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

Revisión: Caracterización de la Calidad Nutricional de la Carne en Algunas Especies de Bagre

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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; Castro, 2002; Suárez *et al*., 2002; Santaella *et al*., 2007; Abeywardena and Patten, 2011 and Dyck *et al*., 2011). Fish meat is basically composed of water (66-81%), protein (16-21%), carbohydrates (<0.5%), lipids (0.2-25%) and ash (1.2 to 1.5%) (FAO, 1999); and is considered to have important biological value (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, Clariidade, 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 *Pseduoplatystoma 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; Perea *et al*., 2008, Weber *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 1. Main components (%) in fish and beef.

Meat	Protein	Lipid	Carbohydrates	Ash	Moisture	References
	(%)					
Catfish	12-22	0.4-5.7	nr	0.8-2	74-85	Weber *et al*. (2008), Perea *et al*. (2008) Ersoy *et al*. (2009), Li *et al*. (2009), Martino *et al*. (2002), Orban *et al*. (2008), Chaijan *et al*. (2010)
Generally fish	16-21	0.2-2.5	0.50	1.2-1.5	66-81	Ruyter (2010)
Beef	20	3	1	1	75	Ruyter (2010)

nr: No reported

Table 2. Composition proximal (%) muscle commercial fish species.

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

mr = No reported

relative equivalence of monounsaturated fatty acids (MUFA) and saturated fatty acids (SFA) in all species, but a content of polyunsaturated fatty acids (PUFA) to a lesser extent in terms of catfish. In this sense, the relationship between PUFA and SFA must be greater than 0.4 in accordance with the recommendations of the National Agency of Health of the United Kingdom (UK, 1994), so that some species of catfish presented disadvantages as indicated by Orban *et al*. (2008) and Domiszewski *et al*. (2011) for *Pangasius hypophthalmus* and Li *et al*. (2009) for *Ictalurus punctatus*.

The importance of long-chain polyunsaturated fatty acids lies in the protective effect on human health (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

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

Especie	SFA	MUFA	PUFA	FUFA/SFA	Ω-6	Ω-3	EPA	DHA	References
Rhamdia quelen	34.9±0.58	34.2±0.98	29.0±1.10	0.84±0.03	22.3±0.71	6.51±0.50	nd	3.9±0.40	Weber *et al*. (2008)
Clarias gariepinus	32.9±3.2	43.3±2	20.5±2.6	0.62±0.08	11.27±2.7	9.5±0.9	1.2±0.1	2.0±0.2	Wing-Keong *et al*. (2003)
Ictalurus punctatus	23.2±0.37	46.79±1.56	6.34±0.78	0.027±0.03	18.61±0.45	2.73±0.55	nd	0.75±0.20	Li *et al*. (2009)
Pseudoplatystoma corruscans	41.4	30.1	18.1	0.44	9.9	8.2	2.2	2.9	Martino *et al*. (2002)
Pangasius hypophthalmus	41.17-47.83	33.28-40.4	12.45-18.76	0.26-0.39	8.84-13.38	2.58-6.69	0.19-1.31	0.83-3.64	Orban *et al*. (2008) Domiszewski *et al*. (2011)
Pangasianodon gigas	45.22	28.26	26.56	0.59	nr	nr	3.46	nr	Chaijan *et al*. (2010)
Pangasius bocourti	30.2-36.5	32.7-39.9	14.8-24.0	0.50-0.53	15.5-22.1	1.63-1.95	nr	0.29-1.36	Thammapat *et al*. (2010)
Salmo salar	24.3±1.6	26.1±0.9	49.6±0.8	2.05±0.1	5.9±0.5	43.7±0.8	3.8±0.2	26.6±1.0	Usydus *et al*. (2011)
Oncorhynchus mykiss	22.1±1.0	31.6±4.0	46.3±3.8	2.009±0.1	8.8±2.2	37.5±6.2	8.0±3.0	17.5±2.0	

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

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 Ozeren, 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), D_3 (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 B_1, B_2 and B_6 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 (myomeres) 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 water quality, type of sediment ponds, body size, temperature, hygiene during handling, slaughter and gutting methods, packaging, transport and storage, among others (Gallart *et al*., 2006; Orban *et al*., 2008; González *et al*., 2009 and Rodríguez *et al*., 2009), which affect the microbial ecology of live fish and therefore the final product. Similarly, freezing and thawing during storage result in the formation of ice crystals within the fibers, causing structural damage and ultra solute concentration in the meat which, in turn, leads to alterations in the cellular reactions and biochemical parameters influencing the physical quality of the meat (Leygonie *et al*., 2012).

