Characterization of the Nutritional Quality of the Meat in Some Species of Catfish: A Review

Nubia Estella Cruz Casallas¹; Pablo Emilio Cruz Casallas² and Héctor Suárez Mahecha³

Abstract. One of the most consumed fish in the world is Silurid, also called "leather fish" or catfish, whose main characteristic is the absence of intramuscular bones and scales, as well as its high productivity. In recent years, the nutritional characterization of the meat of some of these species has been carried out, finding that, although the proximal composition is within the broad ranges for fish, the fat content provides a lower proportion of polyunsaturated fatty acids (PUFA) particularly as regards omega-3 (ω-3), furthermore the ω-6/ω-3 ratio is within the proscriptions of the World Health Organization (WHO) for many of these species of catfish. Likewise, the contents of eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA) and amino acids, minerals and vitamins reveal a high variability between individuals and species associated with the type of cultivation and dietary habits and also with the age and weight at slaughter. Furthermore quality parameters have been defined in relation to susceptibility to autolysis, oxidation and hydrolysis of fats and disturbances caused by microorganisms that cause decisive changes in the physicochemical, microbiological and sensory characteristics. This review compiles current information regarding the nutritional composition of catfish meat and the quality parameters.

Key words. Proximate composition, shelf life, fatty acids, proteins, minerals and vitamins.

Resumen. Una de las carnes de pescado de mayor consumo en el mundo es la de Silúridos, también denominados peces de cuero o bagres, cuya principal característica es la ausencia de espinas intramusculares y de escamas, además de su alta productividad. En los últimos años se ha logrado realizar la caracterización nutricional de la carne de algunas de estas especies, hallándose que aunque la composición proximal se encuentra dentro de los rangos generales para peces, el contenido de grasa ofrece menor proporción de ácidos grasos poliinsaturados (AGP) particularmente en lo referente a la serie omega 3 (ω-3), aunque la relación ω-6/ω-3 se encuentra dentro de lo establecido por la Organización Mundial de la Salud (OMS) para muchas de estas especies de bagre. De igual forma, el contenido de los ácidos eicosapentaenoico (EPA) y docosahexaenoico (DHA), así como el de aminoácidos, minerales y vitaminas, revelan una alta variabilidad individual y entre especies, asociada con el tipo de cultivo y los hábitos alimenticios, así como también con la edad y peso al momento del sacrificio. Asimismo, se han definido algunos parámetros de calidad relacionados con la susceptibilidad a la autolisis, oxidación e hidrólisis de las grasas y con las alteraciones causadas por microorganismos que generan cambios determinantes en las características fisicoquímicas, microbiológicas y sensoriales. Esta revisión recopila la información actual relacionada sobre la composición nutricional de la carne de bagre y los parámetros de calidad.

Palabras clave. Composición proximal, vida útil, ácidos grasos, proteínas, minerales y vitaminas.

Population growth, combined with increasing urbanization and per capita income, has caused an increase in demand for products with higher nutritional values (Diouf, 2009), so fish meat has become a forerunner as a component of a healthy diet, as it is considered a source of high quality food (Molina et al., 2000 and Santaella et al., 2007), due to the contribution of essential amino acids (Hatae et al., 1990) and micronutrients (Luten et al., 2008 and McManus and Newton, 2011), as well as, its high levels of fatty acids omega-3 and omega-6, higher than in most meat sold for human consumption (Gjedrem et al., 2012).

