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Quality Assessment of Aquacultured Freshwater Fish Species during Storage in Ice

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Abstract: ***The following two freshwater fish species {Hybrid Tilapia (Oreochromisniloticus x Oreochromisaureus) and the Common Carp (CyprinusCarpio) were assessed for quality changes during13 days postmortem, stored in ice. Physical, chemical and sensory evaluations were performed at 0, 3, 5, 7, 10 and 13 days postmortem. None of the freshwater fish species had water activity (a_w) below 0.9 throughout the storage period. Torry meter scores of freshwater fish species were (11.33). Among freshwater species common Carp had the highest value compared to Tilapia. However on day 3, Tilapia and Carp had similar L* values, but on day 5 and 7 Tilapia had higher L* values than Carp. For the b* values, Tilapia had slightly higher b* values than Carp (P > .05) through days 3, 5 and 7 of storage and the two species had similar redness values (a*) and carp had a* values higher than Tilapia. Saturation Index and Hue angle can improve our understanding to the changes in the color of the different fish species throughout the storage period. Within freshwater fish species, initially Tilapia and Carp had almost similar SI and Hue angles. On day 3 the two species had similar (P > 0.05) SI and Tilapia had Hue angles higher than Carp (P < 0.05). On the 5th day of storage carp had the highest (P < 0.05) SI. Generally, SI and Hue angle values of freshwater fish species flucuated over the storage periods. TMA values increased with storage period, yet none of the species under investigation reached the rejection (30 mg TMA-N/100g) level. Sensoryly the keeping time of the different fish species were found to be around 9.44and 11.0 days for Carp, and Tilapia, respectively.***

Keywords: Freshwater fish, Tilapia, Carp, Shelf life, postmortem changes, TMA, Sensory evaluation and Hunter color values

1. Introduction

Aquaculture has been practiced early in history and widely spread all over the world . In recent years, aquaculture has developed rapidly and played an important role in the national economy. Tilapia and common Carp are freshwater fish species cultured widely all over the world. Bardach et al., (1972) reported that the Common Carp has the longest history of culture. As early as 475 B.C. Tilapia was already entrenched as one of the world's most important fish by the start of the twentieth century. Fish is a highly perishable food. Therefore, series of changes can be responsible for the fish spoilage after their body defense mechanisms stop. These changes can be caused by many factors (microorganisms, enzymes, physical and chemical activities) which lead to low qualities and deterioration in color, texture, appearance, aroma and flavor. Fish freshness is a property of fish that has a considerable influence on its quality and is the most important single criterion for judging the quality of the majority of fish products. (Howgate1982). Dora and Hiremath (1987) reported that freshness has significant influence on the shelf-life of frozen stored fish. Loss of freshness followed by spoilage is a complex combination of microbiological, chemical, and physical processes (Pedrosa-Menabrito and Regenstnstein, 1988). The consumption of meat and meat products mostly depends on color, appearance, flavor and taste (Risvik, 1994; Van Oeckel et al., 1999; Davoli and Braglia, 2007). However, the storage times in ice are relatively longer, e.g., from 2 to more than 3 weeks. This difference in storage time is due to the nature of the microflora initially present in fish at the moment of capture (El Marrackchi, Bennour, Bouchriti, Hamama, & Tagafait, 1990). Once the fish dies, several postmortem changes take place, which are due to the breakdown of the cellular structure and biochemistry as well as to the growth of microorganisms that are either naturally associated with the fish, or associated to contamination during handling (Ehira & Uchiyama, 1987). Many contaminating bacteria reduce trimethylamine oxide (TMAO) and form TMA, thus the presence of TMA in muscle can give a very good indication of the level of bacterial contamination (Beatty and Gibbons, 1939; Babbitt et al., 1972)., and the amount of TMA produced is an indicator of the activity of spoilage bacteria which is naturally present in the skin and in the guts of many fish species.TMA is associated with the odor of fish spoilage and is clearly a part of the spoilage pattern of many fish species, trimethylamine (TMA) is produced by the reduction of trimethylamine oxide (TMAO). Also, Fat oxidation is an important deteriorative reaction causing flavor, color, and possibly textural changes associated with rancidity (Hobbs 1982). The quality of chilled or iced fish depends, apart from the primary quality of the fresh fish, on the icing or chilling process. Constant storage conditions are important and could influences final quality. The changes in the fish lipids are directly and indirectly responsible for the quality deterioration of fish. The involve lipolysis, lipid oxidation and interaction of the products of these process of the products with non lipid components such as protein (Pachsco-Aguilar et al., 2000). Lipid oxidation is the major limiting factor in cold storage of fat fish (Hultin, 1992). Thus, control of fat oxidation in fish is very important for fresh food that is safe, wholesome and has long shelf life.

