guaviare river in the municipality of San José del Guaviare (Guaviare - Colombia) with an average size and weight of 58.9±5.6 cm and870±87g, respectively, and 25 specimens with an age of 20 months from commercial cultivation, obtained from the El Paraíso fish farm in the municipality of Cumaral (Meta-Colombia). These individuals were obtained by artificial reproduction, induced with carp pituitary extract and cultivated in earthen ponds at a density of 1 animal/m^2, fed *ad libitum* with a commercial ration of 30% crude protein and with an average weight of 625±133g and average fork length of 45.2±2.9 cm at harvest.

The fish were killed by cranial incision and the carcasses were transported to the facilities of the Institute of Aquaculture of the Llanos University in Villavicencio (Meta-Colombia), packed in Styrofoam boxes covered with ice. Then the meat was washed with potable water and the skin was separated. Then, fillets were cut at the level of the dorsal fin and anal opening.

For each one of the sources, 25 fillets of 300g and 30 fillets of 100g were obtained, which were packed in polyethylene Food Saver® bags (NYSE:JAH, EEUU) and vacuum sealed with hand sealing Food Saver® equipment (NYSE:JAH, EEUU). Samples were refrigerated (4°C) and transported to the Instituto de Ciencia y Tecnología de Alimentos ICTA at Universidad Nacional de Colombia (Bogotá-Colombia), where they were held in frozen storage at -18 °C until use.

The analysis of the samples was performed in triplicate according to the Colombian Technical Standard NTC 4348 (2009) which specifies the requirements of whole fish, medallions and pieces, chilled or frozen, suitable for human consumption; and supplemented with NTC 5443 (2006), which specifies the requirements for the handling, transportation and marketing of aquaculture species: cachama, tilapia and trout.

Proximate composition

Proximate analysis was performed on day zero of storage to determine humidity (No. 952.08), crude protein (No. 955.04), crude lipid (No. 948.15) and ash (No. 938.08), using the methodology of the Association of Official Analytical Chemists (2005).

Quality Analysis

On days 0, 15, 30, 60, 90 and 120 of storage, at random and for each source, five 100g fillets were removed from the freezer for the physical-chemical and microbiological analyses and 300g fillets for sensory testing. The samples were thawed at 4 °C for 6 hours and homogenized in a domestic-use food processor (Oster®, EEUU), except for the texture and sensory analysis, which used whole fish.

Microbiological analysis

Using 11 gram samples, the study employed serial dilutions of 10^{-1}, 10^{-2}, $10^{-3}$with sterile peptone water, which were used for the aerobic mesophilic and *psychrophilic* counts, total and fecal coliforms and *Staphylococcus coagulasa* positive (NTC 4779, 2007). The aerobic mesophilic and psychrophilic microorganism counts were performed after incubation at 35 ± 2 ° C for 48 h with 1 mL of each dilution for mesophilic and 4 ± 0.5 ° C for 7 days for psychrophilic, using the SPC agar culture medium (Merck KGaA, Germany), reporting data as colony forming units CFU / mL (INVIMA, 1998).

The total coliform count was made dispensing Brila broth (Thermo Fisher, EEUU) in test tubes with a Durham tube, and incubated with 1 mL of each dilution at 35±2 °C for 48 hours. With the positive tubes, the fecal coliform count was performed, inoculated in 1 mL 2% Brilalactose broth and tryptophan broth (Merck KGaA, Germany) and incubated at 44.5±0.5 °C for 48 hours in a water bath; confirmation of indole production was performed with 2 mL of Kovac's reagent (SAR Ltd, England). Data were reported according to the MPN table. The *Staphylococcus coagulasa* positive count was performed by plating dilutions of 10^{-2} and 10^{-3} in Baird Parker Agar (Merck KGaA, Germany) incubated at 37 °C for 48 h, then the coagulase test was used for suspicious colonies, along with Gram staining(INVIMA, 1998).