One of the orders of fish species most consumed in the world is Silurid, also called "leather fish" or catfish, with about 2200 species distributed in 38 families; the most representative commercially are

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Ictaluridae, Clarididae, Pangasiidae, Pimelodidae and Siluridae (IABIN, 2009), which contribute to a growing market and an entrenched industry, as is the case with the U.S. channel catfish *Ictalurus punctatus*, the South Asian *Pangasius pangasius*, the African *Clarias gariepinus*, the European *Silurus glanis*, and the South American, specifically Brazil, *Rhamdia quelen* and *Pseudoplatystoma corruscans*. Among the main characteristics that have enabled the development of this vital industry are an excellent feed conversion, a short production cycle and a tolerance to high cultivation densities (Waldrop and Wilson, 1996). In the period between 1990 and 2004, the volume of global meat production of catfish in aquaculture increased by over 300%, with an estimated production in 2005 of 1.512.846 t, mainly based on the cultivation of *Ictalurus punctatus* and two species of *Pangasius* (*P. bocourti* and *P. sutshii*) (FAO, 2011), while for the year 2011, 1.3 million t of *Pangasius* spp were produced just in Vietnam, which were directly assigned to the international markets (FAO, 2012). Hybrid production with the Ictaluridae family is also notable, which has been favored by its better growth rates, lower production cycle, tolerance to disease and stress, carcass yield and ease of fishing (Chomnawang et al., 2007). The present review deals with generalities involving the meat quality of catfish, emphasizing the nutritional content of the principal commercial species and their decay processes.

**Nutritional composition of catfish meat.** The nutritional value and physical properties of fish meat can vary considerably between species and between individuals of the same species. Also, the contents of protein and lipids, and the size of muscle fibers, are closely related to the origin (fishing or farming), age, body weight, type of feeding, migratory behavior and reproductive status (Suárez et al., 2002; Solari, 2006 and González et al., 2009); it is widely known that reproductive activity causes stored energy expenditure in the form of lipids or proteins, depending on environmental conditions.

Regarding the nutritional characterization of catfish muscle (Table 1), these species show a proximal composition within the ranges observed in the flesh of other fish species and is very similar to red meat, except for fat content which is considerably varied (Gjedrem et al., 2012). According to Memon et al. (2011), there is an inverse relationship between the moisture content and the fat content in the flesh of many fish species, which is reflected in the color of the fibers, which become whiter as the lipid content decreases, therefore, it is expected that light-colored catfish meat corresponds to leanness.

**Lipid content and fatty acid composition.** According to lipid content, fish meat can be classified as: lean (<2% fat), low fat (2-4%), medium fat (4-8%) and blue or fat (>8%). This classification involves not only individual characteristics of the nutritional quality of the meat, but also the visual aspect, yield during processing and taste (Castro, 2002). The proximate composition reported for several species of catfish (Table 2) reveals a high variability between species; for example, considered as lean are: *Pseudoplatystoma fasciatum*, *Pseudoplatystoma corruscans*, *Pangasius gigas* and *Pangasianodon hypophthalmus*; as low fat: *Rhamdia quelen*; and as medium fat: *Clarias gariepinus* and *Ictalurus punctatus* (Martino et al., 2002; Orban et al., 2008, Weber et al., 2008; Perea et al., 2008, Ersoy and Özeren, 2009, Li et al., 2009 and Chaijan et al., 2010). So far, there is no report of a catfish species classified as blue or fat, as with salmon (*Oncorhynchus kisutch*) and trout (*Oncorhynchus mykiss*) (Perea et al., 2008).

