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Analysis of the Degree of Quality of Fish Fillet in Refrigeration

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Abstract

Fish is a highly nutritious food widely consumed around the world. The production of fish for human consumption is from capture fishing and aquaculture activities. Tilapia is considered one of the fish with the highest production worldwide, being a source of quality protein at an affordable price. On the other hand, and in addition to its nutritional properties, fish is highly susceptible to deterioration and contamination, mainly due to its intrinsic properties, making it able to consume it for short periods of time, so to extend its availability, it is subjected to common conservation processes like refrigeration. Therefore, the present study is focused on the analysis of the degree of freshness and quality of tilapia fillet through sensory evaluation during refrigerated storage for 12 days. The results indicated that the tilapia fillet during storage had a grade of first quality from day 0 to 4th of storage recommended for consumption, second quality on the 6th day and out of quality from the 8th of storage, the latter being not recommended for human consumption.

Keywords

Tilapia, Conservation, Deterioration, Freshness, Quality

1. Introduction

Fish is any food extracted from oceanic or continental waters intended primarily for human or animal consumption [1]. The fish destined for human consumption is obtained through aquaculture and fishing activities, with an annual per capita consumption of 20.5 kg worldwide [2].

Tilapia is one of the fish intended for human consumption. Tilapias are fresh-

water fish native to Africa, belonging to the *Cichlidae* family, classified into three genera: *Tilapia*, *Oreochromis* and *Sarotherodon*, differentiated according to parental care patterns. Species of the genus *Oreochromis* (*O. niloticus*, *O. aureus*, *O. mossambicus*) and their interspecific hybrids (red tilapia) are considered optimal culture organisms as they tolerate high densities, are fast-growing, resistant to diseases, adaptable to captivity, in addition to its meat is of high quality and affordable price [3]. Thus, tilapia for several years has become a product of the highest generation in aquaculture, for example, only in 2018, and within the group of finfish, it represented 10.2% of the total world aquaculture production, being the main providers Asian countries such as China, India, Indonesia, among others [2], and is commercialized in the market internationally mainly as a complete product or fillet [3].

Fish is considered a highly nutritious food and a fundamental part of human nutrition as it is the main source of proteins of high biological value and digestibility, vitamins, minerals, and unsaturated lipids [1] [4]. Fish and its meat, in addition to being a source of quality protein, for developing regions of the world represent an important proportion of animal protein in their diet, contribute to national economies, health, food security and improve livelihoods primarily of artisanal fishermen [5].

However, due to these nutritional properties, fish is a highly susceptible food to deterioration, loss of quality and health risk due to contamination with pathogenic bacteria throughout the food chain; the foregoing mainly because it has a pH close to neutrality, high water activity and content of nutrients easily usable by microorganisms, as well as the activity of enzymes and oxidation reactions present in fish tissues and viscera [1] [4] [6] [7].

In the fishing and aquaculture industry, the term "quality" may have different meanings, commonly associated with species of high commercial value or proportion of the piece, absence of pathogenic microorganisms or chemical compounds, with its state of freshness and appearance related to its deterioration derived from autolysis, oxidation and/or contaminating microbial activity [8].

In the period that elapses from the capture to processing and marketing, the fish can experience various changes in its sensory, physical-chemical and microbiological properties that affect its freshness, degree of conservation and shelf life, which are related to factors such as species, size, shape, fat content, feeding, capture methods, their environment, cooling conditions, storage, transportation, distribution, among others [1] [4] [6] [9].

