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Cumin (*Cuminum cyminum* L.) effects on lipid quality deteriorations of ice-stored red tilapia (*Oreochromus niloticus*) fillets and their correlation with sensory attributes

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Abstract: This study evaluated the effects of powdered cumin sprinkling on the lipid quality deterioration of fresh and ice-stored tilapia fillets and was correlated with sensory attributes during ice storage. Initially, Adding cumin powder (2% w/w) exhibited a preservative effect, with cumin-treated fillets during storage in ice showing significantly lower levels of thiobarbituric acid (TBA), and free fatty acid (FFA). There were significant differences ($p<0.05$) in the TBA, FFA, and peroxide value (PV)of tilapia fillets during ice storage. Generally, obtained TBA values of tilapia fillets during ice-storage were low and within high-quality limits. Lipid oxidation parameter values were significantly increased ($p<0.05$) by the end of storage. Significant differences between treated and untreated fillets in odour, flavour, appearance, and overall acceptability were found. No significant difference ($p<0.05$) in textural attributes was detected. There was a strongly inverse correlation at ($p<0.05$) of FFA and TBA valuesversus off-odour and off-flavour scores ($r = -0.98$, p-value = 0.02), ($r = -0.90$, p-value = 0.10) and ($r = -0.81$, p-value = 0.19) ($r = -0.83$, p-value = 0.17) respectively, in untreated fillets .These findings suggest that TBA and FFA are more suitable indices for spoilage of tilapia fillets. Cumin-treated tilapia fillets maintained their quality better than untreated fillets during storage, as the former achieved higher scores than the latter.
Key words: Cumin· Sensoryattributes· Lipid oxidation· correlation. Ice storage·Tilapia, TBA, PV, FFA.

Introduction

Lipid oxidation is a major of food quality deterioration and has been a challenge for manufactures and food scientists alike. Concerns about lipid oxidation have also been addressed in the aquaculture industry due to the large requirement of long-chain n-3 PUFA in fish diet and the high susceptibility of these PUFA to oxidation[1].

In recent years spices have gained importance as bionutrients, both as functional food ingredients and nutritional supplements. The use of spices as food additives has been widely practised since ancient times. Spices have a definite role to play in enhancing the taste and flavour of any food. Apart from this, spices are believed to have medicinal value. They have been used in a large number of medicinal preparations for the treatment of several disorders, particularly of the digestive system[2].Additionally, and because of its greater

awareness and safety concern regarding synthetic chemical additives, food preserved with natural additives has become more popular. For instance, the antimicrobial and antioxidant properties of essential oils, and their active constituents derived from various plant organs have been empirically recognized[3,4]. However; any processing technologies used in the production of such compounds have to prove their technical/scientific efficiency and product quality to meet the basic requirement of hygiene and safety standards. Therefore, it would be economically more suitable to use powdered spices or herbs as ingredients rather than their extracts to preserve food including fish fillets [5].

Cumin (*Cuminum cyminum* L.) is a small annual plant belonging to the *Apiaceae* family, and is native to the Mediterranean region, where it is cultivated extensively. It is one of the popular spices regularly used as a flavouring agent[6]. Cumin's distinctive flavour and strong, warm aroma is due to its essential oil content that may be considered as an interesting source of antibacterial, antifungal and antioxidant components, which are used as potent agents in food preservation and for therapeutic or nutraceutical industries. Its main constituent and important aroma compound is cuminaldehyde (4-isopropylbenzaldehyde)[7].Freshwater tilapia (*Oreochromis niloticus*) was chosen for this study for its good market acceptance and rusticity for handling. Tilapia is considered promising for aquaculture because of its rapid growth, late reproduction and high multiplication rate. It has a firm, consistent and tasty meat of great market acceptance[8]. The main objective of this study was therefore, to produce ice stored spiced tilapia fillet with a new flavour (cumin) and to demonstrate the effect of powdered-dried cumin (2% w/w)as a natural and low-cost preservative onlipid quality indexes,sensory properties and their correlation with sensory quality when stored in ice.