Table 3 shows the fatty acid profile for catfish and other commercial fish species, highlighting the...
Table 2. Composition proximal (%) muscle commercial fish species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Moisture</th>
<th>Protein</th>
<th>Ash</th>
<th>Lipids</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhamdia quelen</td>
<td>79.6±0.82</td>
<td>15.5±0.19</td>
<td>1.08±0.02</td>
<td>2.51±0.45</td>
<td>Weber et al. (2008)</td>
</tr>
<tr>
<td>Clarias gariepinus</td>
<td>76.8-77.91</td>
<td>15.71-16.2</td>
<td>0.86-1.96</td>
<td>5.02-5.06</td>
<td>Ersoy et al. (2009)</td>
</tr>
<tr>
<td>Ictalurus punctatus</td>
<td>75</td>
<td>18.1</td>
<td>nr</td>
<td>5.69</td>
<td>Li et al. (2009)</td>
</tr>
<tr>
<td>Pseudoplatystoma corruscans</td>
<td>83.8</td>
<td>12.5</td>
<td>2.6</td>
<td>1.1</td>
<td>Martino et al. (2002)</td>
</tr>
<tr>
<td>Pseudoplatystoma faciatus</td>
<td>74.9-77.5</td>
<td>20.3-22.1</td>
<td>1.0-1.1</td>
<td>0.4-1.9</td>
<td>Perea et al. (2008)</td>
</tr>
<tr>
<td>Pangasius hypophthalmus</td>
<td>80.14-85.02</td>
<td>12.65-15.59</td>
<td>1.03-1.50</td>
<td>1.11-3.04</td>
<td>Orban et al. (2008)</td>
</tr>
<tr>
<td>Pangasianodon gigas</td>
<td>78.88±0.17</td>
<td>19.00±0.03</td>
<td>1.47±0.12</td>
<td>0.54±0.14</td>
<td>Chaijan et al. (2010)</td>
</tr>
<tr>
<td>Oncorhynchus kisutch</td>
<td>69.8-75.9</td>
<td>17.8-20.4</td>
<td>1.0-1.2</td>
<td>4.1-8.1</td>
<td></td>
</tr>
<tr>
<td>Oreochromis sp.</td>
<td>72.3-76.9</td>
<td>18.4-20.8</td>
<td>1.1-1.5</td>
<td>2.2-4.5</td>
<td></td>
</tr>
<tr>
<td>Piaractus brachyponus</td>
<td>74.8-79.3</td>
<td>16.7-19.3</td>
<td>1.0-1.2</td>
<td>1.6-6.3</td>
<td></td>
</tr>
<tr>
<td>Oncorhynchus mykiss</td>
<td>60.0-68.6</td>
<td>19.4-20.9</td>
<td>1.1-1.3</td>
<td>7.4-17.0</td>
<td></td>
</tr>
</tbody>
</table>

mr = No reported

Table 3. Fatty acid composition in some commercial fish species (% of total fatty acids).

<table>
<thead>
<tr>
<th>Especie</th>
<th>SFA</th>
<th>MUFA</th>
<th>PUFA</th>
<th>FUFA/SFA</th>
<th>Ω-6</th>
<th>Ω-3</th>
<th>EPA</th>
<th>DHA</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhamdia quelen</td>
<td>34.9±0.58</td>
<td>34.2±0.98</td>
<td>29.0±1.10</td>
<td>0.84±0.03</td>
<td>22.3±0.71</td>
<td>6.51±0.50</td>
<td>nd</td>
<td>3.9±0.40</td>
<td>Weber et al. (2008)</td>
</tr>
<tr>
<td>Clarias gariepinus</td>
<td>32.9±3.2</td>
<td>43.3±2</td>
<td>20.5±2.6</td>
<td>0.62±0.08</td>
<td>11.27±2.7</td>
<td>9.5±0.9</td>
<td>1.2±0.1</td>
<td>2.0±0.2</td>
<td>Wing-Keong et al. (2003)</td>
</tr>
<tr>
<td>Ictalurus punctatus</td>
<td>23.2±0.37</td>
<td>46.79±1.56</td>
<td>6.34±0.78</td>
<td>0.027±0.03</td>
<td>18.61±0.45</td>
<td>2.73±0.55</td>
<td>nd</td>
<td>0.75±0.20</td>
<td>Li et al. (2009)</td>
</tr>
<tr>
<td>Pseudoplatystoma corruscans</td>
<td>41.4</td>
<td>30.1</td>
<td>18.1</td>
<td>0.44</td>
<td>9.9</td>
<td>8.2</td>
<td>2.2</td>
<td>2.9</td>
<td>Martino et al. (2002)</td>
</tr>
<tr>
<td>Pangasius hypophthalmus</td>
<td>41.17-47.83</td>
<td>33.28-40.4</td>
<td>12.45-18.76</td>
<td>0.26-0.39</td>
<td>8.84-13.38</td>
<td>2.58-6.69</td>
<td>0.19-1.31</td>
<td>0.83-3.64</td>
<td></td>
</tr>
<tr>
<td>Pangasianodon gigas</td>
<td>45.22</td>
<td>28.26</td>
<td>26.56</td>
<td>0.59</td>
<td>nr</td>
<td>nr</td>
<td>3.46</td>
<td>nr</td>
<td>Chaijan et al. (2010)</td>
</tr>
<tr>
<td>Pangasius bocourti</td>
<td>30.2-36.5</td>
<td>32.7-39.9</td>
<td>14.8-24.0</td>
<td>0.50-0.53</td>
<td>15.5-22.1</td>
<td>1.63-1.95</td>
<td>nr</td>
<td>0.29-1.36</td>
<td>Thammapat et al. (2010)</td>
</tr>
<tr>
<td>Salmo salar</td>
<td>24.3±1.6</td>
<td>26.14±0.9</td>
<td>49.6±0.8</td>
<td>2.05±0.1</td>
<td>5.9±0.5</td>
<td>43.7±0.8</td>
<td>3.8±0.2</td>
<td>26.6±1.0</td>
<td></td>
</tr>
<tr>
<td>Oncorhynchus mykiss</td>
<td>22.1±1.0</td>
<td>31.6±4.0</td>
<td>46.3±3.8</td>
<td>2.00±0.1</td>
<td>8.8±2.2</td>
<td>37.5±6.2</td>
<td>8.0±3.0</td>
<td>17.5±2.0</td>
<td></td>
</tr>
</tbody>
</table>