For determination of *Vibrio cholerae,* 25g samples were used in 225 mL of alkaline peptone water (3% NaCl) and incubated at 35±2°C for 6 h, and plated in TCBS agar (Thermo Fisher, EEUU) at 35±2 °C, for 48

hours. To determine the presence of *Salmonella* sp, 25 g of each sample were incubated in 225 mL of lactose broth (Thermo Fisher, EEUU) for non-selective pre-enrichment at 37 °C for 24 hours. Then, 1 mL was used in selenite cystine broth (Thermo Fisher, EEUU) and 1 mL tetrathionate broth base (Thermo Fisher, EEUU) for selective enrichment, finally plating was done with XLD (Thermo Fisher, EEUU) and Bismuth sulfite agars (Merck KGaA, Germany). Confirmation was done with Gram staining and Rapid One biochemical test kit (Thermo Fisher, EEUU). Analyses were performed according to NTC 1325 (INVIMA, 1998).

Physicochemical analysis

Determination of total volatile basic nitrogen (TVB-N) was performed by the method proposed by Goulas and Kontominas (2007), performing distillation of 10 g samples with 1 g of Mg oxide in a distiller (Kjeltec System 1002 Distilling Unit, Sweden). The distillate collected in a 25 mL Erlenmeyer with boric acid (2%) and Taschiro indicator drops, was titrated with hydrochloric acid (0.1045 N). The total volatile nitrogen content was calculated by the following equation:

$$\text{mg of VBN/100 g sample} = \frac{(Vs - Vb)\,x14xNx100}{M}$$

In which:

Vs = Volume of hydrochloric acid used in the titration of the sample in mL.
Vb = Volume of hydrochloric acid used in the blank titration in mL.
N = Normality of the HCl
M = Sample weight in grams

The thiobarbituric acid analysis (TBA) was done by the extraction method described by Wang and Xiong (Wang and Xiong, 2005), which quantifies the presence of byproducts of lipid oxidation (malonaldehyde - MDA), through the reaction with thiobarbituric acid (TBA). 0.5 g samples were used, which were carried in 25 mL Falcon tubes, adding 50 uL of ethanolic solution of BHT butylated hydroxyl toluene (5%), 3 mL of TBA (0.375%) and 20 mL of trichloroacetic acid (5% in 0.25 N HCl). The mixture was centrifuged for 4 min (2500 rpm) and then allowed to react in boiling water (93 °C) for 40 minutes. An aliquot of 5 mL of the supernatant was centrifuged with 5 mL of chloroform at 5500 rpm for 20 min in centrifuge Heraeus Megafuge™ 16R (Thermo Scientific, Germany) and then the absorbance was measured in the aqueous phase in a spectrophotometer UV-VIS Genesis 10S(Thermo Scientific, Germany),at 532nm. To measure the concentration of MDA in the sample, a calibration curve of nine points was used, with 1,1,3,3-tetrametoxypropano as a standard compound. The results were expressed as mg of MDA/ kg of sample.

For determination of pH, the study used a 10g homogenized sample and 30mL of distilled water, agitated with a magnetic plate for 30 min and subsequent rest (10 min). The pH was measured with a potentiometer Handy Lab PH11 model D-55014 (Schott Instruments, Germany) (NTC 4348, 2009).

To determine texture, thawed 1 cm^3 pieces of meat were used, and measured by penetration force using a texture analyzer (Texture Analyzer TAXT plus, EEUU). The force was recorded during compression in a texture curve with a probe with a diameter of 2 mm and a penetration speed of 60 mm/minute with 5mm penetration. Data were expressed as Newton force.

For sensory analysis, a semi-trained panel of five people was used, using a hedonic scale of decreasing rejection from 1 to 9, who evaluated appearance, color and smell of raw meat and color, aroma and flavor in cooked meat, with a range of values from 1 corresponding to "dislike extremely" and 9 to "like extremely" (Kostaki *et al.,* 2009). A sensory value of 4 was used as the minimum range of acceptability. The meat cooking process was done with a conventional stove (AR -T, Haceb®, Colombia), with immersion for 10 min in potable water at a temperature of 100 °C.