Material and Methods

Preparation and treatment of fish samples

Live red tilapia (*O. niloticus*) was purchased from a local seafood market in Puchung, Selangor, Malaysia. The average weight of the whole fish was 600 (490 – 750) g, and average length was approximately 28.21 (26 – 30) cm. The tilapia samples were killed, scaled, headed, gutted, washed and filleted (109 g average weight/fillet), using the market facilities. The tilapia fillets were then transported to the laboratory in sealed polystyrene boxes with an appropriate quantity of flaked ice. The fish fillets were divided into two batches. Each batch contained 6 kg. Within 30 min of arrival, the fish fillets were sprinkled with fine cumin at concentration (2% w/w). The second batch was left without treatment as a control. Fillets were packed in polyethylene bags individually and stored in sealed polystyrene boxes with flaked ice (2:1w/w) in a cold room at 4°C. The filleted tilapia was sampled and subjected to chemical and sensory analyses after 0, 3, 6, 9, 12, 15, 18, and 21 days of storage.

Proximate analysis

The fish samples were analysed for proximate composition: moisture content was determined by air-drying of a portion of minced fish fillet at 103 ± 2˚C for 24 h; crude fat, by petroleum ether extraction using the Soxhlet method; crude protein by the Kjeldahl method using potassium sulphate and copper (II) sulphate as the catalysts and 6.25 nitrogen-to-protein conversion factor; and ash by incineration in a muffle furnace at 550 ± °C for 24 h according to the method of by AOAC methods[9].

Extraction of total lipids

Total lipids were extracted from the ground fillet by using chloroform: methanol (2:1 v/v) extraction solution with slight modifications according to the method of Bligh and Dyer[10]. The lipid content was determined gravimetrically and was used to quantify both, total fat, assessment of lipid Oxidation and lipid hydrolysis.

Assessment of lipid oxidation

The amount of TBA was estimated by the direct method (without distillation) of finding the 2-thiobarbituric acid value in oils and fats as was described by Kirk and Sawyer[11].TBA values were measured by reference to an external standard. The standard was prepared from 50 µl of 1,1- to 3,3-tetraethoxypropan diluted to 50 ml with 0.1N HCl and heated at 100 °C for 10 min. A volume of 2.4 ml of the hydrolysedacetal was then diluted to 100 ml with distilled water, giving a stock-solution equivalent to 0.1 mM malondialdehyde. TBA values were expressed in units of mg malonaldehyde kg^{-1} lipid. PV value was determined in the lipid extract of the fish

muscles according to AOCS (1998) official method (Cd-8b-90)[12].The PV values were expressed as meq peroxide kg^{-1} lipid.

Assessment of lipid hydrolysis

Estimation of lipid hydrolysis was conducted, by measurement free fatty acid content in the lipid extract of the fish muscles according to AOCS (1998) official method (Ca 5a-40.)[12]. The content of FFA was expressed as the oleic acid equivalent.

Sensory evaluation

The sensory quality of cooked untreated and cumin-treated tilapia fillets was assessed by ten semi-trained panels at zero time and after three, six, and nine days of ice storing according to Sallam[13]. Panellists were asked to assess the odour and flavour intensity, juiciness, hardness and tenderness, by using an eight-point hedonic scoring scale from 8 = extremely intense/juicy/tender to 1 = extremely bland/dry/tough, respectively. While a nine-point hedonic scale from extremely acceptable (9) to extremely unacceptable (1) was used for evaluation of the appearance. Moreover, a six-point scoring scale, from 6 = no-detected off-odour/off-flavour to 1= extreme detected was utilized for the assessment of the off-odour and off-flavour. Tilapia samples receiving overall scores of more than 4 were considered acceptable, while a score of between 3 and 4 was considered as borderline acceptability. Additionally, a space was provided for further flavour description and additional comments. These attributes were selected to reflect possible sensorial changes in the tilapia fillets, which could be easily detected by the panellists.

Statistical analysis

All experiments were carried out in triplicate. Data were subjected to analysis of variance (ANOVA) by using Minitab version 16. The difference among the mean values of the various treatments and storage period were determined by the least significant difference (LSD) test, and the significance was defined at ($p<0.05$). The results of chemical and sensory analyses were reported as mean values ± standard error.

