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Frozen Cooked Catfish Burger: Effect of Different Cooking Methods and Storage on its Quality

[1]A.Z. HassabAlla, [2]G.F. Mohamed, [2]H.M. Ibrahim and [3]M.A. AbdElMageed

[1]Central Laboratory for Aquaculture Research, Abbassa,
Agricultural Research Centre, Cairo, Egypt
[2]Food Technology Department, National Research Centre, Dokki, Cairo, Egypt
[3]Chemistry of Flavor and Aromatic Department,
National Research Centre, Dokki, Cairo, Egypt

Abstract: This study aimed to prepare fish burgers from catfish and to explore the effects of three different cooking methods (frying, oven-cooking and grilling) and frozen storage for four months (-18°C). Quality and sensory attributes were evaluated. A significant decrease of moisture was observed with a consequent increase in protein, fat and ash contents. Frying produced the highest water loss and fat gain, more than grilling and oven-cooking. TBARS values of the frozen uncooked catfish burger increased after two and four months of storage (-18°C). At zero time a decrease was observed in TBARS values of all frozen cooked burger samples and fried sample was of the highest value compared to the uncooked sample. During the storage, the frozen oven-cooked catfish burger had lower TBARS value than grilled and fried burgers. Fatty acids profile of the frozen cooked burgers at zero time and after four months of storage were affected by the used cooking methods; but greatly affected by frying. Cooking characteristics showed that the fried sample had the highest cooking yield, significant ($P<0.05$) higher fat and low moisture retention %s. Grilled sample realized lowest shrinkage %. Color parameters of all samples during storage were measured and discussed. Redness index was decreased when the storage time was increased. Sensory scores of fish burgers were acceptable up till the 4th month of the frozen storage. Volatile compounds of each sample were analyzed and identified at zero time and after four months of storage.

Key words: Catfish burgers · Cooking methods · Frozen storage · Quality and sensory attributes · Volatile compounds

INTRODUCTION

Fish burgers are one of the most acceptable food products in the world and commonly used as ready-to-eat or precooked products. Fish and fish products are usually consumed after frozen storage and/or after some type of culinary preparation. Heating is applied to food to enhance its flavor, inactivate pathogenic micro-organism and increase shelf life [1]. Some of major changes that occur during processing and final preparation of heated food are due to oxidation.

Freezing and frozen storage of fish product are commonly used because of the consistent, reliable quality, ease of transportation and the fact that they are very close to fresh equivalents. Also, freezing can cause alterations in fish such as increase in the amount of free fatty acids and compounds derived from lipid oxidation and protein degradation [2, 3].

In recent years many studies have been conducted to determine the best cultivation conditions for raising silver catfish [4]. The absence of intramuscular bones and good acceptance by consumers are some characteristics that could facilitate the industrial filleting process of catfish [5]. However, up to the available current knowledge the use of catfish in processed fish products e.g. burgers or patties are lacking [6].

The intent of this study was to prepare fish burgers from catfish and to explore the effects of three different cooking methods (frying, oven-cooking and grilling) and frozen storage for four months (-18°C) on quality and

Corresponding Author: Prof. Dr. H.M. Ibrahim, Food Technology Department, National Research Centre, Dokki, Cairo, Egypt

sensory attributes (approximate composition, TBAR values, fatty acids composition, cooking characteristics, color and sensory attributes as well as volatile compounds).

MATERIALS AND METHODS

Materials: Catfish (*Clarias spp*) as fresh water species was purchased from the local market. Fish were beheaded, gutted, washed and filleted by hand then minced using kitchen processor. Other ingredients that used in preparing the catfish burger formula were obtained from local market.

Catfish Burger Preparation: Catfish burger formula was prepared as follows: minced catfish (93.0%) and the ingredients: wheat flour (3.0%), sugar (1.5%), salt (1.5%), onion powder(1%), garlic powder (1%), black pepper powder (0.25%), thyme (0.25%),cinnamon (0.25%) and cumin (0.25%), were mixed well to obtain a homogenous mixture. Sixty gm of the homogenous mixture were shaped in a circular mould (9 cm diameter and 1cm thickness). The prepared catfish burger samples were divided and assigned to the three repetitions; for each of the three different cooking methods (frying, oven-cooking and grilling) used and to the uncooked fish burger that was used as a control. The uncooked and cooked burger samples were package in poly ethylene bags then quick frozen at -30°C for 5 hr and stored at -18°C for four months.

Cooking Methods: The prepared catfish burger samples were fried in sunflower oil for 4 min on each side at initial 180°C. To prepare oven-cooked catfish burger samples, the conventional oven temperature was sit at 250°C (preheating) and burger samples were cooked for 10 min on each side. The tested catfish burgers were grilled for 6 min on each side in preheated grill with thermostat sit at 350°C.