Statistical Analysis

Data were statistically described and expressed as mean± standard error of the mean (SEM). Initially, the assumptions of homogeneity of variances and normal distribution of the data were verified, using Bartlett's and Shapiro-Wilk tests. The results of the sensory analysis were transformed using a natural logarithm. To compare the chemical composition between the two sources, a student test was used and to determine the effect of storage at 0, 15, 30, 60, 90 and 120 days on the quality variables (microbial count, pH, TVB -N, TBA and texture), analyzes of variance (ANOVA) was carried out following the Tukey test for comparison of means. The nonparametric data reported in the sensory analysis were analyzed based on the Friedman test followed by Dunn's test. In all cases, we used the value of $p < 0.05$ to consider the existence of significant differences. For statistical analysis, we used the statistical software Matlab® version 7.11.0.584 (R2010b, License No. 161051).

Results

Proximate composition

The table 1 shows the results of proximate analysis performed on fresh fillets of wild and farmed. It was observed that farmed meat had higher contents of moisture (77.2±0.8%), protein (20.0±1.1%) and ash (1.4± 0%) when compared with wild meat (74.3±0.2%, 19.8±0.2% and 1.3±0.1, respectively), but without significant differences (p> 0.05); while for lipid content. A contrary behavior was seen, where wild meat had higher contents (4.6±0.3%) than farmed meat (1.5±0.3%), with significant differences (p <0.05).

Table 1. Proximate composition (%) of *L. marmoratus* fillets obtained from wild and farmed in earthen ponds. Data presented as mean ±SEM (n =3).

Provenance	Moisture	Protein	Lipids	Ash
Farmed	77.2±0.8[a]	20.0±1.1[a]	1.5±0.2[b]	1.4±0.1[a]
Wild	74.3±0.2[a]	19.8±0.2[a]	4.6±0.3[b]	1.3±0.1[a]

[a,b] Different letters between rows indicate statistically significant differences according to Tukey test (p<0.05).

Quality Analysis

Microbiological analysis

Microbiological changes observed in the meat during the 120 days of storage are shown in Table 2. The values indicate that all samples, both for wild and farmed, began and ended in acceptable microbiological conditions without exceeding the maximum allowed under the Colombian Technical Standard NTC 4348.

In the count for mesophilic organisms, was observed an increase over time, reaching a maximum of 5.2±0.1 log CFU/g for wild meat and 4.3±0.1 log CFU/g for farmed, with significant differences (p <0.05) from 15 days of storage for the former source and from 90 days for the latter source, respectively. In psychrophilic counts, they were not found to increase over time in storage and in all cases, were less than one. The total coliform count peaked at 6.0±1.0 MPN/g for wild, and at 9.0±2 MPN/g for farmed, with a significant difference (p <0.05) from day 90 of storage. In counting *Staphylococcus coagulasa* positive is observed that for wild meat and farmed meat, the maximum count not exceeded 100 log cfu / g, with no significant differences (p> 0.05) throughout the storage time. Likewise,

Table 2. Variation of the microbiological quality of *L. marmoratus* fillets obtained from wild and farmed in earthen ponds, over a storage period of 120d under freezing conditions (-18°C). Data are mean ± SEM (n =3).

Provenance	Variables	Days of Storage					
		0	15	30	60	90	120
WILD	Mesophilic log UFC/g	3.2±0.0 a	2.7±0.0 b	4.0±0.1 c	4.7±0.1 d	4.7±0.1 d	5.2±0.1 e
	Psychrophilic log UFC/g	<1	<1	<1	<1	<1	<1
	Coliform total NMP/g	5.4±0.9	3.1±0.1	4.8±0.6	6.0±0.0	5.5±0.9	6.0±1.0
	Coliform fecal NMP/g	<3	<3	<3	<3	<3	<3
	Salmonella sp	Absent	Absent	Absent	Absent	Absent	Absent
	Vibrio sp	Absent	Absent	Absent	Absent	Absent	Absent
	Staphylococcus coagulasa + ufc/g	<100	<100	<100	<100	<100	<100
FARMED	Mesophilic log UFC/g	3.7±0.1 a	2.9±0.0 a	3.1±0.1 a	3.0±0.0 a	3.0±0.0 b	4.3±0.1 c
	Psychrophilic log UFC/g	<1	<1	<1	<1	<1	<1
	Total Coliform NMP/g	3.2±0.1 a	6.0±1.3ab	9.1±0.0abc	8.0±1.0 cd	8.6±1.5bcd	9.0±2.0 bcd
	Fecal Coliform NMP/g	<3	<3	<3	<3	<3	<3
	Salmonella sp	Absent	Absent	Absent	Absent	Absent	Absent
	Vibrio sp	Absent	Absent	Absent	Absent	Absent	Absent
	Staphylococcus coagulasa+ log ufc/g	<100	<100	<100	<100	<100	<100

[a,b,c,d] Different letters within rows indicate statistically significant differences according to Tukey test (p<0.05).

no presence of *Salmonella*sp or *Vibrio sp*was detected and fecal coliforms were lower than 3 MPN/g.