Results and Discussion

Proximate analysis

For cumin-treated and untreated tilapia fillets, the average protein, ash, lipid (g $100g^{-1}$ based on dry weight), and moisture g $100g^{-1}$ based on wet weight) contents were (18.74±0.32, 16.8±0.86), (1.60±0.03, 1.27±0.03), (17.96±0.14, 17.71±0.09), and (74.35±0.17, 73.45±0.23), respectively. Generally, moisture content and ash had a significant difference, whereas protein and total lipid contents did not differ significantly ($p<0.05$) between the treated and untreated tilapia fillets. Attouchi andSadok[14]conducted a similar study on the effect of thyme on wild and farmed gilthead sea bream fillets stored in ice. They reported that thyme treatment does not affect on the total lipid content of sea bream fillets. The proximate composition data for untreated fish in the current study coincided with the data presented by Hernández et al[15], Yanaret al[16].

Total lipids

Fish lipid content changes according to species, diet, geographical origin, and season. Changes in total lipids (TL) for treated and untreated tilapia fillets during the 21 day storage period in ice are shown in Table 1. Lipid content ranged from (2.50±0.33%) to (4.84±0.08%) and from (2.15±0.17%) to (3.40±0.07%) in cumin-treated and untreated tilapia fillets, respectively. The mean TL of untreated tilapia fillets (2.66±0.08) was in agreement with previously given content by Al-Shagrawiet al [17] who found the TL value of (2.62±0.20) in cultured tilapia. However, the current results on TL content are higher compared with that found in other studies[18]. A significant difference ($p<0.05$) was observed in TL contents between treated and untreated tilapia fillets during ice storage. Lipid content in fish fillets is affected by storage in ice as well as interaction between treatment and storage time. Overall, cumin-treated fillets had a significantly higher TL content compared with the untreated samples, which may be caused by the amount of fat originally present in the cumin powder.

Table 1: Changes in total lipid content of cumin-treated and untreated tilapia fillets stored in ice

Days in ice	Cumin-treated fillets	Untreated fillets	
0	3.12 ± 0.25 $^{a\ BCD}$	2.77 ± 0.07 $^{a\ BCD}$	
3	3.83 ± 0.06$^{a\ B}$	2.18 ± 0.09 $^{b\ E}$	
6	2.50 ± 0.33$^{a\ D}$	2.36 ± 0.11 $^{a\ DE}$	
9	3.31 ± 0.08 $^{a\ BCD}$	2.15 ± 0.17 $^{b\ E}$	
12	4.84 ± 0.08 $^{a\ A}$	2.49 ± 0.02 $^{b\ CDE}$	
15	3.72 ± 0.04 $^{a\ BC}$	2.89 ± 0.06 $^{b\ BC}$	
18	3.68 ± 0.08 $^{a\ BC}$	3.04 ± 0.03 $^{b\ AB}$	
21	2.89 ± 0.24 $^{a\ CD}$	3.40 ± 0.07 ^{aA}	
Tow way ANOVA	**F-value**	**P-value**	**R-sq**
Days in ice	139.78	<0.05	89.08 %
treatment	15.34	<0.05	
Days × treatment	20.64	<0.05	

Values represent means ± SE of three replicates • (g/100g flesh fish) on base wet weight
$^{a-b}$ Mean values within the same row with the same letter are not significantly different (p < 0:05)
$^{A-D}$ Mean values within the same column with the same letter are not significantly different (p < 0:05).