The cooked catfish burger samples were subjected to sensory evaluation directly after cooking and after the frozen storage at -18°C for four months. Proximate composition for the uncooked and frozen cooked samples was determined at the zero time. Color measurements, Thiobarbituric Acid Reactive Substances (TBARS) values were measured at zero time, after two and four months frozen storage. Fatty acids composition and volatile compounds of the frozen cooked and uncooked fish burger samples were determined at the zero time and after the 4th month of the frozen storage at -18°C.

Proximate Composition: Moisture, fat, protein and ash were determined according to A.O.A.C.[7].

Cooking characteristics: Cooking yield, fat and moisture retention were determined as described by Alesson-carbonell *et al.* [8]. Catfish burger samples were weighted before and after each cooking method. Cooking characteristics were calculated as follows:

$$\text{Cooking yield (\%)} = \frac{\text{Cooked weight}}{\text{Uncooked weight}} \times 100$$

$$\text{Fat retention (\%)} = \frac{\text{Cooked weight x \%fat in cooked burger}}{\text{Uncooked weight x \% fat in uncooked burger}} \times 100$$

$$\text{Moisture retention (\%)} = \frac{\text{Cooked weight x \% moisture in cooked burger}}{\text{Uncooked weight x \% moisture in uncooked burger}} \times 100$$

Shrinkage (%) was calculated as described by A.M.S.A. [9] as follows:

$$\text{Shrinkage (\%)} = \frac{(a - b) + (c - d)}{a + c} \times 100$$

a = Thickness of uncooked burger.
b = Thickness of cooked burger.
c = Diameter of uncooked burger.
d = Diameter of cooked burger.

Thiobarbituric Acid Reactive Substances (TBARS): TBARS was determined spectrophotometrically according to the method described by Ke *et al.* [10] and calculated as mg malonaldehyde /kg sample.

Color Measurements: Color of the uncooked and cooked catfish burger samples was measured for each sample using a Hunter, Lab. Scan XE, Colormeter, calibrated with a white standard: (X=77.26, Y=81.94 and Z = 88.14). The measured color parameters were L*(lightness), a*(redness) and b*(yellowness) and Chroma $[(a^{a2} + b^{b2})^{1/2}]$. The chroma is an expression of the saturation or intensity and clarity of the color [6]. The redness index (a^*/b^*) was determined as described by Chen *et al.* [11].

Fatty Acids Profile: The determination of fatty acids profile was carried out according to Luddy *et al.* [12]. The fatty acids methyl esters were analyzed by Gas Chromatography (GC) analysis using Perkin Elmer Auto System xL equipped with flame ionization detector (FID) available at Analysis and Evaluation of Flavor & Aroma Unit, National Research Center, Cairo, Egypt under the following conditions: Fused Silica capillary column DB5 (60m x 0.32mm id),oven temperature was maintained initially at 150°C and programmed from 150°C to 240°C at rate 3°C /min, held at 240°C for 30min, injector temp.230°C, detector temp.250°C and carrier gas: Helium, flow rate 1mL/min.

Sensory Evaluation: For the determination of sensory quality of the investigated fish burger scoring test was used [13].The cooked catfish burger samples were served to ten trained panelists to evaluate sensory attributes (color, taste, odor, texture and general acceptability) by using 9-points descriptive scale. According to the scoring table, scores (7-9) indicated "high quality", scores (4-6) indicated "moderate quality" and scores (1-3) indicated the limit of "unacceptability".

Volatile Compounds

Isolation of Headspace Volatiles: The aroma concentrate of each catfish burger sample collected by dynamic headspace method according to Fadel *et al.* [14].

Gas Chromatographic Analysis: GC analysis was performed by using Hewllet-Packard model 5890 equipped with flame ionization detector (FID). A fused silica capillary column DB5 (60m x 0.32 mm i.d.) was used. The oven temperature was maintained initially at 50°C for 5 min and then programmed from 50 to 250°C at a rate of 4°C/min. Helium was used as carrier gas, at flow rate 1.1 ml/min. The injector and detector temperatures were 220 and 250°C, respectively. The retention indices (Kovats index) of the separated volatile components were calculated with hydrocarbon (C8-C22, Aldrich Chemical Co.) as references.

Gas Chromatographic-mass Spectrometric Analysis: The analysis was carried out by using a coupled gas chromatography Hewllet-Packard (5890)/mass spectrometry Hewllet-Packard-MS (5970). The ionization voltage was 70 eV, mass range *m/z* 39-400 amu. The GC conditions carried out as mentioned earlier. The isolated peaks were identified by matching with data from the library of mass spectra (NIST) and comparison with those of authentic compounds and published data [15]. The quantitative determination was carried out based on peak area integration.

Statistical Analysis: Data were analyzed with the Analysis of Variance (ANOVA) with three replications according to Snedcor and Cochran [16] using Mstat-C program. When significant differences ($P<0.05$) were detected, the least significant difference (LSD) test was used to separate the mean values according to Steel and Torrie [17].