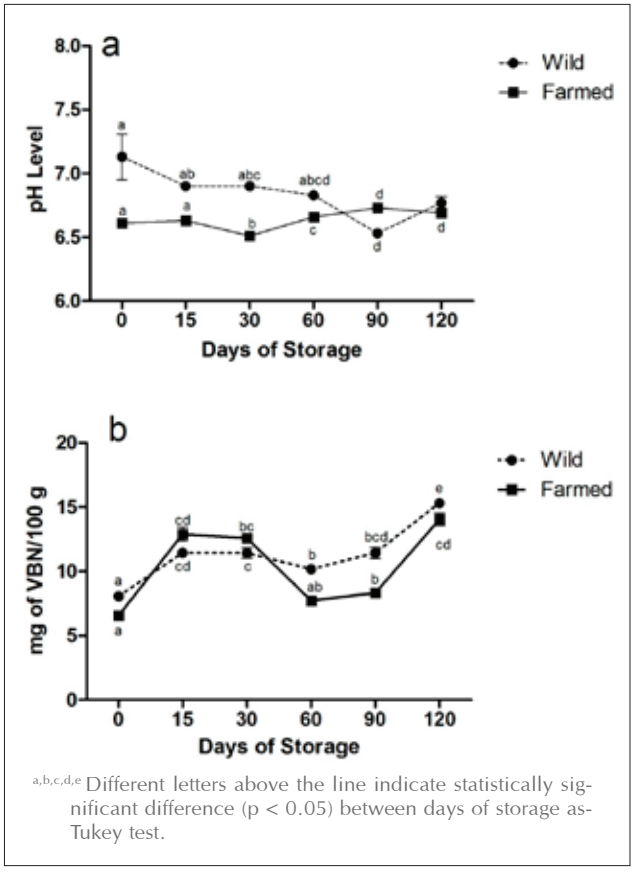
Physicochemical analysis

The figure 1 presents the means and standard error of the variation of pH and TVB-N and figure 2 shows the means and standard error of the results obtained in terms of TBA and texture changes during the 120 days of storage at-18°C. The pH (Figure 1a) for the two sources was found within the range of values of neutrality, with the wild meat in between 6.5±0 and 7.1±0.2 with significant difference from day 90 of storage and farmed meat between 6.6±0 and 6.7±0 with significant differences ($p < 0.05$) from day 30 of storage. Regarding the formation of total volatile basic nitrogen (TVB-N) (Figure 1b), a progressive increase was observed over time, showing a decrease by day 60, which was quickly recovered, reaching a maximum of 15.3±0.2 mg of VBN/100 g for wild meat and 14.0±0.5 mg of g VBN/100g for farmed meat. Similarly, it was found that in no one of the cases was the maximum allowable value (30 to 40 mg/100g of meat) set by NTC 4348 exceeded.

The peak TBA value (Figure 2a) of the wild meat was 0.09±0 mg of MDA/kg of sample, while for the farmed meat was 0.05±0 mg of MDA/kg with statistically significant differences ($p < 0.05$) from day 60 in the wild meat and day 90 for the farmed meat, but below the maximum allowed (4 mg/kg) in fish meat in order to be considered of good quality. In texture (Figure 2b), no significant differences were found ($p > 0.05$), obtaining values between 0.4±0.1 and 0.7±0.1 Newton force for wild meat and between 0.4±0.1 and 0.6±0.1 for the farmed meat.