Lipid oxidation parameters

Lipid oxidation in fish depends on numerous factors (the species, storage temperature, fat composition, etc.) [15]. Secondary oxidation was determined by measuring TBA, as shown in (Figure 1). Generally, the TBA values of cumin-treated and untreated tilapia fillets were low during ice storage and did not exceed 0.28 and 0.37 mg MDA kg^{-1} lipid, respectively. A statistically significant difference ($p<0.05$) was observed in TBA values of both cumin-treated and untreated tilapia fillets, indicating the strong antioxidant effect of cumin, which acts as a radical scavenger. At the end of the present study, although increases were observed in TBA values during the time of storage, these values were within the high-quality limits based on the classification reported by Poliet al.[19] that lipid oxidation products, particularly malonaldehyde, accumulate in very small amounts during shelf life determination of sea bass stored in ice. Nunes et. al.[20] observed that TBA concentration in freshly caught fish is typically between 3 and 5 mg MA kg^{-1}, whereas levels of 5 mg MA kg^{-1} to 8 mg MA kg-^{1} are generally regarded as the limit of acceptability for fish stored in ice. At the end of the present study, although increases were observed in TBA values during the time of storage, these values were within the high-quality limits based on the classification reported by both researchers. Hajlaoui, et al.[7] suggested that *C. cyminum* essential oil may be considered as an interesting source of antibacterial, antifungal, and antioxidant components that can be used as potent agents in food preservation and in the therapeutic or nutraceutical industries. The inhibitory effect of cumin was higher in treated fillets than in untreated ones, as evidenced by TBA results at 9, 12, 15, 18, and 21 days. This finding is in agreement with that in a previous study, which reported thyme powder inhibitory activity as showing a significant difference ($p<0.05$) in TBA values of both wild and farmed sea bream fillets treated with thyme powder in comparison with untreated counterparts [14]. Decrease in the TBA of untreated fillets at 6 and 18 days may be caused by a loss of low molecular weight decomposition products during the advancement of oxidation[21]. Or can be explained as a result of the different phases of peroxides decomposition, the formation of carbonyls, and the interaction compounds with nucleophilic molecules present in the muscle (free amino acids, peptides, proteins, aminated phospholipids)[22, 23.]This can be attributed either to the interaction of TBA-reactive products with other tissue constituents, or to malonaldehyde utilization by surviving microflora[24]. TBA values might not give actual rates of lipid oxidation. However, the TBA content in current study was lower than the refrigerated hot-smoked tilapia at 4°C [16], but similar to those in tray-packed tilapia fillets stored at 0°C [25] and ice stored untreated wild and farmed sea bream fillets and treated with thyme powder[14]. The difference might be affected by different storage temperature and processing methods.

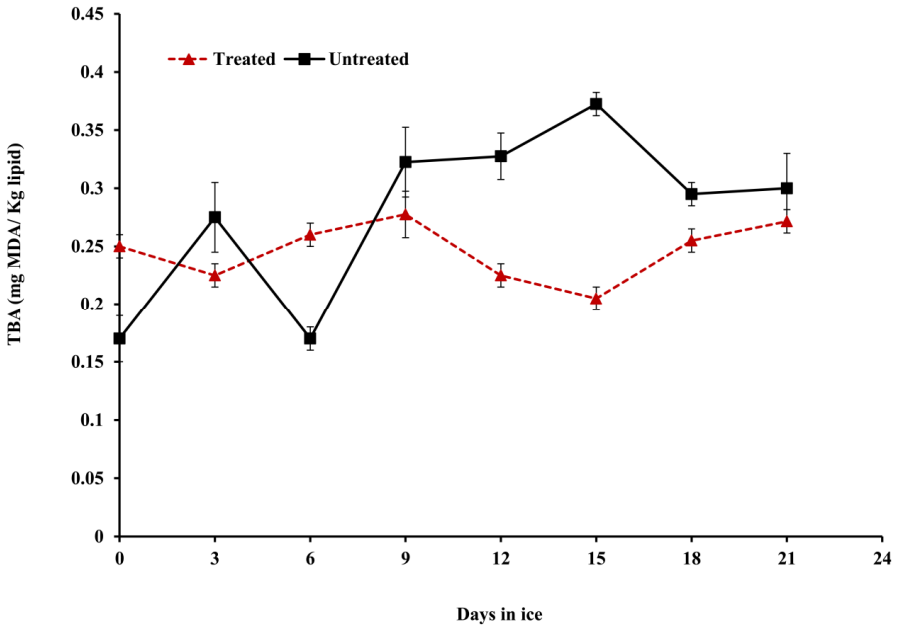

Figure 1.: Changes in thiobarbituric acid value (TBA) of cumin-treated and untreated tilapia fillets stored in ice. Vertical bars = S.E.