RESULTS

Proximate Composition: The changes in moisture, protein, fat and ash contents of the frozen uncooked and cooked catfish burger samples are shown in Table 1. A significant ($P<0.05$) decrease of moisture content and an increase in the fat, protein and ash contents of the burger samples were observed after the cooking processes. After frying the moisture content decreased significantly while the fat, protein and ash contents increased. During the oven-cooking, the catfish burger lost water with a consequent increase in protein, ash and fat contents. However, dehydration was lower than during frying. This finding agreed with the previously reported results for silver catfish fillets [18, 19]. The fat, protein and ash contents of grilled sample increased with respect to the uncooked catfish burger sample. Also, the grilling method caused lower water loss than frying and higher than oven-cooking. This may be related to the rate of food temperature (quicker in frying) and cooking method temperature (lower in oven-cooking than in grilling).

Cooking Characteristics: Cooking characteristics for catfish burger samples showed that the fried catfish burger sample had significant high cooking yield and low moisture retention %s (Table 2). Regarding to the shrinkage, the fried sample had higher % than that of grilled sample and lower than that of oven-cooked sample. The oven-cooked catfish burger sample had the highest shrinkage % and the lowest cooking yield. Grilled burger sample was found to realize the lowest shrinkage and the highest moisture retention %s. A significant higher fat retention % was noticed for all cooked catfish burger samples. Frying provided a significantly higher retention % of fat hence the fried catfish burger sample had the highest fat content.

Table 1: Proximate composition (%) of frozen uncooked and cooked catfish burgers samples

Sample	Moisture	Fat	Protein	Ash
Uncooked	71.23a±4.23	5.55c±0.56	18.67c±1.30	1.70c±0.11
Fried	53.79c±2.15	9.11a±1.00	31.92a±2.50	2.23a±0.17
Oven-cooked	63.40b±3.40	7.25b±0.79	24.62b±1.53	1.95bc±0.13
Grilled	61.01b±3.01	8.21ab±0.91	25.35b±1.60	2.02ab±0.15
LSD at α 0.05	6.183	1.565	3.373	0.266

Means with different letters within each column are significant at α 0.05 level.

Values are means ± SD (n = 3)

Table 2: Cooking characteristics (%) of the cooked catfish burger samples

Cooking parameters	Samples			
	Fried	Oven-cooked	Grilled	[1]LSD
Cookingyield	98.89a±1.93	86.11b±4.81	96.11a±4.20	7.692
Shrinkage	10.00b±3.00	21.67a±2.08	8.67b±0.58	4.264
Fatretention	162.32a±3.16	112.49c±6.28	142.17b±6.21	10.820
Moisture retention	74.68±1.46	76.64±4.28	82.32±3.59	N.S

Means with different letters within each column are significant at α 0.05 level

[1] LSD at α 0.05. Values are means ± SD (n = 3)

Table 3: TBARS values (mg malonaldehyde/kg sample) of the catfish burger samples during frozen storage at -18°C

Sample	Storage time						
	Zero		Two months		Four months		[1]LSD
Uncooked	B	2.31±0.29	B	3.10 a±0.34	A	5.73±0.55	0.8165
Fried	B	2.18±0.28	B	2.45 bc±0.30	A	5.02±0.46	0.7120
Oven-cooked	B	1.87±0.25	B	2.12 c±0.27	A	4.49±0.43	0.6535
Grilled	C	1.67±0.24	B	2.76 ab±0.34	A	4.83±0.45	0.7064
[2]LSD	N.S		0.5924		N.S		

Means with different letters (small or capital) within each column or row are significant at α 0.05 level.

Capital letters i.e significant among three levels of storage time (horizontal).

[1]LSD at α 0.05 for storage time. [2] LSD at α 0.05 for cooking methods. Values are means ± SD (n = 3)

TBARS: Generally, after cooking processes a decrease was observed in TBARS values of the frozen cooked burger samples at the zero time compared to the frozen uncooked sample (Table 3). Fried sample was of highest TBARS value followed by oven-cooked burger and the grilled sample was of the lowest value. No significant differences were observed between TBARS values of fried, oven-cooked and grilled burgers at the zero time relative to the uncooked samples. Regarding to the changes occurred during frozen storage, the TBARS value of the frozen uncooked burger sample at zero time increased gradually after 2 and 4 months. Also, an increase in TBARS values was noticed in all frozen cooked burger samples during the storage period. After two months of storage; the grilled burger sample had the highest TBARS value; while after 4 months the fried sample was of the highest TBARS value as compared to the oven-cooked samples. There was a significant ($p<0.05$) difference after 2 months while after the 4th month of storage no significant differences were noticed for all frozen cooked burger samples.