nd= No detected n= No reported SFA: Saturated fatty acids MUFA: Monounsaturated fatty acids PUFA: Polyunsaturated fatty acids
Ω-6: Omega-6 Ω-3: Omega-3 EPA: Eicosapentanoic acids DHA: Docosahexaenoic acids

(Suárez et al., 2002), specially from the essential fatty acids linoleic and arachidonic, belonging to omega-6 (ω-6), and the essential fatty acids α-linolenic, docosahexaenoic (DHA) and eicosapentaenoic acid (EPA) of omega-3 (ω-3); the latter two having high nutritional value due to their anti-inflammatory and cytoprotective properties (Wanten and Calder, 2007). In this sense, catfish presented clear deficiencies when compared with other commercial species like Salmo salar and Oncorhynchus mykiss (Usydus et al., 2011). Contrary to reports on catfish, Izquierdo et al. (1999) indicated that trout has a proportion of...
ω-3 27% greater than that of ω-6 and, also, when subjected to cultivation processes these contents are unchanged. In farmed catfish, the contents of EPA and DHA decrease markedly from those presented under a natural environment (Kris-Etherton et al., 2002). However, it is clear that an appropriate feeding management increases the number of these contents; phytoplankton is the principal contributing source (Carrero et al., 2005 and Li et al., 2009).

In the ratio between omega-6 and omega-3 (ω-6:ω-3), the World Health Organization (WHO, 2005) suggests 5:1 for human diets (Teira et al., 2006), for the beneficial effects on health (Carrero et al., 2005 and Wood et al., 2003). In the studied species of catfish (Table 3), there is generally a high proportion of ω-6 fatty acids and low values of ω-3; however, for species like Rhamdia quelen, Clarias gariepinus, Pangasius hypophthalmus and Pseudoplatystoma corruscans the values of this ratio are within the range recommended by the WHO (Martino et al., 2002; Wing et al., 2003; Weber et al., 2008; Orban et al., 2008 and Domiszewski et al., 2011); although in Rhamdia quelen and Ictalurus punctatus the presence of EPA has not been detected (Weber et al., 2008 and Li et al., 2009); just as some studies report the presence of α-linolenic fatty acid (precursor of EPA and DHA), linoleic and arachidonic acid in significant amounts (Perea et al., 2008; Li et al., 2009; Chaijan et al., 2010 and Usydus et al., 2011), which presumably presents an advantage in terms of quality indices mainly due to the neutral effect of the atherogenic processes in linoleic acid (Perea et al., 2008).

