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Effects of Frozen Storage on Quality Characteristics of Some Fishery Products Processed From Bluefin Tuna and Common Carp

Gehan A. Ghoneim[1], Faten Y. Ibrahim[1], Mohammed B. Ahmed[2], Basma S. Elkhamisy[1] and Fify R. Anees[3]*
[1]Department of Food Industries, Faculty of Agriculture, Mansoura University, Mansoura, Egypt.
[2]Department of Food Toxicology and Contaminants, National Research Centre, 33 El-Bohouth St., Dokki, Cairo, P.O. Box: 12622, Egypt.
[3]National Institute of Oceanography and Fisheries (NIOF), Cairo, Egypt.

THE current investigation aimed to evaluate quality characteristics of some processed fish products of bluefin tuna (*Thunnus thynnus*) and common carp (*Cyprinus carpio*) during frozen storage. Burger, nuggets and fingers products were prepared from Tuna and carp fish and stored at -18 °C for six months. The studied criteria were evaluated every 2 months as interval time during storage period. It could be noticed that TSN (Total- Soluble Nitrogen) of tuna and carp burger were 0.912, 0.730 mg/100g sample and decreased to 0.740, 0.571mg/100g sample after 6 months of storage. The same trend of decrease of TSN was observed in fish nuggets and fish finger which processed from tuna and carp. Values of TVB-N showed a decrement in all products samples which processed from tuna fish, while an increment in all processed products from carp fish during frozen storage was observed. It was noticed that during frozen storage period, the cooking loss values increased and vice versa, cooking yield decreased. It was concluded that studied tuna and carp products showed good properties in frozen storage at -18 °C for six months.

Keywords: Physiochemical criteria, Fish burger, Nuggets, Finger, Cooking loss, Texture indices

Introduction

Tuna is among the most consumed fish and is marketed as chilled, frozen, smoked, canned, breaded and battered, salted and dried forms (Murthy et al., 2014). Tuna meat has numerous health benefits because of its high-quality protein content, low content of saturated fatty acids and high content of omega-3(n-3) fatty acids which known to support human health (Tucker, 1997). Omega-3 fatty acids have known to decrease levels of cholesterol, which is known by the hypocholesterolic effect (anti-atheriosclerosis), consequently reduces the incidence of heart diseases and stroke (Patterson, 2002; Daviglus et al., 2002; Ikem & Egiebor, 2005). Additionally, tuna meat is a very rich source of vitamins such as A, B_{12}, and D and essential minerals such as calcium, phosphorus, iron, iodine and fluorine (Ismail, 2005).

Carps, barbels and other cyprinids has shown a continuous increase, risingfrom about 0.6 million tons annually in the mid-2000s to over 1.8 million tons in 2018, and explains most of the increase in catches from inland waters in recent years (FAO, 2020). Fish burger as a ready meal for fishery consumption, has been welcomed by consumers more than any other fishery products and currently supplied in various forms with thicknesses of different production and in the form of frozen. Around 15 different products are produced from carp and tuna fish (Haq et al., 2013). Fish nuggets and fingers contain health

Corresponding author: fify_anees@yahoo.com
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beneficial polyunsaturated fatty acids, high quality easily-digestible proteins and other important nutrients such as vitamins and minerals which are necessary for nutrition of human (Border et al., 2005; Sánchez-Alonso et al., 2007).

As a result, it is highly recommended to consume carp meat and their products to acquire the above-mentioned health benefits. In Egypt, canned salted tuna meat is the most commonly consumed form of tuna products. However, other meat based products; such as burger, sausages, nuggets, hot dogs and salami, are basically depended on cattle and poultry meat. Therefore, the current study focused on the assessment of the chemical and physico-chemical characteristics of tuna and carp meat and their products at zero time (fresh) and during the storage under freezing condition. Consequently, these evaluation data of the nutritive value, safety, texture indices, and other quality characteristics will draw the consumer's attention and encourage him to increase his consumption form these fish based healthy products. So, the main goal of such study is investigate the possibility of producing new fishery products such as burger, nuggets and fingers from bluefin tuna and carp fish.Also, also to study the effect of frozen storage at -18 °C on some quality characteristics of studied products.

Materials and Methods

Materials

Tuna and carp fish

Bluefin tuna (*Thunnus thynnus*) and common carp (*Cyprinus carpio*) were bought from Burullus Center in Kafr El-Sheikh Governorate, Egypt.

Commercial fish burger, nuggets and fingers

Control fish products (burger, nuggets and fingers) were purchased from a local market at El Mansoura city, Egypt.

Vegetables

Garlic, red pepper, shallots, and yellow pepper were purchased from a local vegetable market at Mansoura city, Egypt.

Other ingredients

Breadcrumbs, butter, olive oil, wheat flour, vinegar, corn flour, salt, eggs, spices (cumin, white and black pepper) were also purchased from a local market at El Mansoura city, Egypt.