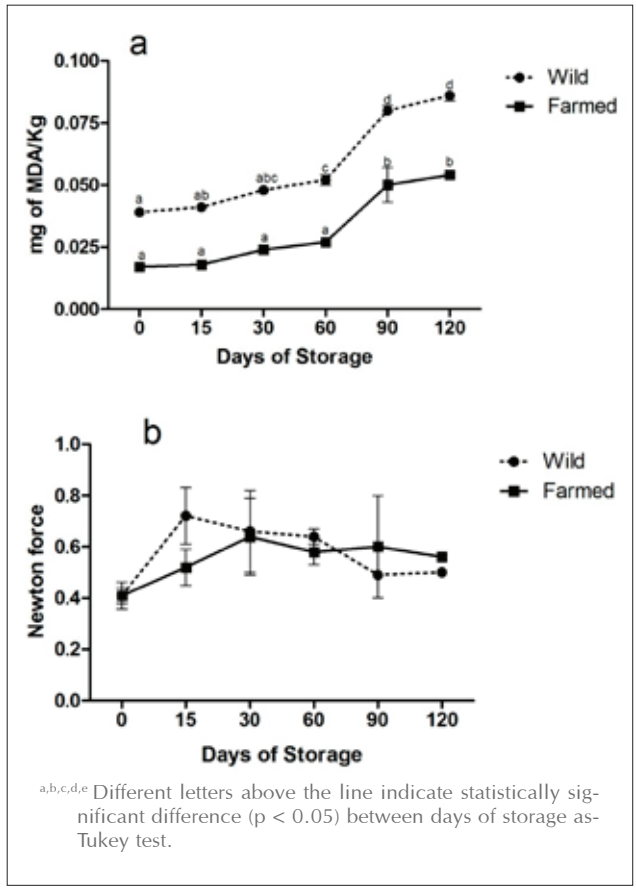
Sensory analysis

The sensory evaluation results of *L. marmoratus* fillets, vacuum packed and stored for 120 days at -18 °C, are presented in Table 3, showing that the two sources in sensory evaluation scored above 4 for all attributes and that the variation in time of storage showed no signifi-



[a,b,c,d,e] Different letters above the line indicate statistically significant difference ($p < 0.05$) between days of storage as-Tukey test.

Figure 1. Variation of pH (a) and the concentration of Total Nitrogen volatile bases (b) of fillets *L. marmoratus,* obtained from wild and farmed in earthen ponds during 120 day storage under freezing conditions(-18°C).Data presented as mean ±SEM(n =3).



[a,b,c,d,e] Different letters above the line indicate statistically significant difference ($p < 0.05$) between days of storage as-Tukey test.

Figure 2. Variation of TBA (a) and the Texture(b) of fillets *L. marmoratus*, obtained from wild and farmed in earthen ponds during 120 day storage under freezing conditions(-18°C).Data presented as mean ±SEM(n =3).

Table 3. Variationofthe sensory attributes of fillets *L. marmoratus* raw and cooked, from wild and farmed for 120dof storage under freezing conditions(-18°C). Data presented as mean ± SEM (n =3).

Origin and Attributes * 0		Days of Storage					
		15	30	60	90	120	
WILD	Raw Meat						
	Appearence	7.4±0.7	7.2±0.9	7.2±0.6	8.0±0.3	7.2±0.6	8.2±0.2
	Color	7.4±0.9	7.0±0.8	7.2±0.6	8.0±0.3	7.2±0.5	8.2±0.2
	Smell	7.0±0.8	6.4±0.9	7.2±0.6	7.4±0.5	7.2±0.6	6.8±0.7
	Cooked Meat						
	Color	5.8±1.0	7.2±0.7	7.4±0.5	6.8±0.5	7.6±0.5	8.0±0.0
	Aroma	7.2±0.7	7.2±0.7	7.6±0.2	7.4±0.6	6.8±0.6	7.6±0.5
	Flavor	7.4±0.7	7.6±0.4	7.2±0.8	7.2±0.6	7.4±0.4	8.0±0.0
FARMED	RawMeat						
	Appearence	6.0±1.1	6.8±0.7	6.6±1.0	7.2±0.5	7.6±0.7	7.2±0.7
	Color	7.2±0.7	6.6±0.5	6.2±0.8	7.2±0.6	6.6±0.6	7.2±0.7
	Smell	6.4±0.7	6.2±0.6	7.0±0.8	7.2±0.6	6.6±0.6	7.6±0.4
	Cooked Meat						
	Color	6.6±O.7	7.4±0.5	8.0±0.5	7.6±0.5	7.0±0.4	6.8±0.4
	Aroma	6.2±0.9	7.8±0.2	7.4±0.4	7.2±0.4	6.6±0.8	6.6±0.7
	Flavor	7.0±0.7	8.0±0.3	8.4±0.4	7.6±0.4	7.4±0.5	6.6±0.7