2. Materials and Methods

2.1 Materials

Freshwater fish species

1) Hybrid tilapia (Oreochromisniloticus × Oreochromisaureus)
2) Common Carp (Cyprinuscarpio)

Freashwater species (Hybrid Tilapia and Common Carp) with a weight of about (350 – 400 g) were caught early in the morning from a local fish farm. The fish were transported live in oxygenated water in plastic bags. Upon arrival at the laboratory, fishes were divided into five treatment groups and stored in crushed ice in five fish ice boxes (70 × 40 × 35 cm each). Hybrid Tilapia and common Carp were stored in box A, B, C, S, and H respectively. The ratio of fish to crunched ice was 1:1 (w/w) and storage temperature was about (3-4OC) over the storage period. Whenever, necessary boxes were drained of melted ice water and more crushed ice was added to the boxes to maintain the temperature at around 3-4 ^{o}C. The properties of the water used for aquacultured fish species shown on Table 1. The Proximate compositions of fish feed used for the aquacultured fish species shown on Table 2.

Table 1: Properties of the water used for the aquacultured fish species

Composition	Unit	Values
pH		7.22
Total suspended matter	*Mg/L*	5
Total dissolved solid	*Mg/L*	1763
Total alkalinity	*Mg/L*	225
Total hardness	*Mg/L*	725
Nitrate	*Mg/L*	204
Potassium	*Mg/L*	17.5
Magnesium	*Mg/L*	84.0
Iron	*µg/L*	38.0
Copper	*µg/L*	3.5
EC	*ms/cm*	2.65
Salinity	*ppm*	2000

Table 2: Proximate compositions of fish feed used for the aquacultured fish species

Composition	Feed Value
Dry matter	92 %
Organic matter	91 %
Crude protein	36 %
Crude fat	6 %
Crude fibre	3 %
Nitrogen free extractives	46 %
Ash	9 %
Calcium	1.70 %
Phosphorus	0.90 %
Iron	100 ppm
Copper	8 ppm

2.2 Methods of Analysis

Fish meat was assessed initially and after 3, 5, 7, 10 and 13 days of cold storage. Assessments include proximate chemical analysis and trimethylamine (TMA) contents and color evaluation including saturation index and hue angle, pH, water activity and sensory evaluation for freshwater fishes.

Physical assessments

1) Torry meter

The changes in the freshness of fish species with storage times initially and at the end of each storage period were measured by using Distell freshness Meter "Torrymeter" device (Distell Industries LTD, Scotland, UK) .

2) H measurement

The pH was determined by adding 5 gm ground fish meat to 20 ml distill water. The mixture was well homogenized and the pH was measured using a digital pH meter (Cole-Parmer Instrument Co., Vernon Hills, Illinois, USA).

3) Color measurement

Color of fish meat was measured objectively using Hunter lab color measurement device (Hunter color Quest 45/0, Hunter Associates Laboratory, Reston, VA. USA) to measure

Hunter values L*, a* and b*. These values were then used to calculate the saturation index and Hue angle according to Little (1975) as follows:

Saturation index : SI = $(a^{2} + b^{2})^{½}$

Hue angle: H = $\underline{(\tan^{-1} b/a) \times 180}$

Π

a = Hunter a* value

b = Hunter b* value

tan = tangent

4) Water activity measurement

Water activity reflects the active part of the moisture content as opposed to the entire moisture contents of a product. The water activity of fish meat from each storage period was determined with the A2101 water activity meter (Rotronic, USA) which is a combination of a ventilated humidity and temperature probe (AWVC) with a micro processor based indicator (AW Quick).

2.3 Chemical assessments

1) Proximate Analysis

Moisture, protein, fat and ash contents of marine fish meat at 0 and 5 days of storage period were determined according to the AOAC procedures (AOAC, 1995).

2) TMA Determination

The method of Muray and Gibson (1972) used to determine the TMA content of freshwater fish species.