Color Measurements: The frozen cooked catfish burger samples, at zero time, showed significant increase in the yellowness (b*) value after the applied cooking processes (Table 4). Chroma and (L*) values indicated increased saturation; while the lightness decreased after cooking processes for all samples. Similar changes for L* and b* values were found for uncooked and grilled catfish burger [6].After two months of storage at -18°C, L^* values of the

Table 4: Color parameters of the catfish burger samples during frozen storage at18°C

Color parameters	Samples: Uncooked	Fried	Oven-cooked	Grilled	[1]LSD
			At zero time		
L^*	49.02±5.00	45.59±4.50	43.42±4.40	41.53±4.20	N.S
a^*	*4.47b±0.44	09.23a±0.90	7.92a±0.76	*8.70a±0.88	1.445
b^*	16.75b±1.50	21.17a±2.00	22.04a±2.10	21.09a±1.90	3.556
Chroma	17.34b±1.75	23.09a±2.35	23.42a±2.35	22.81a±2.30	4.146
Redness Index	*0.27c±0.04	0.44a±0.03	0.36b±0.03	0.41ab±0.04	0.067
			After two months storage (-18°C)		
L^*	50.71a±5.10	43.81ab±4.30	42.05b±4.25	38.37b±3.85	8.282
a^*	*3.06c±0.32	8.82a±0.89	7.27b±0.75	*7.01b±0.69	1.309
b^*	17.88±1.80	20.92±2.10	20.64±2.03	19.11±2.00	N.S
Chroma	18.14±1.71	22.70±2.05	21.88±2.10	20.36±2.00	N.S
Redness Index	*0.17c±0.01	0.42a±0.03	0.35b±0.03	0.37ab±0.03	0.052
			After four months (-18°C)		
L^*	51.19a±5.10	43.21ab±4.30	41.59b±4.15	37.31b±3.70	8.175
a^*	*2.59c±0.25	8.34a±0.80	7.05b±0.70	*6.61b±0.61	1.177
b^*	18.13±1.80	21.35±2.00	21.93±2.10	18.66±1.80	N.S
Chroma	18.31c±1.30	22.92ab±1.90	23.04a±2.00	19.80bc±1.40	3.159
Redness Index	*0.14c±0.01	0.39a±0.03	0.32b±0.02	0.35ab±0.03	0.048

Means with different letters within each column are significant at α 0.05 level. [1] LSD at α 0.05.
* i.e. significant among three levels of storage time (vertical). Values are means ± SD (n = 3)

frozen cooked burger samples were noticed to be decreased. Meanwhile, a^* and b^* values increased as compared to the corresponding values of the frozen uncooked samples. Changes of color parameters were in the same trend for the frozen cooked samples stored for four months. For instance, the lightness (L*) values of frozen fried, oven-cooked and grilled samples were decreased. Meanwhile, the redness (a*) and yellowness (b*) values increased in all frozen cooked samples; but the grilled sample had the lowest increasing value. The L*, b* values and chroma of the uncooked catfish burgers were increased after the frozen storage for 4 months. No significant differences in (b^*) values after frozen storage for 2 and 4 months. The redness index (a^*/b^* ratio) of the uncooked and cooked burger samples decreased when the storage time increased (Table 4).

Fatty Acids Profile: The dominant fatty acids in the frozen uncooked and cooked fish burger samples at zero time were palmitic (C16:0), oleic (C18:1) and linoleic (C18:2) acids (Table 5). These findings accorded well with some previously reported results for silver catfish fillet [19]. The frozen uncooked catfish burger sample, at zero time, showed considerable amounts of palmitoleic acid (C16:1), stearic acid (C18:0) and linolenic acid (C18:3). Meanwhile, myristic (C14:0) and arachidonic (C20:4) acids had low levels. Fatty acids profile of the frozen cooked burger samples, at zero time, were affected by oven-cooking and grilling methods but greatly affected by frying due to fat absorption. Markedly increase was noticed in the oleic acid (C18:1) content of the fried sample. Regarding the frozen oven-cooked burger sample, concentration of oleic (C18:1), linoleic (C18:2) and linolenic (C18:3) acids decreased as compared to the uncooked burger sample.

Relative to the uncooked burger sample, grilled sample at zero time showed some decrease in the level of palmitic acid (C16:0), marked decrease in linoleic acid (C18:2) and slight decrease in linolenic acid (C18:3), while no change was found in the level of palmitoleic acid (C16:1). It was worthy to notice that the observed changes of the investigated frozen cooked catfish burgers (Table 5) were not homogeneous for the different fatty acids contents because some fatty acids decreased, some increased and others did not change. This is in agreement with Garcia-Arias *et al.* [20].

By increasing the period of storage to 4 months at -18°C for the uncooked burger sample a rise in the Σ of saturated and monounsaturated fatty acids contents (due to increase of palmitic and oleic acids contents) and a decrease in the Σ of poly unsaturated fatty acids (due to absence of linoleinic and arachidonic acids) were observed (Table 5).