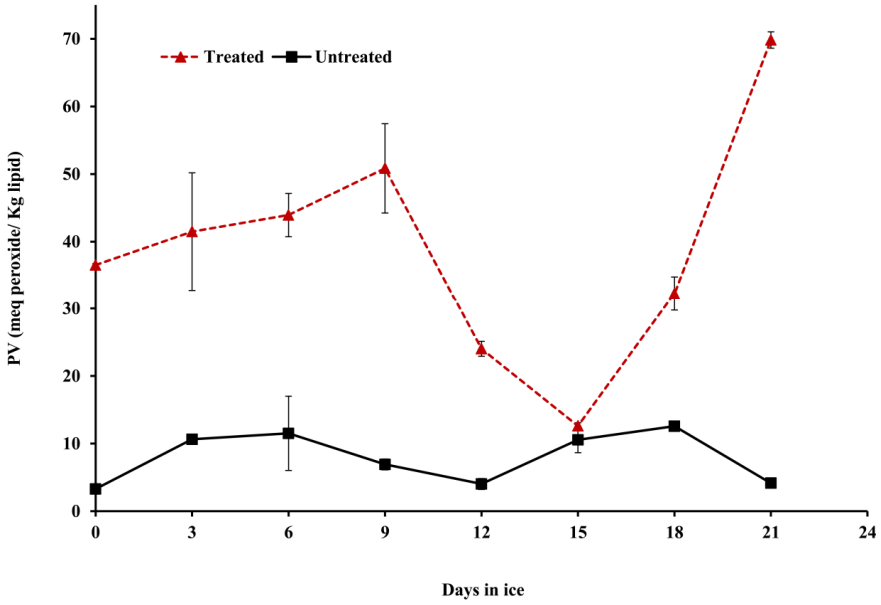

Figure 2.: Changes in peroxide value (PV) of cumin-treated and untreated tilapia fillets stored in ice. Vertical bars = S.E.

Primary oxidation of treated and untreated red tilapia fillets during storage in ice was monitored by measuring the PV, as shown in (Figure 2). Increase in PV was noticeable in both groups of fish fillets within the first three days of storage in ice ($p<0.05$). After 9 days of storage, a dramatic decrease in PV was found in treated tilapia fillets, followed by increases until the end of storage. During ice- storage of untreated tilapia fillets, PV values showed fluctuations reaching a maximum level of 12.58±0.06 meq peroxide kg^{-1} lipid before sharply decreasing to 4.16±0.44 at the end of storage. PVs of untreated fillets did not exceed the 20 meq peroxide kg^{-1} lipid maximum recommended lipid value for human consumption. A statistically significant difference ($p<0.05$) was observed in the PVs of both cumin-treated and untreated tilapia fillets. The high PVs of cumin-treated fillets at zero time compared with the control sample were not reflected in the actual rate of lipid oxidation. This

phenomenon indicated a high rate of lipid oxidation in all fillets, which could be attributed to interaction with natural coloured pigments and compounds from the essential oil content in cumin. Such essential oils are responsible for cumin's distinctive flavour and strong, warm aroma. For untreated fillets, PV increased up until 6 days of storage, followed by a decrease then an increase up to the end of storage. Slight decreases in PVs for untreated fillets during storage and at the end of storage suggested that the hydroperoxide formed might be decomposed into other compounds. Lipid hydroperoxides are formed by various pathways, including the reaction of singlet oxygen with unsaturated lipids or the lipoxygenase-catalyzed oxidation of polyunsaturated fatty acids [21].

Lipid hydrolysis parameter

Examining the extent of lipid hydrolysis was deemed important to the study because FFA formation has previously proved a great incidence on lipid oxidation[26, 27].The presence of FFA is due to enzymatic hydrolysis of esterified lipids. Hydrolytic changes of muscle lipids in untreated and treated tilapia fillets during storage in ice are shown in (Figure 3). The FFA content of untreated and treated tilapia fillets increased as the storage time increased ($p<0.05$). The increase was observed in FFA from 2.24 to 19.19 and 2.27 to 10.45 (oleic acid equivalent) in untreated and treated tilapia fillets respectively, during storage in ice. No difference in FFA content was observed within the first 9 days in both groups of fillets ($p<0.05$). However, the inhibitory effect of cumin was markedly higher at 15, 18, and 21 days of storage in ice. At the end of the 21 day storage period, lipid hydrolysis occurred to a great extent, as evidenced by the highest FFA content in the untreated fillets. FFA can undergo further oxidation to produce compounds with low molecular weight, which are responsible for the rancidity of fish and fish products [21]. Moreover, as per quality specifications for crude fish oil, maximum acceptable values of FFA 1-7% or 2-5% are proposed[28]. Although, this study showed that the free fatty acid level of untreated and cumin treated lipid reached 7% limit during 15th day of ice-storage, but no unpleasant or rancid odour was detected.