Sensory evaluation

A 10-member sensory panel, consisting of the staff members and students of Food Science and Technology Department, College of Agricultural and Food Sciences, king Faisal University, semitrained according to the procedure of Cross *et al.*, (1978), evaluated the fresh fish meat odor intensity by means of 9-point hedonic scale (9 = intense fresh fish odor, 1 = devoid of fresh fish odor).

Statistical Analysis

The data collected were subjected to analysis of variance and whenever appropriate the mean separation procedure of Duncan was employed (Steel and Torrie, 1980). The SAS program (SAS, 1988) was used to perform the GLM analysis.

3. Results and Discussion

3.1 Physical analysis

1) Torry meter scores

On the average freshwater fish species had torry meter score (11.33). Among freshwater species common Carp had the highest value compared to Tilapia and. In the first three days of storage changes in torry meter values Tilapia showed substantial increase from 10.8 to 11.8 during this period. On the 3rd day of storage Tilapia and Carp had similar ($p > .05$) torry meter values. However, torry meter values of these species started to decrease till the 7th day of storage while that of Tilapia showed slight increase. The gradual changes (decrease) in torry meter readings in the first few days of storage agree with the observation of Aldakheel (1984) but contradict with that of Lees and Smith (1980). (Fig. 1) .

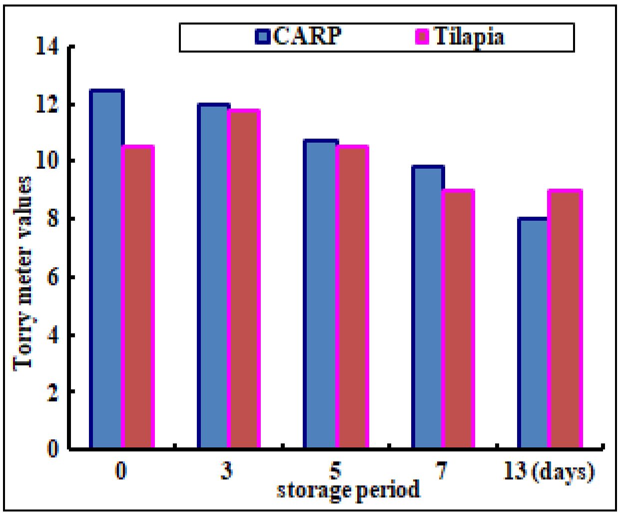

Figure 1: Changes in the torry meter values of freshwater species with storage period

2) pH values

Fsh species under investigation had pH value higher than 6.8. The pH of freshwater species decreased steadily with postmortem time. Initially and throughout the storage period studied the Carp had lower pH value (Fig. 2).