Considering frozen storage time and cooking methods, fatty acids profile of the frozen cooked samples after storage for 4 months at -18°C, cleared that the palmitic(C16:0), oleic(C18:1) and linoleic (C18:2) acids were present in larger amounts. However, the fried and grilled samples had lower oleic (18:1) acid content as compared to their corresponding at zero time.

Regarding the effect of cooking methods, after 4 months frozen storage it was observed an increase in Σ of SFA and PUSFA contents and a decrease in Σ MUSFA of

Table 5: Fatty acids (%) of the catfish burger samples during frozen storage at -18°C

	Samples				
Color parameters	Uncooked	Fried	Oven-cooked	Grilled	[1]LSD
		At zero point			
Saturated					
Myristic C14:0	*0.37c±0.02	*0.00d±0.00	*2.00a±0.10	*0.96b±0.05	0.103
Palmitic C16:0	*28.39ab±2.84	20.50c±2.05	33.27a±3.33	26.96b±2.70	5.212
Stearic C 18:0	5.78c±0.29	*8.69a±0.43	7.36b±0.37	7.43b±0.37	0.694
Σ SFA	34.54±5.18	29.19±4.38	42.63±6.39	35.35±5.30	N.S
Monounsaturated					
Palmitoleic C 16:1	*3.23b±0.16	*1.89c±0.09	4.37a±0.22	*3.23b±0.16	0.309
Oleic C 18:1	*33.60b±3.36	*50.40a±5.04	25.99c±2.60	*45.63a±4.56	7.546
Σ MUSFA	*36.83b±3.68	*52.29a±5.23	30.36b±3.04	*48.86a±4.89	8.101
Polyunsaturated					
Linoleic C 18:.2	*23.40a±2.11	*18.38b±1.65	22.77a±2.05	*10.18c±0.92	3.291
Linolenic C 18:3	*4.61a±0.23	*0.00c±0.00	*2.80b±0.14	*4.34a±0.22	0.326
Arachidonic C 20:4	*0.62c±0.02	*0.14d±0.01	*1.44a±0.06	*1.27b±0.05	0.084
Σ PUSFA	*28.63a±2.86	*18.52b±1.85	*27.01a±2.70	*15.79b±1.58	4.354
		After 4 months of storage (- 18°C)			
Saturated					
Myristic C 14: 0	*1.02a±0.05	*0.34b±0.02	*0.00c±0.00	*0.38b±0.02	0.060
Palmitic C 16: 0	*37.10a±3.71	20.55b±2.06	37.69a±3.77	26.30b±2.63	5.888
Stearic C 18:0	5.59d±0.28	*10.66a±0.53	6.60c±0.33	7.98b±0.40	0.746
Σ SFA	43.71±6.56	31.55±4.73	44.29±6.64	34.66±5.20	N.S
Monounsaturated					
Palmitoleic C 16:1	*4.39a±0.22	*1.55c±0.08	4.52a±0.23	*2.71b±0.14	0.337
Oleic C 18:1	*42.97a±4.30	*21.96c±2.20	31.10b±3.11	*26.25bc±2.63	5.946
Σ MUSFA	*47.36a±4.74	*23.51c±2.35	35.62b±3.56	*28.96c±2.90	6.595
Polyunsaturated					
Linoleic C 18:2	*8.94d±0.72	*36.67a±3.30	19.90c±1.79	*24.76b±1.49	3.862
Linolenic C 18:3	*0.00c±0.00	*10.66a±0.53	*1.00b±0.05	*10.00a±0.50	0.687
Arachidonic C 20:4	*0.00b±0.00	*0.00b±0.00	*0.00b±0.00	*1.62a±0.06	0.060
Σ PUSFA	*8.94d±0.89	*47.33a±4.73	*20.90c±2.09	*36.38b±3.64	6.012

Means with different letters within each column are significant at α 0.05 level. [1] LSD at α 0.05.

* i.e. significant between two levels of storage time (vertical). Values are means ± SD (n = 3)

fried sample. Σ SFA and MUSFA levels in oven-cooked burger sample increased while Σ PUSFA decreased. Frozen storage caused an increase in Σ PUSFA and a decrease in Σ of SFA and MUSFA contents of grilled sample.

Sensory Quality: The changes in the sensory parameters of the burger samples were presented in (Table 6). General acceptability and odor scores of the fried burger were significantly higher than those of oven-cooked and grilled burger samples. Meanwhile, oven-cooked sample gained higher scores for taste and color parameters compared to the other two cooked samples. Grilled sample showed low sensory scores, however; it was indicated by the panelists as of moderate quality.