Methods

Preparation of minced fish meat

Tuna and carp samples were directly conveyed to the laboratory, carefully washed under the tap water, filleted, cut into small pieces, and minced prior to be manufactured into deferent fish products.

Preparation of fish burger

Tuna and carp burger was prepared according to the method of Bochi et al. (2008) with some alternations. The fresh minced fish meat (200 g) was transferred to a mixing bowl containing wheat flour (35 g), corn flour (5 g), salt and white pepper (3 g for each). The burger mixture was blended very well and was formed in a layer with a 1 cm of thickness, then kept in a deep-freezer at -18 ºC for 1 h. After that, the layer was cut into equals squares and immersed in whiskered eggs followed by the coverage with seasoned breadcrumbs. Tuna and carp burger was collocated separately in a cork dish then covered with polyethylene and stored frozen at -18 ºC for six months.

Preparation of fish nuggets

Fish nuggets formulation was done according to Ulfah et al. (2016) with some alternations. The fresh minced fish meat (200 g) was transferred to the mixing bowl. Wheat flour (35 g), corn flour (5 g), salt (3 g), white pepper (1.5 g) and cumin (2 g) were added to the fish meat and the mixture was well blended. The nuggets mixture was straightened to a 1 cm of thickness, and then was kept in a deep freezer at -18 ºC for about 1 h. Following that, the nuggets layer was cut into equal small squares and immersed in whiskered eggs then covered by seasoned breadcrumbs. Fish nuggets were collocated in a cork dish then covered with polyethylene and stored frozen at -18 ºC for six months.

Preparation of fish fingers

The ingredients of fish finger were according to Cakli et al. (2005) with some modifications. Fresh fish minced meat (240 g) turned into the mixing bowl. Commercial wheat flour (35 g), corn flour (5 g), salt (3 g), white pepper (1.5 g), olive oil (10 g), vinegar (5 g) and black pepper (2 g) added to the fish meat. Fish mixture was straightened with 1 cm thickness, and then was cut into equal small fingers which were put in a whiskered egg then put in seasoned breadcrumbs. Tuna fingers were collocated in a cork dish then covered with polyethylene and stored in a freezer set at -18 ºC for six months.

Amino acids profile of Tuna and Carp fish meat

Amino acid profile was determined at Food and Feed Quality Laboratory, Regional Center for Food and Feed (RCFF), Agricultural research center, Egypt according to AOAC (2016).

Protein fractions content of fish samples and products

Determination of Total Soluble Nitrogen (TSN) and Soluble Protein Nitrogen (SPN), used as an index of denaturation and aggregation of protein, were determined using the micro kjeldahl method of AOAC (2016).

- Determination of Non-Protein Nitrogen (NPN) was carried out as described by Bodwell & MeClain, (1971).
- Determination of Total Volatile Basic Nitrogen (TVBN) was carried out as described by Malle & Tao (1987).

Physiochemical properties of fish samples and products

Cooking characteristics of fish burger, nuggets and fingers were determined as follow:

- *Cooking loss after frying:* Cooking loss was calculated using the equation described by Dreeling et al. (2000).
- *Cooking yield after frying:* Cooking yield was determined using the described equation by Gok et al. (2011).

Protein Water Coefficient (PWC) and protein water fat coefficient (PWFC) were determined according to Tsoladze (1997).

Statistical analysis

Statistical analysis was performed by using the statistical software package CoStat, version (2005). All comparisons were first subjected to one way analysis of variance (ANOVA) and significant differences between treatment means were determined using Duncan's multiple range test at $p < 0.05$ as the level of the significant (O'neill & Wetherill, 1971).

Results and Discussion

Protein fractions of fresh tuna and carp fish meat

Data from Table 1 showed some protein fraction which to define fish spoilage namely NPN, SPN, TSN, TVBN. The obtained results indicated that values of Non-protein nitrogen (NPN) in fresh tuna and carp meat were 0.242 and 0.229 mg/100g sample, respectively. While, soluble protein nitrogen (SPN) values were 0.718 and 0.539 mg/ 100 g sample, respectively. Total soluble nitrogen (TSN) values recorded 0.960 and 0.768 mg/ 100g tuna and carp fish meat sample, respectively.

Total volatile basic nitrogen (TVBN) is considered a common chemical method, which used to define fish spoilage. TVBN is the main components of bad odor of fish or decomposition. Therefore, the determination of these compounds has a great importance, because it represents a measurement of the freshness compounds. TVBN levels were 21.32 and 17.05 mg/100g sample, for tuna and carp meat, respectively. These results are in agreement with Abd El-Aziz & Mostafa (1998), who reported that values of TVBN were 20-22 mg/100g and 15-18.5 mg/100g for tuna and carp meat, respectively.