Conservation techniques for fish or products are varied and are necessary to keep them in good condition until consumption, helping to reduce the process of deterioration or decomposition that causes the detriment of its quality. Thus, the preservation methods in foods, including fish, are applied to extend their nutritional, sensory and safety characteristics for a longer consumption time. They are based on altering the optimal conditions of biological activity (enzymatic and microbial) to water elimination, acidification and changes in salt concentrations, changes in temperatures (refrigeration, freezing or cooking), among

others [5] [10]. The fillet is the edible portion of the fish most in demand by consumers [11], being in its fresh refrigerated state one of the common presentations for marketing and consumption. The fresh chilled fillet is a food product defined as the muscular portion of the fresh, healthy, clean fish, free of belly, with or without skin and/or scales, according to its presentation, obtained by cutting parallel to the spine and subjected to refrigeration where the product must be conveniently free of torn ends, tears, fins, severely discolored meat and blood clots [12]. Therefore, the objective of this study is to analyze the degree of quality of tilapia fillet (*Oreochromis niloticus*) subjected to conservation by refrigeration at 4˚C for twelve days.

2. Materials and Methods

2.1. Studio Location

The study was carried out at the facilities of the Technological University of Nayarit (UT NAYARIT), municipality of Xalisco, Nayarit, Mexico (**Figure 1**). The municipality has a warm sub-humid climate, altitude of 989 meters above mean sea level (MAMSL), the average annual temperature of 25˚C, average annual rainfall of 1100 mm and geographic coordinates (21˚26'37"N and 104˚53'59"W) [13] [14].

2.2. Fish Sourcing and Processing

The fish consisted of 9 adult specimens of tilapia (*Oreochromis niloticus*) weighing 821.5 ± 166.6g and being 30.6 ± 4.1 cm long, randomly collected and acquired alive from the Nayarit Unit of the Northwest Biological Research Center (UNCIBNOR+), which is located 14 km from the Technological University of Nayarit. They were transferred to the facilities of the Technological University of Nayarit (UT NAYARIT) and were kept in non-exhausting conditions, without feeding, in containers of approximately 1 m^3 capacity until slaughter by thermal shock with ice, and processing to obtain the fillet by longitudinal manual cutting in the dorsal musculature all along the spine to obtain skinless fillet on each side of the fish. The processing and handling were carried out under good practices and hygiene conditions (**Figure 2**).

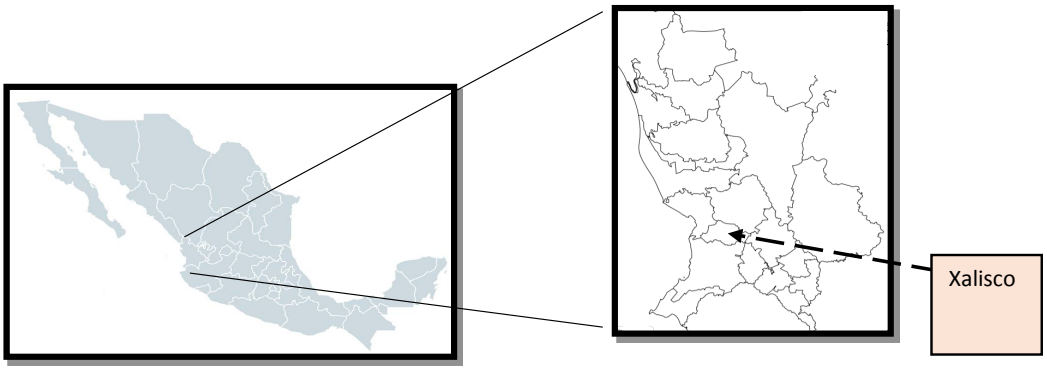

Figure 1. Macro location of the state of Nayarit and its Xalisco municipality [15].