The sensory scores of the cooked fish burger samples decreased after frozen storage for 4 months (Table 6). However, the frozen cooked burger samples remained as quite near of fresh cooked acceptable quality as judged by the panelists. Taste panel results showed that both frozen fried and oven-cooked burger samples, gained equal acceptability scores. On the other hand, the frozen cooked fried sample was noticed to be of higher sensory scores for taste and odor than those of the oven-cooked which gained a significant high color score. Also, it was noticed that there was no significant difference in texture scores for all frozen cooked catfish burger samples after storage for four months. The frozen grilled sample stored for 4 months had the lowest sensory scores; however it was indicated as of moderate quality by the panelists. Therefore, the taste panel evaluation showed that all samples were acceptable up till the 4th month of frozen storage at -18°C.

Volatile Compounds: Thirty volatile compounds were identified by kovats index values and MS spectra [15] and

Table 6: Mean scores of sensory evaluation of the cooked and frozen cooked catfish burgers

Sensory parameters	Samples			
	Fried	Oven-cooked	Grilled	LSD
		After cooking processes		
Color	*7.80a±0.26	8.00a±0.26	*5.60b±0.26	0.529
Taste	7.43b±0.26	*8.23a±0.26	5.40c±0.26	0.529
Odor	*8.20a±0.26	*7.70a±0.26	*6.20b±0.26	0.529
Texture	*7.30a±0.26	6.00b±0.44	5.60b±0.20	0.632
Acceptability	*8.46a±0.26	7.86a±0.44	*5.80b±0.44	0.774
		After four months storage (-18°C)		
Color	*6.30b±0.26	7.93a±0.44	*4.63c±0.26	0.663
Taste	7.40a±0.17	*6.95a±0.26	5.03b±0.26	0.477
Odor	*7.53a±0.26	*5.93b±0.26	*4.37c±0.26	0.529
Texture	*5.90±0.26	5.56±0.26	5.56±0.17	N.S
Acceptability	*7.20a±0.26	7.20a±0.36	*4.44b±0.26	0.599

Means with different letters within each column are significant at α 0.05. LSD at α 0.05.
* i.e. significant between two levels of storage time (vertical). Values are means ± SD (n = 3)

Table 7: Volatile compounds identified in dynamic headspace of the catfish burger samples. (* values expressed as relative area percentage to total identified compounds)

Peak No.	KI[a]	Components	**Samples at zero time				**Samples after 4 months stored at (- 18°)				[b]Methods of Identification
			K_1	K_2	K_3	K_4	K_1	K_2	K_3	K_4	
1	609	Dimethyl sulfide	-	-	*10.38*	15.43	7.89	2.20	24.84	11.01	MS,KI,St
2	613	Ethyl acetate	2.64	2.32	12.26	35.86	0.86	15.74	6.21	5.18	MS,KI,St
3	642	2-Butanone	-	-	9.71	-	-	0.97	0.91	-	MS,KI
4	651	(*E*)-2-Octene	-	-	-	-	10.48	6.43	9.95	14.30	MS,KI
5	686	2,4-octadiene	-	0.10	-	-	0.35	-	0.88	0.83	MS,KI
6	712	Geosmin	-	-	-	-	0.99	-	1.40	1.25	MS,KI
7	720	2,3-Butandione	-	1.04	-	-	0.03	-	0.47	0.45	MS,KI
8	732	1-Penten-3-ol	-	-	-	2.17	1.41	-	5.41	6.14	MS,KI
9	740	2,3-Pentandione	-	1.45	1.11	3.57	-	0.36	0.16	1.39	MS,KI
10	753	Dimethyl disulfide	-	-	11.08	29.56	0.75	-	3.58	2.72	MS,KI,St
11	765	1,3,5-Octatriene	-	-	-	-	1.15	-	2.31	3.33	MS,KI
12	800	*P*-Xylene	-	-	0.50	0.99	0.37	0.27	0.89	1.19	MS,KI
13	809	Hexanal	-	-	4.13	-	32.83	49.70	11.26	11.71	MS,KI,St
14	845	(*E*)-2-Hexenal	-	-	-	-	-	-	0.65	2.14	MS,KI
15	860	2-Methylisoborneol	-	0.07	-	0.39	2.18	3.07	0.25	1.92	MS,KI
16	869	1-Hexanol	-	-	-	-	2.38	1.06	2.40	3.15	MS,KI,St
17	896	Heptanal	-	0.13	-	0.49	0.61	0.11	0.43	0.53	MS,KI
18	930	α-Pinene	-	0.33	1.44	0.83	1.40	0.24	0.52	1.31	MS,KI,St
19	974	(*Z*)-4-heptenal	0.50	0.60	2.61	1.39	4.31	0.18	2.47	2.35	MS,KI
20	985	2-Pentylfuran	-	0.15	3.58	-	3.47	-	6.01	0.87	MS,KI,St
21	996	Methional	-	-	1.37	-	15.93	8.23	-	11.85	MS,KI
22	1005	Octanal	-	-	6.56	1.88	3.85	0.23	5.91	3.53	MS,KI
23	1011	(*E*,*E*)-2,4-heptadienal	-	0.94	1.22	-	6.25	4.73	-	6.21	MS,KI
24	1033	Limonene	0.35	0.90	6.28	2.42	1.01	-	0.96	0.62	MS,KI,St
25	1055	(*E*)-2-Octenal	-	0.61	2.41	1.13	1.49	4.78	0.77	0.43	MS,KI
26	1256	(*E*)-Decanal	-	1.79	12.03	-	-	0.47	0.56	0.16	MS,KI
27	1352	2,4-Decadienal	1.19	0.98	0.87	0.52	-	0.36	0.73	0.57	MS,KI
28	1416	2-Acetylpyridine	0.59	2.95	6.19	0.65	-	0.42	0.76	0.23	MS,KI
29	1461	Ethylhexadecanoate	0.59	1.76	0.78	0.61	-	0.16	1.17	1.26	MS,KI
30	1502	4-Methylthiazole	94.64	83.87	2.39	2.10	-	0.19	8.13	3.36	MS,KI