**Protein content.** Fish meat is considered a protein of high biological value, not only because it has all the essential amino acids, but also because it presents digestibility rates superior to those of beef, eggs, and milk (Flores, 1987). The crude protein content in fish flesh varies between 17% and 21%, depending on the species, the nutritional and production cycle, as well as the body part (Chaijan et al., 2010). Research on muscle protein content in commercial catfish reported levels between 12% and 21%, depending on the origin (cultured or natural), reproductive cycle and type of feeding (Martino et al., 2002; Llanes et al., 2008; Orban et al., 2008; Weber et al., 2008; Ersoy and Özeren, 2009; Chaijan et al., 2010 and Thammapat et al., 2010). The amino acids found in greater proportion in the flesh, in order, are: lysine, leucine, phenylalanine/tyrosine, arginine and threonine (Campos et al., 2006; Adeyeye, 2009; Szlinder et al., 2011 and Usydus et al., 2011).

**Vitamins and minerals.** Just as with the proteins and lipids, in fish tissues there is also a high variation, inter- and intra - species, in the vitamin and mineral content (Usydus et al., 2011). In Clarias gariepinus, Ersoy and Özeren (2009) reported that potassium is the mineral found in the highest proportion (1.817 ± 132.4 mg kg⁻¹), followed by sodium (308 ± 0.35 mg kg⁻¹), magnesium (184 ± 18.5 mg kg⁻¹) and calcium (40.1 ± 0.08 mg kg⁻¹); whereas in Pangasius hypophthalmus Orban et al. (2008) noted that sodium had the highest proportion (387.5 ± 135.9 mg kg⁻¹) followed by potassium (335.6 ± 3.42 mg kg⁻¹), while presenting low magnesium levels (12.08 ± 0.15 mg kg⁻¹). This means that, contrary to what happens with other fish meat, for these two species, the Ca/P ratio could be affected, which is one of the indicators that confers the importance of the fish meat as a nutritional source (Izquierdo et al., 2001); however, in a study by Perea et al. (2008), which compared the content of Fe, P and Ca in six fish species marketed in Colombia, they observed that concentrations of these minerals in Pseudoplatystoma fasciatum are within optimal levels, even above those reported for Piaractus brachypomus, making this species of catfish an important source of P and Fe.

According to Greenfield and Southgate (2003), the vitamin content in the flesh of fish varies depending on the geographic availability, seasonality and physiological state. In a comparative study of traded species by Szlinder et al. (2011), they observed that Pangasius hypophthalmus has low levels of vitamins A (1.6 μg/100 g), D₃ (0.31 μg/100 g) and E (0.20 μg/100 g) when compared to species such as Tilapia milotica, carp and salmon; while, Ersoy and Ozeren (2009) reported, for Clarias gariepinus, a content of vitamin A niacin and vitamin E of 18.1, 1.13 and 0.34 mg/100 g, respectively, and significant values of B₆, B₂ and B₁₂ vitamins. However, the limited information on the quantification of vitamins in catfish meat limits the ability to define the true vitamin value.

**Quality parameters. Muscle structure.** In catfish, as in all teleost, the muscular package consists of segmental muscles (myomerces) arranged in adjacent bands that become more pronounced along the back, separated by layers of collagen (myocommata). Similarly, in these species, there are both red muscle and white muscle, the latter being the most abundant.
The red muscle has a high content of hemoprotein compounds, such as myoglobin (Mb) (80%), and greater content of lipid (Omega-3, 6 and 9) and vitamins (A and B) (Veggetti et al., 1990), providing greater nutritional benefits; but in a marketing context, presents instability during storage or processing (Solari, 2006). Instead, the white muscle of catfish presents stable textural characteristics due to the larger size of the muscle fibers, making it very efficient in industrial processes.