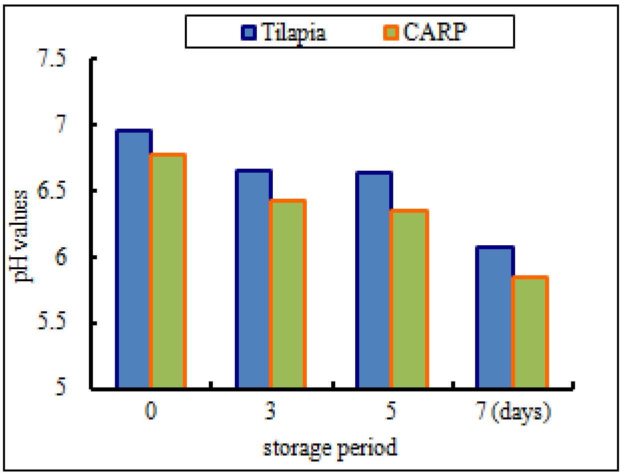

Figure 2: Changes in the pH values of freshwater species with storage period

3) Color measurement

Fish meat pigment; usually deteriorate with postmortem time leading to visual changes in the color appearance. Changes in the Hunter color values L*, a* and b* and changes in the Saturation Index (SI) and Huangles (Hue) stored in ice were followed for up to 7 days of storage. Generally, throughout the storage period tested freshwater fish species had initially a* values ($P < .05$). However on day 3, Tilapia and Carp had similar L* values, but on day 5 and 7 Tilapia had higher L* values than Carp. For the b* values, Tilapia had slightly higher b* values than Carp ($P > .05$) through days 3, 5 and 7 of storage. However, the two species had similar redness values (a*) and carp had a* values higher than Tilapia. The differences in the b* (yellowness) between the two species are very minimal throughout the storage period tested. The lightness values (L*) of the two species were similar in the first 3 days of the storage, thereafter (day 5 and 7) Tilapia had L* values that were significantly ($P < .05$) higher than that of carp. Initially, the two species had similar redness values (a*). In conjunction with Hunter color L*, a* and b* values, Saturation Index and Hue angle can improve our understanding to the changes in the color of the different fish species through out the storage period. The saturation index is the attribute of color perception that expresses the degree of departure from the grey of the same lightness. While Hue angle is the attribute of color perception by means of which an object is judged to red, yellow, green, blue or purple. Within freshwater fish species, initially Tilapia and Carp had almost similar SI and Hue angles. On day 3 the two species had similar ($P > 0.05$) SI and Tilapia had Hue angles higher than Carp ($P < 0.05$). On the 5th day of storage carp had the highest ($P < 0.05$) SI while a wide variation was observed in the Hue angles of the two species. Tilapia reached its maximum SI value on the 7th day of storage while Carp reached that value on the 5th day of storage. Tilapia reached its maximum Hue angle on the 5th day of storage and the Carp on the 3rd day of storage. Generally, SI and Hue angle values of freshwater fish species fluctuated over the storage periods (Table 3) and (Table 4).

4) Water activity (a_w)

It is well known that moisture content of fish meat can include both an immobilized part e.g. water of hydration and an active part which, under normal circumstances, can be exchanged between fish meat and its environment. Water activity (a_w) of fish meat product reflects the active part of its moisture content as opposed to its entire moisture content. Initially, and throughout day 3 carp had higher water activity than Tilapia. However, through day 5 and 7 Carp had lower water activity than Tilapia. In general, water activity (a_w) of the two species decreased with storage period. Obviously the water activity (a_w) of the Carp at day 0 of display was significantly higher ($p < 0.05$) than the Tilapia species. This may indicate that Tilapia meat bound water to its tissue stronger than the Carp. Also it is to be noted that the water activity of two species decreased with storage period till day 5 of storage where it starts to increase with storage time. At day 7 the water activity (a_w) in Carp was the lowest among the fish species investigated. Leistner and Rodel (1975) concluded that for a product to be shelf stable, its water activity (a_w) must be (< 0.95) in combination with other parameters. Lowering the water

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activity to (< 0.90) reduces risk of microbial spoilage and none of freshwater fish species under investigation achieved that level (Fig. 3)

Table 3: Changes in hunter values of freshwater fish species with storage period

St. days	Hunter values	Tilapia	Carp
0	L*	39.65^{a}_{1}	39.50^{a}_{1}
	a*	9.36^{a}_{1}	10.0^{a}_{1}
	b*	12.52^{a}_{1}	12.60^{a}_{1}
3	L*	42.98^{a}_{2}	42.39^{a}_{2}
	a*	8.50^{a}_{12}	10.10^{b}_{1}
	b*	13.55^{a}_{1}	12.85^{a}_{1}
5	L*	45.95^{a}_{3}	36.13^{c}_{3}
	a*	7.63^{a}_{2}	14.93^{b}_{2}
	b*	14.90^{a}_{2}	13.69^{a}_{2}
7	L*	43.84^{a}_{2}	38.47^{c}_{4}
	a*	8.89^{a}_{13}	11.54^{b}_{3}
	b*	14.46^{a}_{2}	13.52^{a}_{2}

-Means in the same row bearing different superscripts letters differ significantly ($p < .05$).
-Means in the same column bearing different numericals for the same parameter are significantly different ($p < .05$).

Table 4: Changes in saturation index (SI) and Hue angles (Hue) of freshwater fish species stored in ice for up to 7 days

Fish species	SI and Hue values	Storage period (days)			
		0	3	5	7
Tilapia	SI	15.63^{a}_{1}	16.00^{a}_{1}	16.74^{b}_{1}	16.97^{b}_{1}
	Hue	53.25^{a}_{1}	57.92^{b}_{1}	62.91^{c}_{1}	58.42^{b}_{1}
Carp	SI	16.09^{a}_{2}	16.35^{a}_{1}	20.26^{b}_{2}	17.78^{c}_{2}
	Hue	51.56^{a}_{2}	51.83^{a}_{2}	42.52^{b}_{3}	49.52^{c}_{2}

-Means in the same row bearing different superscripts letters differ significantly ($p <.05$).
-Means in the same column bearing different numericals for the same parameter are significantly different ($p < .05$).