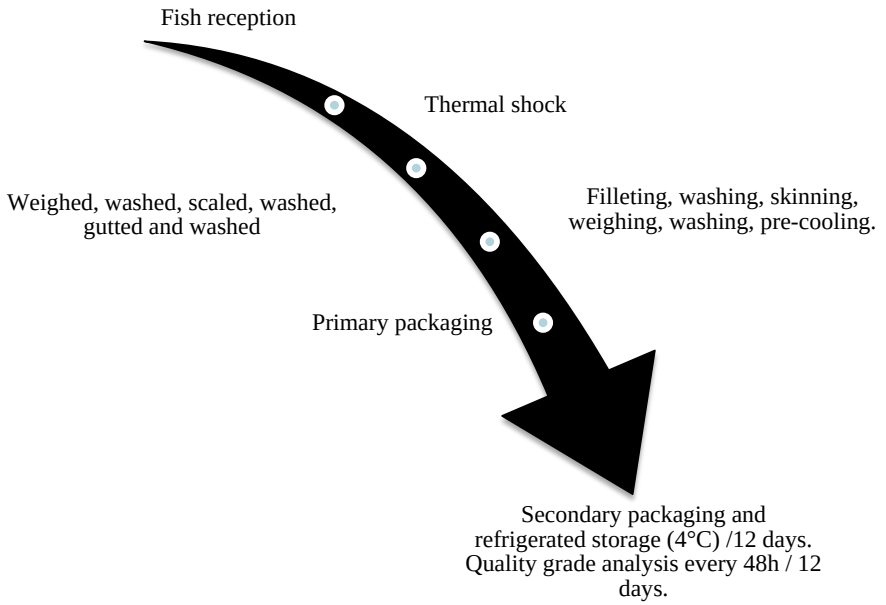

Figure 2. Process flow diagram for obtaining and storing tilapia fillet (*O. niloticus*) in refrigeration at 4˚C for twelve days.

2.3. Initial Packaging (Primary Packaging)

After filleting and skin removal, pre-cooling was performed by immersing the fillet in potable quality, ice-water at temperatures of ≤5˚C for 5 minutes. For the initial or primary packaging, 100 g of fillet were weighed and placed manually in a primary container which consisted of a 16.5 cm wide by 17.5 cm long polyethylene bag with hermetic closure. Once in their primary packaging, the fillets were taken to their secondary packaging.

2.4. Secondary Packaging and Final Storage

For final storage, the fillets in their primary packaging were placed in an expanded polystyrene isothermal container with dimensions 18.5 cm long, 12 cm wide and 16 cm high (previously washed, dried and disinfected). Cooling gel bags were also added inside the container. This secondary container was finally subjected to refrigeration conditions at a temperature of 4˚C for 12 days (**Figure 3**).

2.5. Quality Grade Analysis

For determining the degree of quality, it was made through the sensory evaluation of the tilapia fillets stored under refrigeration at 4˚C every 48 hours for 12 days, following the procedures of the standards NMX-FF-032-SCFI-2001 [12] and NMX-FF-032-SCFI-2011 [16]. The procedures for determining the grade of quality of fillets are based on a system of deduction of points from base 100 evaluating different sensory factors in the fillet (**Table 1**). Adding the total of the applied deductions and subtracting it from the base to obtain the final qualification of the fish fillet. According to the qualification obtained from the evaluation,