Compounds listed according to their elution on DB5 column.
[a]Kovats index. [b]Compound identified by GC-MS (MS) and / or by Kovats index on DB5 (KI) and / or by comparison of MS and KI of standard compound (St) run under similar GC-Ms conditions. - Not detected.
**K_1 = Fried, K_2 = Oven-cooked, K_3 = Grilled and K_4 = Uncooked

listed with their area percentages % in (Table 7). These included 9 aldehydes, 3alcohols, 3ketones, 4sulfur, 7hydrocarbons, 2esters and 1 furan and 1pyridine compounds. Also, 4-methylthiazole comprised (2.10 and 2.39%) in uncooked (K_4) and grilled (K_3) samples, respectively at zero time; it increased to reach (3.36 and 8.13%) in both samples after storage for four months (-18°C). The same compound comprised a very high concentration and became predominant in both fried (K_1) and oven-cooked (K_2) samples (94.64 and 83.87%)

respectively at zero time; then decreased to be not detected in the fried sample and recorded 0.19% in the oven-cooked sample as a results of frozen storage.

Dimethyl sulfide which not detected in both K_1 and K_2 samples recorded 10.38 and 15.43% in K_3 and K_4 samples respectively at zero time. The same sulfide after storage for 4 months showed remarkable increase in K_1, K_2 and K_3 (7.89, 2.20 and 24.84%) respectively; meanwhile its percentage reached 11.01% in K_4 sample.

Dimethyl disulfide at zero time was not detected in $K_1$and K_2 samples as well in the frozen stored K_2 sample for 4 months; it's concentration appeared slight (0.75%) in the frozen stored K_1 sample. Although this compound was considered as major in both K_3 and K_4 samples (11.08 and 29.56%) respectively at zero time, it showed a sharp decrease to reach 3.58 and 2.72%, respectively after 4 moths of frozen storage.

Methional, at zero time was not detected in K_1, K_2 and K_4 burger samples (Table 7) and comprised a small concentration in grilled sample K_3 (1.37%). After the 4^{th} month of storage it was absent in K_3 and showed remarkable increase in the other three samples (K_1, K_2, K_4) to reach 15.93, 8.23 and 11.85% respectively.

As shown from Table 7; 1, 3, 5-Octatriene, (*E*)-2-Hexenal and 2, 4-heptadienal increased during storage in most investigated samples. These results agreed with the observed decrease in linolenic acid (Table 5). Heptanal, (*Z*)-4-heptenal,Octanal, (*E*)-2-Octenal, (*E*)-2-Decanal, 2,4-decadienal showed the same increasing trend; whereas hexanal showed high concentration by storage for 4 months especially in fried (K_1) and oven-cooked (K_2) samples.

DISCUSSION

Cooking induces water loss in the food that in turn increases its lipid content in most cases and only some fat is lost in the case of the oiliest fish. Also, this effect is dependent on the type of cooking [21]. The decrease in the moisture content has been described as the most prominent change that makes the protein, fat and ash contents increase significantly in cooked fish fillets [20]. The high increase in fat content of fried burgers may be attributed not only to water loss but also due to oil absorption during cooking process. The fat increase can be due to the oil penetration on food after water is partially lost by evaporation [22]. The fat, protein and ash contents of grilled sample increased with respect to the uncooked sample. This increase may be due to a concentration effect caused by moisture loss [23].

The cooking process led to water evaporation and lipid migration in the fish burgers and the intensity of these changes is important to product acceptance [6]. It is worth noting that all the used cooking methods resulted in water loss and caused an increase of the other nutrients. Cooking methods (boiling, frying and grilling) used for African catfish fillets resulted in a significant water loss and frying produced the highest water loss and fat gain, with higher RV (retention value) of fat (125.25±22.90%) [23]. Moisture and fat retention are related to the ability of protein matrix to retain water and bind fat [6].