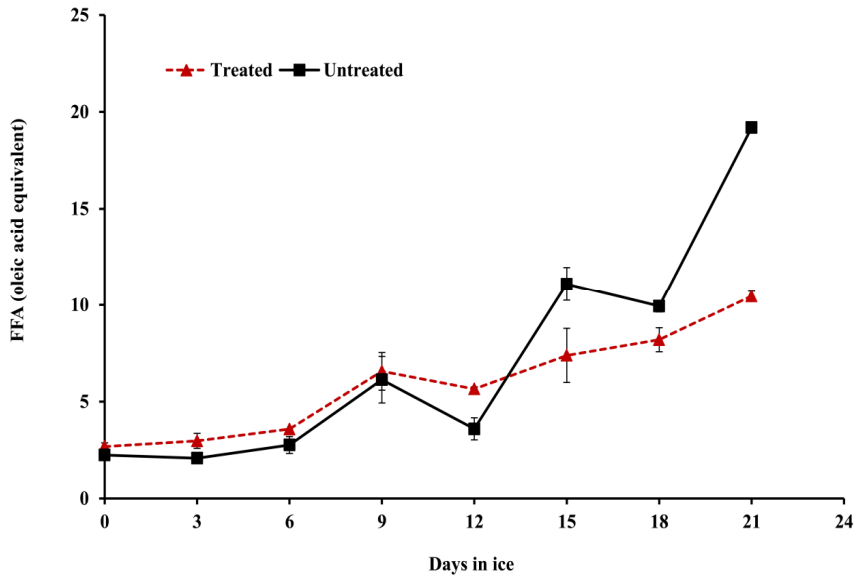

Figure 3.: Changes in free fatty acid (FFA) content of cumin-treated and untreated tilapia fillets stored in ice. Vertical bars = S.E.

Sensory Evaluation

Changes in sensory attributes of cooked cumin-treated and untreated tilapia fillets through 9 days of storage are shown in (Figure 4). The characteristic odour and flavour of cumin-treated and untreated tilapia fillets slightly decreased in intensity during storage in ice. Despite the long storage time (9 days), the sensory attributes of cooked untreated and cumin-treated fillets remained similar to those of the counterpart samples at zero time. Storage duration had no effect ($p<0.05$) on the sensory attributes of all cooked tilapia fillets. No significant difference ($p<0.05$) was detected for the juiciness, tenderness, chewiness, and hardness between the control and

cumin-treated samples. However, significant differences were found in the odour, flavour, appearance, and overall acceptability between untreated and cumin-treated fillets as shown in (Table 2) and (Figure 4).

Table 2: Show two-way ANOVA of sensory attributes scores of cooked cumin-treated and untreated tilapia fillets stored in ice

Two-Way ANOVA	Odour		Flavour		Appearance		Chewiness		Hardness	
	F-value	P-value	F-value	P-value	F-value	P-value	F-value	P-value	F-value	P-value
Days in ice	1.27	>0.05	1.03	>0.05	0.95	>0.05	1.67	>0.05	1.61	>0.05
Treatment	5.75	<0.05	4.56	<0.05	5.28	<0.05	0.58	>0.05	0.44	>0.05
Days × treatment	0.30	>0.05	0.18	>0.05	0.40	>0.05	0.28	>0.05	0.25	>0.05
Two-Way ANOVA	**Tenderness**		**Juiciness**		**Overall acceptability**		**Off-odour**		**Off-flavour**	
	F-value	P-value	F-value	P-value	F-value	P-value	F-value	P-value	F-value	P-value
Days in ice	0.59	>0.05	1.02	>0.05	0.08	>0.05	1.00	>0.05	0.71	>0.05
Treatment	0.39	>0.05	1.69	>0.05	9.78	<0.05	1.20	>0.05	1.41	>0.05
Days × treatment	0.76	>0.05	0.38	>0.05	0.16	>0.05	0.61	>0.05	0.59	>0.05