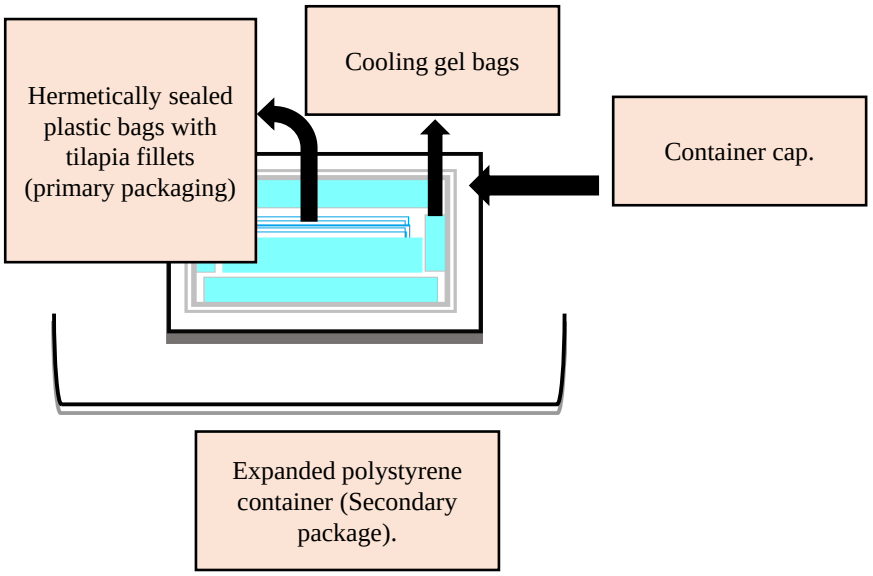

Figure 3. Top view of secondary packaging consisting of an expanded polystyrene container for refrigerated storage at 4˚C of tilapia fillet for twelve days.

Table 1. Point evaluation system for determining the quality grade of fish fillets through sensory characteristics [12] [16].

Factor	Quality Variation	Deduction
Scaleless presentation	Up to 10 pieces per sample	0
	From 11 to 15 pieces per sample	4
	Deduct 3 points for every 5 additional pieces presented	
Hard fishbones	One fishbone per sample	2
	From 2 to 4 fishbones per sample	3
	From 5 to 10 fishbones per sample	5
	From 11 to 18 fishbones per sample	16
Skin scraps (Skinless presentation)	Absence	0
	Up to 8.0% on sample's surface	4
	From 16% to 25% on sample's surface	10
	Over 25% on sample's surface	16
Belly scraps	Absence	0
	Up to 5% on sample's surface	2
	From 6% a 11% on sample's surface	2
	Deduct 4 points for every additional 5% present on sample's surface.	
Color	Species' characteristic	0
	Minimal changes in natural coloration, up to 3 cm^2	2
	Notorious changes in natural coloration from 3 cm^2 to 10 cm^2	6
	Abnormal for contamination	16
	Every blood spot larger than 5 mm per sample	4

Continued

Odor	Species' characteristic	0
	Moderate change from characteristic smell	4
	Light rancid/acid smell	10
	Rancid/Acid smell	16
Texture	Firm and stretch	0
	Slightly soft, with a slow recovery after digital pressing	3
	Notoriously soft with a slow recovery after digital pressing.	11
Cooked	**Odor**	
	Disgusting	16
	Characteristic	0
	Flavor	
	Disgusting	16
	Characteristic	0

the fish fillet will be classified in three different grades of quality: first quality, second quality and out of classification; the latter, when any fish fillet qualifies with less than 85 points in its quality grade evaluation and will correspond to fillets with sensory characteristics of deteriorating products with the presence of ammonia odors. The sensory evaluation for the degree of quality was carried out from 11 a.m. to 12 p.m. (noon) at the UT Nayarit facilities. The total number of evaluating panelists was ten, where each evaluating panelist was provided with fillet portions. For the analysis of the cooked fillet, the fillet was cooked by placing it in a plastic bag, sealing it and cooking it in boiling water for approximately 20 minutes until reaching a temperature of 71˚C in its thermal center, being subsequently evaluated.

2.6. Analysis of Data

Statistical data analysis was performed using Microsoft Excel spreadsheet software for Windows version 15 (2013). The results presented are the mean values of the evaluations obtained through the panelists' points deduction system.

3. Results and Discussion

Fillet Quality Grade

Freshness is an attribute that varies continuously and means the fish has properties like those owned in life or after being caught or harvested. Among the main methods of evaluating the freshness or deterioration of fish, the sensory, physical, chemical, and microbiological stand out [4] [17]. Sensory evaluation is the most used method, due to its low cost, efficiency, and practicality, being commonly carried out in the fishing sector and sanitary inspection services [1].