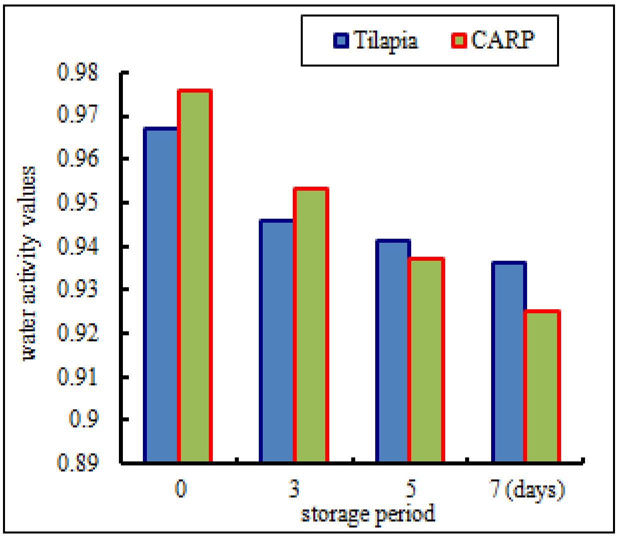

Figure 3: Changes in the water activity (a_w) values of freshwater fish species with storage period

5) Chemical analysis

1- Proximate analysis

The moisture content of Tilapia reported in this study agree very well with that reported by Erickson (1992). Within freshwater fish species no differences in moisture content were observed. However, throughout the storage period studied, no significant differences ($P > .05$) in moisture content were noticed in freshwater fish species. Storage period had no effect on the protein content of freshwater fish species. The initial fat content of Tilapia in the current study matched closely the fat content found previously for Tilapia by Erickson (1992).Within freshwater fish species, Tilapia had a fat content that was significantly ($P < .05$) lower than the carp. Generally, storage time had no effect on the fat and ash contents. within freshwater fish species no major differences in M/P was found either initially or after 5 days of storage. Transition metal ions, particularly iron and copper are considered to be major catalysts for oxidation. At very low concentrations < 0.1 ppm, they can decrease the induction period and increase the rate of oxidation. Within freshwater fish species Carp had the highest ($P < .05$) iron content. Upon storage (day 5) the iron content of all freshwater fish species decreased ($P < .05$), With regard to copper content, on the average aquacultured fish species had higher content than marine species. However, the effect of storage on the copper content was similar to that of iron i.e. a decrease in content with storage (Table 5) and (Table 6) .

2- Trimethylamine (TMA)

Trimethylamine (TMA) is produced in fish meat by the reduction of trimethylamine oxide (TMAO). Thus, the measurement of TMA can be used as an indicator of the degree of spoilage and protein putrefaction (Dyer and Mownsey, 1945). The results of TMA of different freshwater fish species stored in ice for up to 13 days showed that most freshwater fish species do not have the precursor trimethylamine oxide (TMAO)in sufficient amounts and this matched closelywith (Hebard *et el.*, 1982). Also, low levels of TMA were observed in European catfish (*silurusglanis*), which was stored in ice for 30 days. Manthey *et al.*, *(*1988). Very low amounts (0.05 – 0.07mg/100g) of TMA were found in fresh Tilapia fillets (Reddy *et al.*, 1995, 1994). Cann*et al (*1983) observed lower amounts of TMA on the last day of storage in cod and herring fillets stored at 0°C than in those stored at 5 and 10°C. However m, Trimethylamine (TMA) of freshwater fish species had increased with the time of storage. throughout the storage period. TMA had gradually increased in Carp and Tlapia, afterward the degree of changes increased to reach high of 0.25 mg TMA/100g in Carp and 0.21 mg TMA/100g in Tilapia on day 13. The level of changes reached a low of 0.15 mg TMA/100g on day 13. Low temperature storage might have slowed down TMA production (Ishida *et al.*, 1976), TMA levels vary with fish species, season and type of storage (Herbard, *et el.*, 1982). (Table 7) .