* Attributes ranked by hedonic scale decreasing 0-9.the value of 1correspondingto "dislike extremely", 9 "like extremely", with 4 being the minimum range of acceptability as Kostaki *et al.*, (2009).

cant differences for indicating an alteration in the shelf life. In wild meat, the lowest attribute valuation was the smell of raw meat, which scored between 6.4±0.9 and 7.4±0.5 during the sampling, and color in cooked meat with a rating between 5.8±1.0 and 8.0±0; while in the farmed meat, the lowest qualified attribute was color and smell of raw meat with a rating that fluctuated between 6.2±0.8 and 7.2±0.7 and between 6.2±0.6 and 7.6±0.4, respectively, and the aroma in cooked meat which a variation between 6.2±0.9 and 7.8±0.2.

Discussion

According to the results of the proximate analysis performed on the fresh fillets of yaque *L. marmoratus* meat, it can be inferred that this species may be an important source of food, in which the protein content is not only within the average reported for fish meat in general (17 and 21%) (Gil, 1989), but is superior to other commercially important catfish such as *Pangasiushypophthalmus* (12.65 to 15.59%), *Clariasgariepinus* (15.71 to 16.2%) and *Ictaluruspunctatus* (18.1%) (Orban *et al.*,2008; Ersoy and Özeren, 2009; Li *et al.,* 2009). Also, the lipid content provides significant energy and, according to the classification proposed by Castro-González (2002), meat from individuals captured in the wild can be considered as "medium fatty", similar to the classification assigned to *Clariasgariepinus* and *Ictaluruspunctatus* fillets (Ersoy and Özeren, 2009; Li *et al.,* 2009). On the other hand, fillets from farmed individuals are classified as "lean meat", equal to the rating given to *Pseudoplatystomafasciatum*, *Pseudoplatystomacorruscans*, *Pangasiushypophthalmus* and *Pangasianodongigas* (Orban *et al.*, 2008; Martino *et al.*, 2002; Perea *et al.*, 2008; Chaijan *et al.*, 2010).

It is widely known that high levels of lipids in the meat of fish increase susceptibility to oxidative rancidity and therefore, the onset of degradation processes (Pacheco *et al.*, 2010), which added to the microflora are determinants of product quality. Therefore, it can be inferred that wild meat possesses a greater risk of degradation than that of farmed meat, however, storage conditions (-18 °C and vacuum packaging) not only impede the growth of microorganisms but also decrease susceptibility to autohydrolysis and consequently the degradation of the meat (Kubitza, 2012). The International Commission on Microbiological Specifications for Foods- ICMSF (2005) believes that the level of microbial contamination in the muscle at which fish show signs of alteration is 7.0 log cfu/g. In the present research, the mesophilic and psychrophilic counts did not exceed this value in any one of the samplings, which is the reason why the meat retained good characteristics. Lubes (2005) and Noseda *et al.* (2012)

conducted microbiological assessments on catfish fillets under different preservation processes, involving the use of packaging of low and high permeability and modified atmospheres, and found counts greater than 6 log cfu/g for total aerobic mesophilic and greater than 7 log cfu/g for total aerobic psychrophilic; values that were associated with the end of the product shelf life and which were related to the contents of TVB-N, TBA and pH.

Regarding the pH, it was found that for both wild and farmed meat, the values remained within the range of neutrality during the 120 days of storage, probably due to the low content of glycogen. Thus, the results obtained for pH in this study were similar to those reported in other catfish, with values ranging between 6 and 7 under different storage conditions (Rodríguez *et al.,* 2009; Pacheco *et al.,* 2010; Lubes, 2005;Molina *et al.,* 2000; Chomnawang *et al.,* 2007).