Through sensory analysis, it is possible to determine the degree of quality of

tilapia fillet for this the Mexican standards [12] and [16] describe how to carry out said procedure where the evaluation system that includes the factors in the fillet to be evaluated, and corresponding score to determine the degree of quality. The fishery products destined for human consumption by the aforementioned standards, classify the evaluated fish fillet in the three quality grades: first quality, which is when the sum of deductions assigned to the sensory characteristics ranges from 90 - 100 points, second quality of 85 - 89.5 points and out of classification < 85 points. Any fillet with a rating of less than 85 points is considered in a state of alteration and does not comply with the classification of the indicated standards.

Figure 4 presents the results of the sensory analysis of ten untrained evaluator panelists based on a point deduction system for different sensory factors of tilapia fillet (Table 1). It was determined that from day 0 to 4 the tilapia fillet had a first quality classification obtaining 98 points, on day 6 it obtained the second quality classification with 85 points and finally from day 8 it showed a category of out of classification with 53 points, points and later reaching 45 points on day 12 of refrigerated storage. The fillets from day 8 of storage presented low scores, is therefore not recommended for human consumption (Figure 4).

Figure 5 establishes the relationship between the number of days of storage elapsed and the average score from the evaluation scheme. Therefore, the higher the score obtained, the fresher the fish fillet will be, along with better quality, and the lower the score and the longer the storage time, the lower the quality and freshness. It is important to point out that the period of storage, quality and freshness, will depend on the storage conditions, where factors such as pre and postmortem handling of the fish, the speed of cooling after capture, maintenance of the cold chain, fishing gear, time of the year, fishing area or cultivation, among

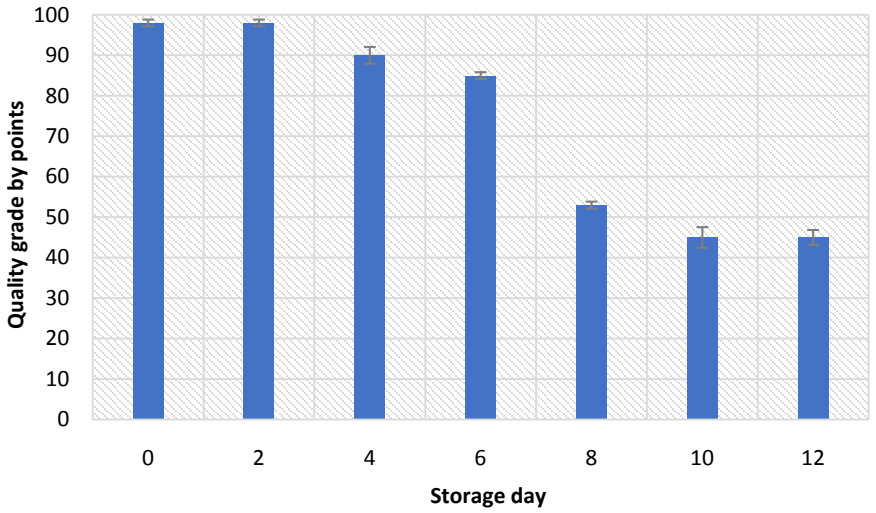

Figure 4. Quality grade by points applied to the fillet of tilapia (*O. niloticus*) refrigerated at 4˚C for twelve days. *Each total score per day represents the average of deductions assigned to the sensory characteristics of the product made by 10 untrained evaluating panelists.