Table 5: Proximate chemical analysis of freshwater fish species fish with storage period

Fish species	St. (days)	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	M/P
Carp	0	78.68^{a}_{1}	17.26^{a}_{1}	3.38^{a}_{1}	1.02^{a}_{1}	4.56^{a}_{1}
	5	77.76^{c}_{1}	17.27^{c}_{1}	3.23^{c}_{1}	1.08^{b}_{1}	4.50^{c}_{1}
Tilapia	0	79.94^{a}_{1}	17.24^{a}_{1}	1.94^{b}_{1}	1.08^{a}_{1}	4.64^{a}_{1}
	5	79.27^{c}_{1}	17.49^{c}_{1}	1.88^{d}_{1}	0.93^{c}_{1}	4.53^{c}_{1}

-Means in the same column for the same storage period bearing similar superscripts letters are not significantly different ($p>.05$).

-Means in the same column for the same fish species bearing different subscripts numericals are significantly different (p <.05).
(n = 5)

Table 6: Changes in iron and copper contents of freshwater fish species with storage period. (mg/100g)

Fish species	Iron		Copper	
	Storage period (days)			
	0	5	0	5
Tilapia	0.442^{a}_{1}	0.324^{a}_{2}	0.108^{a}_{1}	0.044^{a}_{2}
Carp	0.859^{b}_{1}	0.560^{c}_{2}	0.078^{c}_{1}	0.064^{c}_{1}

-Means in the same row for iron or copper bearing different superscripts numericals differ significantly (p < .05).
-Means in the same column bearing different letters are significantly different (p < .05).

Table 7: Changes in trimethylamine (TMA) values of freshwater fish species with storage period. (mg /100g) .

St. (days)	Carp	Tilapia
0	0.06^{a}_{1}	0.07^{a}_{1}
3	0.10^{a}_{2}	0.11^{a}_{2}
5	0.12^{a}_{2}	0.10^{a}_{2}
7	0.16^{a}_{3}	0.15^{a}_{3}
10	0.20^{a}_{4}	0.17^{a}_{3}
13	0.25^{a}_{5}	0.21^{a}_{4}

-Means in the same row bearing different superscripts letters differ significantly (p < .o5)
-means in the same column bearing different numericals are significantly (p < .05) different. n = 5

Sensory scores

The major cause of deterioration in the fish muscle is lipid oxidation and this deterioration causes the development off flavors and off-aroma from the formation of volatile odor compounds. Generally, sensory scores of freshwater fish species under investigation tended to decrease (P < .05) with storage period. In case of Liston *et al.*, (1961), the panel member agreed beforehand that a score of 2 on a 5-point scale corresponded to the lower limit of edibility. In the current study we decided beforehand that a score of 4.5 on a 9-point scale correspond to the lower limit of acceptability. Applying this criterion i.e. 50% reduction of the maximum sensory score, the (Fig. 4).

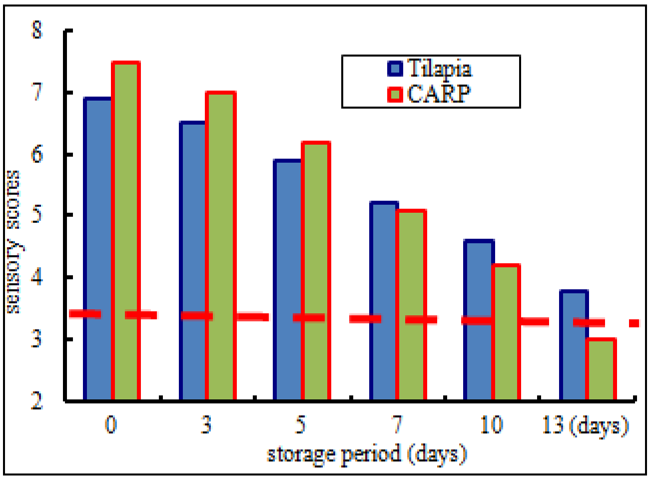

Figure 4: Changes in the sensory evaluation values of freshwater fish species with storage period

4. Conclusions

A number of shelf life indices namely (TMA, Torrymeter, aw, pH, color and sensory) could be used to monitor changes in the quality freshwater fish species with postmortem time. However, none of the freshwater fish species under investigation had a TMA greater than 30 mg TMA-N/100g fish, which is the rejection limit, at any one of the storage period tested. Sensory evaluation indicated that marine fish species had approximately, shelf life of (9 – 10). Additional studies are needed to fully assess the applicability of the changes in some of the chemical as well as physical shelf life indices that could supplement sensory evaluation tests in predicting quality deterioration of fresh fish. Fish should be stored at temperatures near the freezing point of water (0 ºC) for maximum shelf life and at this point microorganisms, enzymes, and chemical activities will be minimized.

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