Physico-chemical characteristics. In catfish meat, as in all meats, deterioration processes occur as soon as the fish dies. Deterioration processes include degradation of proteins and ATP, decreased pH, lipid oxidation and production of undesirable compounds such as trimethylamine (TMA-N) and volatile bases with low molecular weights (TVB-N), which are produced by bacterial action. Simultaneously, the muscle undergoes changes of texture and color (Li *et al*., 2011). These changes can be classified as biochemical, physical and microbiological, which determine the degree of acceptance by consumers and that, combined with nutritional assessment, determine the life of the meat (McMillin, 2008). Table 4 compiles the benchmarks of quality and life of meat during storage for some *Silurid* species.

Due to the lower glycogen content in the fish meat, the pH does not present a significant reduction in post mortem processes, being located close to neutrality, which leads to accelerated self hydrolysis and bacterial growth and, consequently, to degradation of the meat (Kubitza, 1999). In catfish, pH values have been reported ranging between 6 and 7 under different storage conditions (Molina *et al*., 2000; Lubes, 2005; Chomnawang *et al*., 2007; Rodríguez *et al*., 2009 and Pacheco *et al*., 2010). Fluctuations during this period do not provide significant variations in degradation processes, but must correlate with the biochemical, microbiological and sensory analyses. 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, Kolodziesjska *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.

Species	Conservation treatment	Type of packaging	Shelf rated	Storage º T	Maximum values reported				Shelf life	References
					pH	TVB-N	TBA	Microbiological count		
Pseudoplatystoma curuscans	Fresh meat	Packing of high and low permeability	28 days (cooling) 84 days (freezing)	5 ºC and -16 ºC	nr	nr	nr	>8 log CFU/g of total aerobes mesophylic	Two weeks under refrigeration and exceeded the 84- day trial in freezing	Molina *et al.* (2000)
Pseudoplatystoma sp	Salted fillets (36%)	Without vaccum packaging and vacuum packaging	90 days	4 ºC and ambient temperature (27 ºC)	<6,3	Up to 24.99	Up to 4.99	nr	nr	Rodríguez *et al.* (2009)
Pangasius hypophthalmus	Fillet samples from three months of storage at -18ºC	Without packaging vacuum and modified atmosphere	24 days	4 ºC	nr	nr	nr	8.4±0.2 log CFU/g total aerobes psychrophilic	7 days for unpackaged fillets, vacuum packed 10 days and 12-14 days inmodified atmosphere	Noseda *et al.* (2012)
Brachyplatystoma rousseauxii	Salted and smoked fillets at different times	High density film vacuum and high density film without vaccum	28 days	2 ºC	6.76±0.04 Without vacuum and 6.69 with vacuum	26.1±1.1 without vacuum and 23.2±0.3 with vacuum	1.98±0.09 without vacuum and 1.25±0.08 with vacuum	nr	Exceeded the 28 days trial	Pacheco *et al.* (2010)
Leiarius marmoratus	Fresh produce with time delay for cooling (0.2, 4.6 and 8 h)	None	21 days	0 ºC±3	6.63 to 6.88,	13.8 to 20.7	nr	>6 log CFU/g total aerobes mesophilic and >7 log cfu/g total aerobes psychrophilic	Exceeded the 21 day trial	Lubes (2005)
Clarias macrocephalus x Clarias gariepinus	Fresh fillets of 6.8 and 10 months of age	Polybags	15 days	4 ºC	7.07±0.08	44.37	nr	nr	9 days	Chomnawang *et al.* (2007)
Bagre marinus	Without and with placing in chlorinated water	Polybags	24 days	2 ºC	Up to 7.1	Up to 18.35	Up to 3.20	Up to 8.5 log CFU/g total aerobes psychrophilic	20 days	Reyes y Arocha (2009)

TVB-N: total volatile bases nitrogen (mg N volatile/100 g sample), TBA: reaction to Tiobarbituric 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 °C, 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 °C (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) conducted microbiological assessments on catfish meat under different processes of conservation, which involved the use of gaskets of low and high permeability and modified atmospheres, and found counts over 6 log CFU g^{-1} for total mesophilic aerobes and greater than 7 log CFU g^{-1} for total psychrophilic aerobes related to the termination of the product life and were correlated with the contents of TVB-N, TBA and pH.

Sensory issues in catfish meat. The high susceptibility to autolysis, oxidation and hydrolysis of fats and to alteration by microorganisms generate changes that affect the quality of the fish meat in terms of color, aroma, flavor and texture (Molina *et al*., 2001 and Wood *et al*., 2003). These sensory changes depend on the species and the method of storage and are measured based on previously designed scales. A general description is provided by the European Union in the guide for assessing the quality of fish. The suggested scale is 0 to 3, with 3 being the highest quality (Huidobro *et al*., 2011).

In possessing catfish meat with a relatively low fat content, it is expected that the lifetime will be greater when compared with other species such as salmon or trout. Reyes and Arocha (2000), Molina *et al*. (2001), Lubes (2005), Chomnawang *et al*. (2007), Rodríguez *et al*. (2009), Pacheco *et al*. (2010) 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 °C), and up to 20 days at refrigeration temperatures (2-4 °C).

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