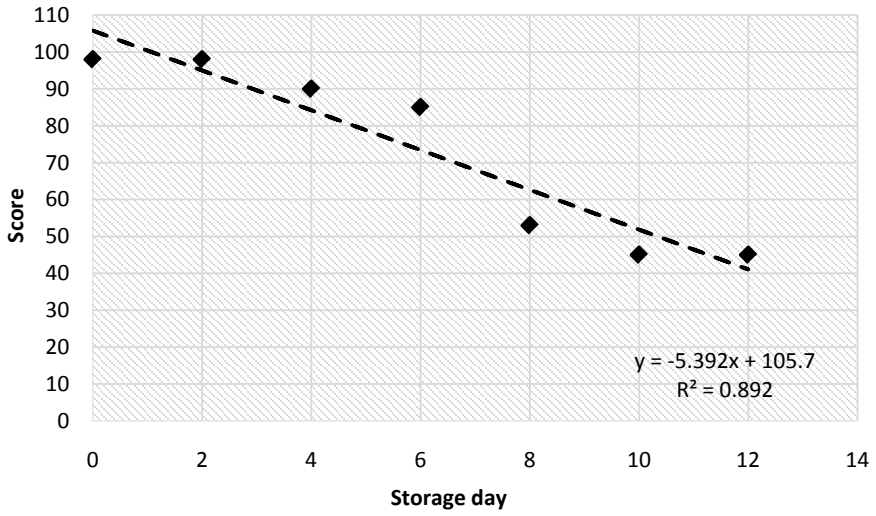

Figure 5. Linear regression of the mean quality grade score for tilapia fillet (*O. niloticus*) stored refrigerated at 4˚C for twelve days.

others, may affect the quality of the fish [18] (**Figure 6**). Generic sensory evaluation methods to determine the degree of quality of fishery products such as those used in this study are useful. However, they may give rise to different opinions or judgments by not considering differences or characteristics between species of fish or products to be evaluated.

In related studies on sensory evaluation of fish fillets, Santaella *et al.* [19] reported that sea bream fillets (*Sparus aurata L.*), stored in ice-based refrigeration systems, presented sensory evaluations, outlining that after fifteen days of storage they reached rejection levels for a total storage period of twenty-two days. Meanwhile, Domínguez and Saibene [20] indicated, through sensory evaluation as well, that for shad fillet (*Prochilodus lineatus*) preserved in flake ice in a chamber from 0˚C to 3˚C, it had a shelf life of six days.

Tome *et al.* [21] in a study for tilapia (*Oreochromis* spp) evaluated for twenty-one days in refrigeration at 0˚C, reported through sensory evaluation a state of alteration beginning at the 10th day of storage. Pinnacchio [22] carried out the sensory evaluation of several species of refrigerated fish (0˚C to 3˚C) such as *Leporinus obtusidens*, *Salminus brasiliensis*, *Luciopimelodus patl* and *Prochilodus lineatus*, indicating that, at the 10th day, all the specimens studied were in a putrefaction state.

Refrigeration is a short-term food preservation method commonly used due to its ease, effectiveness, and low cost based on lowering the temperature (between 0˚C and 5˚C), slowing down enzymatic activity and developing microorganisms, extending their life useful, nutritional, and sensory properties of commercial quality [23] [24] [25]. However, refrigeration favors humidity and microbial growth, which is why it is necessary to monitor the expiration and storage time of foods under these conditions [25]. At a temperature of 4˚C, the shelf life is correlated with its pH, chemical composition, and microbiological contamination, being kept refrigerated for only a few days [24].

Figure 6. Fresh fillet of tilapia (*O. niloticus*) day zero of storage in this study.

In fish, postmortem changes such as biochemical, physical, and microbiological are responsible for the loss of freshness and deterioration of its quality. These changes are found depending on the type of species, handling, storage, and conservation conditions [19] [26].

Fish and products, in accordance with storage conditions, are a favorable medium for microbial growth. In refrigeration this growth is of aerobic, Gram-negative bacteria and represents the main cause of deterioration in products causing some changes such as discoloration, gas production, and pH changes, among others [27].

Along with the sensory changes, aroma and flavor are the most frequent characteristics associated with the quality of the fish. The bad smell of fish is derived mainly from the microbial action of non-protein nitrogen compounds such as peptides, amino acids, nucleotides, volatile bases, and the reduction from trimethylamine oxide to trimethylamine; Although freshwater fish contain low amounts of trimethylamine oxide, unpleasant odors come from carbonyls and alcohols from polyunsaturated fatty acids [19] [26].