Degradation processes of catfish meat. The shelf life of a food is the period of time in which, under certain controlled conditions, the product retains specific quality characteristics, including organoleptic or sensory, nutritional and hygienic-sanitary ones; all directly related to the level of food security (Pelayo, 2010). Among the variables that affect the life of fish meat, some have been identified that are related to the harvest and postharvest, such as microbiological, which determine the degree of acceptance (Llerena and Nue, 2002) and Pacheco et al. (2010) indicate that in order that the pH be kept as low as possible, it is important to maintain low temperatures during the dressing process, which minimizes the biochemical reactions of degradation involving the release 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. A high proportion of lipids in fish meat provides enhanced susceptibility to oxidative rancidity and hence the onset of degradation processes (Pacheco et al., 2010) that can be measured through quantification of the first stages of this reaction (peroxide value) or through the quantification of the thiobarbituric acid reaction (TBA) of by products such as aldehydes, ketones and other compounds with an unpleasant odor and flavor, which quantifies the presence of malondialdehyde (MDA mg kg⁻¹). This parameter has been reported in catfish meat for some species such as Pseudoplatystoma sp, Brachyplatystoma rousseauxii and Bagre marinus, which achieve concentrations of 5, 1.98 and 3.2 MDA mg kg⁻¹, respectively, under different conservation treatments and storage temperatures (Pacheco et al., 2000; Reyes and Arocha, 2000 and Rodríguez et al., 2009). According to Licciardello et al. (1979), fish meat that has a TBA number greater than 4 mg kg⁻¹ is considered poor quality; but for smoked fish products, Kolodziej et al. (2002) determined that 3 to 4 MDA mg kg⁻¹ is the minimum that affects chemical stability in the product.

In the formation of total volatile basic nitrogen (TVB-N), it is important to note that this variable is associated primarily with the activity of microorganisms and the pH variation during the post mortem stages and which, in freshwater fish species, mainly consists of the formation of ammonia, while in marine species it is the formation of ammonia and trimethylamine oxide (Pacheco et al., 2010). Thus, the TVB-N could be used as an effective indicator of deterioration of meat due to the high degree of relation with sensory analyses regarding product acceptance (Massa, 2006), with
Table 4. Quality assessment and fillets shelf life some Silurid species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Conservation treatment</th>
<th>Type of packaging</th>
<th>Shelf rated</th>
<th>Storage T</th>
<th>Maximum values reported</th>
<th>Microbiological count</th>
<th>Shelf life</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Pseudoplatystoma curuscans</em></td>
<td>Fresh meat</td>
<td>Packing of high and low permeability</td>
<td>28 days (cooling) 84 days (freezing)</td>
<td>5 °C and -16 °C</td>
<td>nr</td>
<td>nr nr</td>
<td>&gt;8 log CFU/g of total aerobes mesophylic</td>
<td>Two weeks under refrigeration and exceeded the 84- day trial in freezing</td>
</tr>
<tr>
<td><em>Pseudoplatystoma</em> sp</td>
<td>Salted fillets (36%)</td>
<td>Without vacuum packaging and vacuum packaging</td>
<td>90 days</td>
<td>4 °C and ambient temperature (27 °C)</td>
<td>&lt;6,3</td>
<td>Up to 24.99 Up to 4.99</td>
<td>nr</td>
<td>nr</td>
</tr>
<tr>
<td><em>Pangasius hypophthalmus</em></td>
<td>Fillet samples from three months of storage at -18°C</td>
<td>Without packaging vacuum and modified atmosphere</td>
<td>24 days</td>
<td>4 °C</td>
<td>nr nr nr</td>
<td>nr</td>
<td>8.4±0.2 log CFU/g total aerobes psychrophilic</td>
<td></td>
</tr>
<tr>
<td><em>Brachyplatystoma rousseauiii</em></td>
<td>Salted and smoked fillets at different times</td>
<td>High density film vacuum and high density film without vacuum</td>
<td>28 days</td>
<td>2 °C</td>
<td>6.7±0.04 Without vacuum and 6.69 with vacuum</td>
<td>26.1±1.1 Without vacuum and 23.2±0.3 with vacuum</td>
<td>1.98±0.09 Without vacuum and 1.25±0.08 with vacuum</td>
<td>nr</td>
</tr>
<tr>
<td><em>Leiarius marmoratus</em></td>
<td>Fresh produce with time delay for cooling (0.2, 4.6 and 8 h)</td>
<td>None</td>
<td>21 days</td>
<td>0 °C±3</td>
<td>6.63 to 6.88, 13.8 to 20.7</td>
<td>nr</td>
<td>&gt;6 log CFU/g total aerobes mesophylic and &gt;7 log CFU/g total aerobes psychrophilic</td>
<td>Exceeded the 21 day trial</td>
</tr>
<tr>
<td><em>Clarias macrocephalus x Clarias gariepinus</em></td>
<td>Fresh fillets of 6.8 and 10 months of age</td>
<td>Polybags</td>
<td>15 days</td>
<td>4 °C</td>
<td>7.07±0.08</td>
<td>44.37</td>
<td>nr</td>
<td>nr</td>
</tr>
<tr>
<td><em>Bagre marinus</em></td>
<td>Without and with placing in chlorinated water</td>
<td>Polybags</td>
<td>24 days</td>
<td>2 °C</td>
<td>Up to 7.1</td>
<td>Up to 18.35 Up to 3.20</td>
<td>Up to 8.5 log CFU/g total aerobes psychrophilic</td>
<td>20 days</td>
</tr>
</tbody>
</table>