In order to maintain the pH values as low as possible, is important to maintain low temperatures during the process of gutting and filleting(Pacheco *et al.,* 2010), which minimizes degradative biochemical reactions involving the liberation of inorganic phosphate and ammonia as a result of enzymatic degradation of ATP and the buffering capacity of the proteins contained in the fish muscles.

Analyzing the results of the formation of total volatile basic nitrogen (TVB-N) of the two sources, progressive increase over time was observed, but with a decrease towards day 60, which was quickly recovered. This behavior is attributed to decreased autolytic activity and the beginning of the microbial degradation process, which is common in all meats (Pacheco *et al.,* 2010). Similarly, it was determined that these peaks did not contribute to the production of undesirable aromas in the product, so one would expect a high level relationship between this variable and the results of a sensory evaluation of product acceptance (Massa, 2006). In a study by Lubes (2005), it was concluded that in*Leiariusmarmoratus*fillets, when was exposed to different retention times before being stored at 0°C, the TVB-N content had values between 13.8 and 20.7 mg VBN/100g of muscle, without reaching in any case the maximum during the 21 days of the study; while Chomnawang *et al.,* (2007) reported that the hybrid *Clariasmacrocephalus*× *Clariasgariepinus* reached the maximum allowable level of TVB-N only after 9 days when stored in polyethylene bags at 4 °C (Rodríguez *et al.,* 2009).

In turn, the content of TBA showed peak values that did not exceed 0.1 mg of MDA/Kg of meat, reflecting the behavior of the meat with regard to the lipid content. This indicates that, although wild meat presents increased susceptibility to oxidative rancidity, observed concentrations did not exceed the values needed to be considered a low-quality meat (4 mg of MDA/kg of meat). In other catfish meat, such as *Pseudoplatystoma*sp, *Brachyplatystomarousseauxii*, *Bagremarinus*, this parameter has reached concentrations of 5, 1.98 and 3.2mg of MDA/kg, respectively, under different preservation treatments and storage temperatures (Rodríguez *et al.,* 2009; Pacheco-Aguilar *et al.,* 2000; Reyes and Arocha, 2000).

In the texture analysis, the white muscle of the catfish presented stable characteristics, due to the larger size of the muscle fibers, making it very efficient in industrial processes. However, the processes of freezing and thawing during storage result in the formation of ice crystals within the muscle fiber, causing structural damage and solute concentration in the meat, which in turn, lead to alterations in the biochemical reactions at the cellular level and affect the physical quality parameters of the meat (Leygonie *et al.,* 2012). The variation in the texture of the *L. marmoratus* meat stored for 120 days at -18 °C showed no significant differences ($p < 0.05$), indicating that for both types of meat the processes of freezing and storage did not cause alterations of the muscle fiber structures.

Sensory changes in color, odor, flavor, taste and texture are related to the before mentioned parameters, but these sensory changes depend on the species and storage method. Since *L. Marmoratus* yaque meat possesses relatively low fat content, small concentrations of TBA and TVB-N and a low microbial activity, it is expected that the shelf life will be longer in comparison with other species such as salmon or trout. Rodríguez *et al.*(2009), Pacheco *et al.* (2010),Lubes (2005), Noseda *et al.*(2012) Molina *et al.*(2000), Chomnawang *et al.*(2007) and Reyes and Arocha (2000) indicated that catfish meat smell and taste decrease in value over time, due to the increase of metabolites and degradation products of ammonia compounds, but that the implementation of management practices such as washing with chlorine, salting or modified atmosphere or vacuum packaging achieve increased product shelf life of up to 84 days when stored at freezing temperatures (-16 to 0 °C) and up to 20 days at refrigeration temperatures (2 to 4 °C). In this study, it was shown that the shelf life of *L. marmoratus* yaque meat can exceed the evaluated storage time and that the storage temperature and probably the type of packaging contributed to the fact that attributes such as color, flavor and aroma were not altered, both in raw and cooked meat.

Conclusions

We conclude that *L. marmoratus* yaque meat, from both wild and farmed, when vacuum packed and frozen at -18 °C, presents quality characteristics such as pH, TBA, TVB-N, texture, microbiological count and sensory analysis within the acceptable ranges for human consumption and that, under these conditions, the meat may have a shelf life longer than 120 days.

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