It has been reported that the deterioration of fish and its meat presents four phases which are: phase I, due to autolytic changes, caused by enzymes, freshly killed fish has a sweet, marine, delicate flavor. The deterioration is scarce, with a slight decrease in the characteristic aroma and flavor. Phase II, autolytic changes, caused by enzyme with significant reduction of the natural taste and smell of the fish. The meat acquires a neutral yet non-unpleasant flavor and a pleasant texture. Phase III, bacteriological changes, where signs of deterioration begin to show, there is the presence of strong unpleasant flavors, rancid and unpleasant odors; there are also significant changes in texture; the meat becomes soft and watery, or leathery and dry. And phase IV, with even more bacteriological changes, where the fish is spoiled, rotten and inedible [9].

The signs of deterioration in fish are commonly perceived through the sense organs, called sensory changes, and can be noticed at the level of the producers themselves, industrialists, health inspectors, handlers, and final consumers [19] [28]. Therefore, sensory evaluation is a tool to evaluate and determine the deterioration and useful life of fish, due to the relative ease, speed and low cost of

being carried out, greatly influencing the acquisition and purchase of these foods of aquatic origin [19] [28].

The term quality in fish and products can have different meanings, focusing on appearance and freshness, degree of deterioration or absence of dangers to the health of the consumer such as bacteria, viruses, parasites or chemical compounds. So the quality can be something different for each person. It is generally thought that high-quality fish is that which is consumed within the first few hours post-mortem, but it has been reported that very fresh fish in rigor mortis is difficult to subject to filleting and skinning actions. Therefore, for the processor, slightly older fish subjected to rigor mortis is more recommended [4].

The evaluation of the quality of the fish can be carried out by chemical, physical, microbiological and sensory methods. The evaluation of sensory characteristics to determine the quality of fresh fish analyzes and interprets the characteristics of the food through the human senses of sight, smell, taste, touch, and hearing [4]. Since the consumer is considered the ultimate judge of fish quality, the use of chemicals or any other methods must be correlated with sensory evaluation. In addition, sensory evaluations must be carried out under controlled conditions to reduce variations and their effects such as the environment or personal prejudices of evaluators [4].

Different methods of sensory evaluation of fresh fish intended for human consumption have been developed in various countries around the world, either generically or for specific species (Cod, Haddock and Sole among others) in order to determine its quality and freshness [29]. One of these methods is the quality index used in Europe based on the significant sensory parameters of raw fish and a scoring system for characteristics in eyes, gills, skin, odor and hardness, among others, classifying the products evaluated into three quality levels [4] [29]. While in countries such as Mexico, generic evaluation methods or standards have been developed for fish and products such as "fillets", also based on a scoring system for characteristics such as odor, color and texture, among others, classifying final products in three levels as are the standards used in this study.

4. Conclusions

Fish is a food of low stability and short shelf life due to intrinsic characteristics, such as its pH close to neutrality, high moisture content and water activity that favors deterioration due to microbial activity, autolysis, and oxidation.

Until the 4th day, the tilapia fillet refrigerated at 4˚C for twelve days reached a first quality classification for its acceptance for consumption. Meanwhile, on the 6th day, it reached the classification of second quality and finally, on the 8th day it acquired an out-of-classification quality level due to negative sensory evaluations and food rejection.

The decrease in temperature to preserve fish and products is widely known and used, having great importance worldwide for the commercialization and availability of fresh and quality food. Refrigeration is a preservation method by reducing temperature. However, it has a short-term conservation effect through

the reduction of temperature that slows down the microbial and enzymatic activity responsible for deterioration. Therefore, to preserve fish for a longer time, the combined use of refrigeration with other methods that exert an inhibitory effect on the main factors associated with deterioration, such as microbial and enzymatic activity and oxidation, is recommended.

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Author's Contribution

All authors contributed equally to the development of the research and manuscript.

Conflicts of Interest

The authors declare no conflict of interest in the development and publication of this manuscript.

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