TVB-N: total volatile bases nitrogen (mg N volatile/100 g sample), TBA: reaction to Thiobarbituric acid (mg MDA/kg sample), nr: not reported information.
values between 30-40 mg/100 g being reported as the limits of acceptability for cold and temperate water fish (Benjakul et al., 2003).

In an investigation by Lubes (2005), it was revealed that Leiarius marmoratus meat, when subjected to different retention times before being stored at 0 ºC, had TVB-N content values between 13.8 and 20.7 mg of N/100 g meat, without reaching the permitted maximum during the 21 days of the trial; while Chomnawang et al. (2007), reported that the hybrid Clarias macrocephalus × Clarias gariepinus reaches the permitted level of TVB-N after only 9 days when stored in polyethylene bags at 4 ºC (Rodríguez et al., 2009).

Microbiological quality. Based on available information, it is expected that the biochemical composition of fish meat, as well as, variations in temperature and composition of the storage atmosphere favor microbial growth, considering the level of microbial contamination in the muscle from which fish will start to be significantly altered is 7.0 log CFU g⁻¹ (ICMSF, 2005). The bacteria that commonly impact refrigerated fish correspond to different genera of Gram-negative bacillus such as Achromobacter spp., Pseudomonas spp., Falvobacterium spp., Shewanella spp., and Cytophaga spp. Similarly, Vibrio spp., Clostridium spp., Micrococcus spp., Alteromonas spp., Moraxella spp., enterobacteriaceae, coliform microorganisms, Basillus spp. and Listeria spp have been reported; as well as lactic acid bacteria, molds and yeasts (Mossel et al., 2002). Vermeiren et al. (2005) indicate the possibility of B. thermosphacta intervening in decomposition processes even with counts below 7.0 log CFU g⁻¹ and therefore its presence, even in low numbers, should not be overlooked. Molina et al. (2000), Lubes (2005) and Noseda et al. (2012) indicate that the smell and taste of catfish meat decrease in value over time, due to the increase of metabolites and ammonia compounds from degradation, but that the implementation of meat management practices, such as washing with chlorine, salting or modified atmosphere or vacuum packaging, achieve increased product shelf life up to 84 days, when stored at freezing temperatures (0 to -16 ºC), and up to 20 days at refrigeration temperatures (2-4 ºC).

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