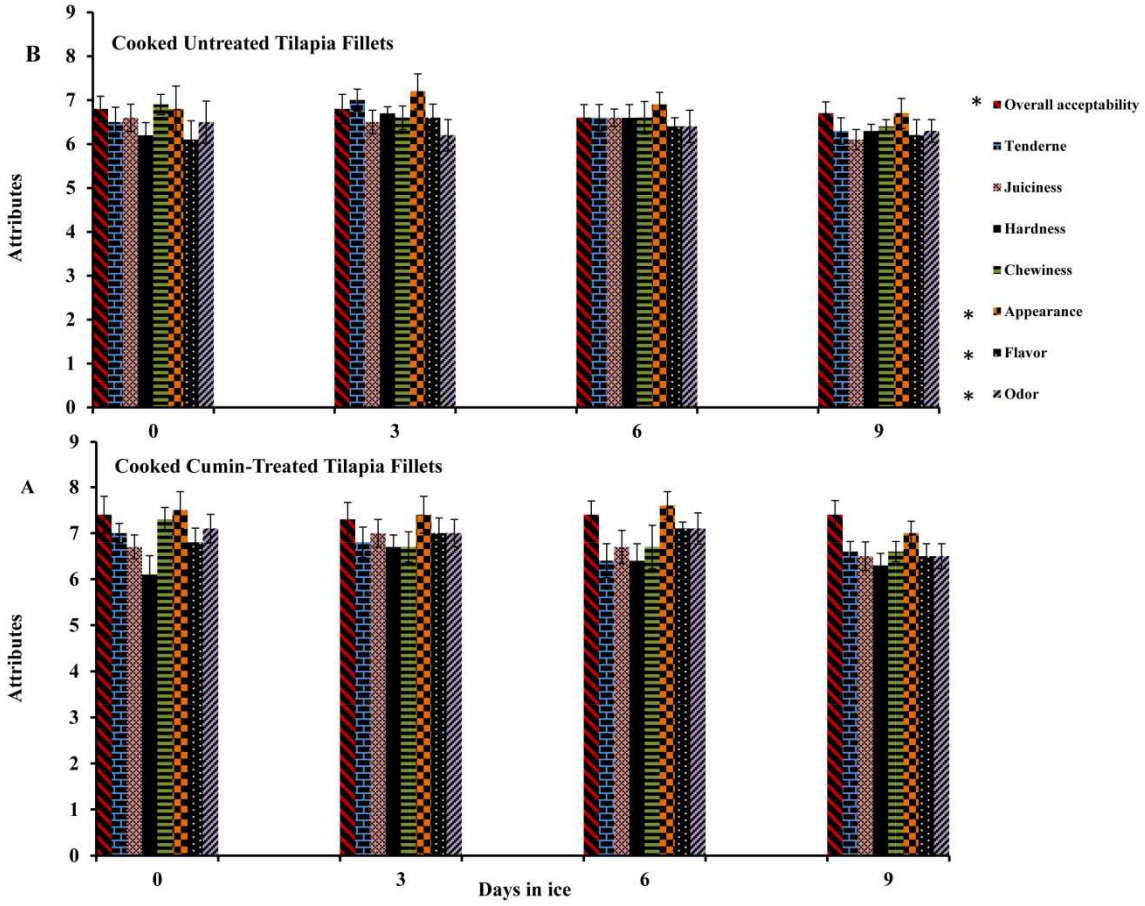

Figure 4.: Changes in sensory attributes scores of cooked cumin-treated fillets (A) and untreated (B) during iced storage. * Front of series name indicates significant difference (P<0.05). Vertical bars = S.E.

Formation of secondary lipid oxidation products is one of the main causes of the development of undesirable odours in fish muscle, especially the so-called fishy odour[29]. The compounds associated with off-odour or off-flavour is generated by enzymatic reactions, lipid auto-oxidation, microbial action, and environmentally or thermally derived reactions[30]. As shown in Table 2 that, the intensity of the off-odour and off-flavour scores between the control and cumin-treated fillets were not difference significantly at ($p<0.05$). No significant differences ($P<0.05$) were identified for the intensity of the off-odour and off-flavour scores with increasing storage time. Additionally, no strong and extreme off-odour or off-flavour could be detected, by any of the 10 panelists. In this study, cumin-treated fillets had the highest PV but this finding was unlikely to affect sensory responses. In the odour and taste acceptability panel results, rancid characteristics were never cited by panelists. In the present study, the small detectable amounts of lipid oxidation parameters, such as TBA and FFA, in red tilapia, a freshwater fish, could reflect the high quality attributes of all tilapia fillets, which remained edible during at least 21 days of storage.

At the end of the present study, the cumin-treated tilapia fillets showed the highest score (7.4±0.30) for overall acceptability, whereas untreated fillets scored 6.7±0.26. The sensory assessment of all cooked tilapia fillets showed that no score for the fillet attributes dropped beyond the limit of acceptability, as all mean acceptability scores remained above 4 by the end of the evaluation. The present findings show that cumin-treated tilapia fillets maintained better quality compared with untreated fillets during storage in ice, as the former achieved higher scores compared with the latter.