With regard to the oxidative rancidity, as occurs particularly in fatty fish, is a very complex deterioration and one of the common methods for the determination of lipid oxidation is TBA method [24]. The malonaldehyde eventually formed in the fried and grilled catfish fillets samples could be lost either by dissolution in the frying oil or due to formation of adducts with proteins [19]. Increasing of the TBA value during frozen storage at (-18°C) has been demonstrated for fish burgers made from tilapia and for fish balls made from carp [3, 25]. Any rancid flavor or odor was not detected in peak TBA values that were measured as 6.7mg malonaldehyde/kg for filleted spot (*Leiostomus xanthurus*) and 7mg malonaldehyde / kg stored at -18ú C for 12 months [26]. Maintaining eating quality for 3 months was largely due to the efficiency of freezing temperature, vacuum packaging and the antioxidant properties of garlic, pepper and ginger to control rancidity [27, 28]. Thus, the presently evaluated catfish burger samples were acceptable from quality evaluation viewpoint.

Color change induced by the cooking processes could mask some undesirable changes. Hence, it is important to evaluate the effect of cooking processes on the color of the prepared fish burger. The observed increase of (a*) values of the frozen cooked samples may be due to fish meat pigments. Fish species give three different varieties of mince meat color (white, dark and medium). Medium (red) colored mince fish is produced from fish high myoglobin and haemoglobin content of flesh, these fish species include catfish [29]. Worthy to mention that, during heating of meat and fish food products several reactions occur, including the Millard reaction, protein penetration, fat & water exudation and these reactions responsible for color and taste development of cooked products [30]. The increase in Hunter L^* of frozen tuna meat has been ascribed due to the decrease in water holding capacity, which might be due to the hydrolysis of muscle proteins or aggregation of myofibrillar proteins during frozen storage [31,32]. The redness index (a^*/b^* ratio) was used as an index of apparent change in redness [11]. A strong positive correlation has been reported between total pigment concentration and (a^*) value [33].

The fish species and the cooking method may be used as determinant factors for the content of essential fatty acids in the consumed products [34]. Fatty acids profile of the frozen cooked burger samples, at zero time, were affected by oven-cooking and grilling methods but greatly affected by frying due to fat absorption. The observed non homogeneous of the different fatty acids contents was attributed to the water and lipids leached out during cooking than to lipid reactions during heat treatment [35].

It is known that the sensory quality have much variation in seafood quality between species, as well as different products of the chemical, bacteriological and sensory changes, depending on storage temperature and conditions, whether the product is fresh or processed and the type of processing that is carried out. Therefore, the acceptable limits for each quality criteria may vary greatly for each type of product [36]. The taste panel evaluation showed that all samples of catfish burgers were acceptable up till the 4th month of frozen storage at-18°C. The acceptability of fish and fishery products during frozen storage depends on the changes in their sensory attributes [37].

Aroma is one of the foremost criteria used by consumer to assess the quality, acceptance and preference of food products. To investigate the changes in volatiles compounds the aroma in the headspace of the prepared burger samples during frozen storage was subjected to the high resolution gas chromatographic (HRGC) and GC-MS analysis. Some previous studies investigated sensory attributes of cooked catfish (*Silurus glanis*) flesh [38]. Also, many authors have analyzed volatile compounds in fish [39, 40]; but up-to the knowledge no study had been published concerning volatile compounds of catfish (*Silurus glanis*) [41]. Sulfur containing compounds play an important role in the characteristic aroma profile of the studied fish burger samples. There was agreement between quantitative and olfactometric results for many volatile compounds such as 4-methylthiazole (which has a cooked meat odor), i.e. an estimated concentration increase corresponded to an odor intensity increase and the converse [41]. The identification of some volatile compounds was difficult and this can be attributed for two main reasons: i) volatile compounds could be present at low estimated concentration so that the MS background was too high to obtain interpretable mass spectra. ii) they might be co-eluted with other compounds that make the identification difficult to perform [41].

Dimethyl disulfide is often present in foodstuffs and usually affects overall food aroma because of its low threshold value of 12ppb [42]. It may be thermally generated from Methional [43]. Methional was formed by the strecker degradation of methionine during cooking [44]. Methional was characterized as the most potent odorant in cooked mussel [40] and was previously reported as a necessary and significant component of the desirable aroma of cooked lobster or cooked clam this due to its low threshold value of 0.2ppb [45,46].

1, 3, 5-Octatriene, (*E*)-2-Hexenal and 2, 4-heptadienal compounds previously reported to be formed by the oxidation of n-3 polyunsaturated fatty acids [47]. It has been reported that, at 6 months of frozen storage, mean hexanal levels for the intact catfish fillet were significantly higher than for the mince [48]. All these aldehydes are known to be per-oxidation products of poly and mono unsaturated fatty acids; also accorded well with the results of previous work [49, 50].

From the obtained data it was concluded that the frozen cooked catfish burger samples were in the good quality limits and acceptable from viewpoint of quality and sensory evaluation up till the 4th month of frozen storage (-18°C).

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