Table 3: Correlations between the differences lipid deteriorations indexes of untreated tilapia fillets at ($p<0.05$)

Attributes	**TBA**		**PV**		**FFA**	
	R	**P-value**	**R**	**P-value**	**R**	**P-value**
Off-odour	- 0.81	0.19	0.03	0.97	- 0.98	0.02
Off-flavour	- 0.83	0.17	- 0.26	0.74	- 0.90	0.10
Texture	- 0.50	0.50	0.43	0.57	- 0.95	0.50
Overall acceptability	- 0.65	0.35	0.44	0.56	- 0.95	0.05

Correlation lipid quality deteriorations indexes with sensory quality when stored in ice

Lipid oxidation produces a number of substances, some of which have unpleasant flavours and odours. Some may also contribute to texture changes, by forming covalent bonds with muscular proteins[31]. The Correlations between the differences lipid parameters index and sensory attributes of untreated tilapia Fillets at ($p<0.05$) as was shown in Table 3. Although not significant, TBA values had very high inverse correlation with off-odour ($r = -0.81$, p-value = 0.19) and off-flavour ($r = -0.83$, p-value = 0.17). TBA values also had moderate inverse correlation with overall acceptability ($r= -0.39$, p-value= 0.61) and texture($r= -0.50$, p-value= 0.50). In agreement with these findings, Lubis and Buckle [32] reported good correlations between TBA and tasting in dried-salted sardines. Piccini et al., [33] also observed a close correlation between the organoleptic scores and the oxidative rancidity in tuna loins and hake fillets, whether control or irradiated. The TBA variations are showed a very significant correlation with both fillet hardness ($r = 0.61$) and all the attributes evaluated in the sensory analysis ($r = 0.82–0.98$) of meagre fillets were stored on ice at 4 C for 18 days[15]. Higher correlation coefficients were observed between TBA and sensory scores of farmed($r > 0.974$) than of wild samples ($r > 0.747$) [34]. According to Connell (1995)[35], TBA values of 1–2 mg MDA kg^{-1} in fish muscle are associated with the development of questionable flavours and odours.

A weak correlation was found between PV and off-odour($r=0.03$, p-value= 0.97) and off-flavour($r= -0.26$, p-value= 0.74). However, a moderate correlation was found between PV and overall acceptability ($r= 0.55$, p-value= 0.45) and texture ($r= 0.43$, p-value= 0.57) as was shown in Table 3. A close relationship between the rancid odor development and the PV assessment has been obtained in Cobia frozen fillets ($r = 0.76$) by Taheri and Motallebi[36].

There was a strongly inverse and significant correlation ($p<0.05$) of FFA values versus off-odour scores ($r = -0.98$, p-value = 0.02). On the other hand, a strongly inverse but not significant correlation was observed for FFA values versus off-flavour scores($r = -0.90$, p-value = 0.10). The FFA values had a very high inverse correlation with overall acceptability ($r = -0.89$, p-value = 0.11) and texture ($r = -0.95$, p-value = 0.50) as shown

in Table 3 .Our findings are in agreement with those of other authors who showed that there are the best correlation values between sensory analysis and the FFA content. Thus, fair values were obtained for FFA content when compared to odour, firmness and colour (r^2 = 0.82, r^2 = 0.83 and r^2= 0.83, respectively)[37]. FFA formation has been reported to be strongly correlated to lack of acceptability[38], according to previous research where interaction with proteins leading to toughening and enhancement of lipid oxidation development have been proposed[39].

Conclusions

Significant differences ($p<0.05$) in PV, TBA, FFA, odour, flavour, appearance, and overall acceptability parameters were observed between untreated and treated fillets during the 21 day storage period. The inhibitory effect of cumin was markedly higher in the FFA, TBA values, flavour, and appearance for the treated rather than the untreated fillets. There was a strongly inverse correlation at ($p<0.05$) of FFA values versus overall acceptability, texture, off-odourand off-flavour scores in untreated fillets. These findings suggest that TBA and FFA are more suitable indices for spoilage of tilapia fillets. In our study, acidic, rancid and ammoniacal odours were not detected until day 21, when the TBA value was 0.30 and 0.27 mg MDA/kg lipid of cumin-treated and untreated tilapia fillets. Overall, the cumin-treated tilapia fillets maintained better quality compared with untreated fillets during storage in ice, as the former achieved higher scores compared with the latter.

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