Amino acids composition in fresh Tuna and Carp fish meat

Amino acids composition of fresh tuna and carp fish meat were reported in Table 2. The presented results showed that Lysine is the most abundant essential amino acids in the both of tuna and carp fish meat. It recorded 6.25 % and 6.26 % from total amino acids in fresh tuna and carp fish meat, respectively. The same results showed also that Leucine (5.77 and 5.71%), Hisitidine (4.39% and 2.27%) followed by Valine (3.77% and 3.78%) and Therionine (3.57% and 3.40%) of total amino acids in fresh tuna and carp fish meat, respectively. These findings were in similar with those reported in butter catfish by (Sayad et al., 2016).

TABLE 1. Protein fractions of fresh tuna and carp fish meat.

Fish type	NPN (mg/100g)	SPN (mg/100g)	TSN (mg/100g)	TVBN (mg/100g)
Tuna	0.242±0.002[a]	0.718±0.004[a]	0.960±0.004[a]	21.32±0.140[a]
Carp	0.229±0.005[b]	0.539±0.006[b]	0.768±0.006[b]	17.05±0.080[b]

Mean in the same column having different small letters are significantly different ($P < 0.05$).

On the other hand, glutamic acid represented the highest non-essential amino acids, where fresh tuna and carp fish meat contained 9.93 and 10.94 %, respectively. Followed by Aspartic, which recorded 6.45 and 6.77%, Alanine (5.04 and 5.00%) while Arginine was4.66 and 4.5% in fresh tuna and carp fish meat, respectively. The ratio between EAA to NEAA is considered an index to define protein quality (Romano et al., 2019). Optimal ratio reported in tuna was 1.05 and signify a high quality protein; from another wise a very high ratio was reported in carp (0.94).

The content of total essential amino acids presented in Table 2 and it ranged from34.49 % in carp to36.78% in tuna, while the content of total non-essential amino acids ranged from 34.92 to 36.32 % in tuna and carp fish flesh, respectively. The predicted protein efficiency ratio (P-PER) of studied fish flesh samples were calculated, it could be noticed that P-PER ratio ranged from 1.86 in tuna to 1.85 in carp (Adeyeye, 2009).

Dietary protein plays a valuable role providing amino acids for the bio built of the body proteins. It is very necessary to supply all essential amino acids to human in a suitable amount for optimum protein synthesis. Fish proteins include all the essential amino acids needful for human nutrition, which increase the overall protein quality of a diet (Mohanty & Kaushik, 1991).

TABLE 2. Amino acids composition in fresh Tuna and Carp fish meat.

Amino acids	**Tuna meat**	**Carp meat**
A) Essential amino acids (EAA) (%)		
Leucine	5.77	5.71
Isoleucine	3.45	3.44
Lysine	6.25	6.26
Methionine	2.17	3.15
Cysteine	1.51	0.79
Phenylalanine	3.15	3.12
Tyrosine	2.75	2.57
Threonine	3.57	3.40
Hisitidine	4.39	2.27
Valine	3.77	3.78
Total (EAA)	36.78	34.49
B) Non- essential amino acids (NEAA) (%)		
Alanine	5.04	5.00
Arginine	4.66	4.57
Proline	2.78	2.72
Aspartic	6.45	6.77
Glutamic	9.93	10.94
Glycine	3.35	3.33
Serine	2.71	2.99
Total (NEAA)	34.92	36.32
Total amino acids	71.7	70.81
P-PER	1.86	1.85

Effect of frozen storage on tuna and carp processed products

Effect of frozen storage on protein fractions of tuna and carp products for six months.

NPN, SPN, TSN and TVBN in tuna and carp products during frozen storage were presented in Table 3 From these results, it could be noticed that TSN (total- soluble nitrogen) of tuna and carp burger were 0.912, 0.730 mg/100g sample decreased to 0.740, 0.571 mg/100g sample after 6 months of storage. These results are in accordance with the findings with Dantas & Attayde (2007) who found similar values of TSN in fresh water fish with values fluctuating from 9.5% to 10.35% on dry weight basis. In addition, SPN (soluble- protein nitrogen) values decreased being 0.395mg/100g sample in tuna fish burger and 0.243 mg/100g sample in carp fish burger.

The flavor of seafood depends on the species, the fat content, and the presence as well as the type of non-protein nitrogenous compounds as reported by Venugopal & Shahidi (1996). From presented data in this Table it could be observed that NPN (non-protein nitrogen) values increased as time of frozen storage increased which were 0.237, 0.258, 0.306 and 0.345 mg/100g sample in tuna fish burger and 0.182, 0.223, 0.291 and 0.328 mg/100g sample in carp fish burger at zero, 2, 4 and 6 months of frozen storage, respectively.

Total-volatile basic nitrogen (TVBN) is known as a product of bacterial spoilage and endogenous enzymes action and its content is often used as an index to assess the keeping quality and shelf life of products (Eec, 1995). From the same table, TVBN values for tuna burger were 21.74 mg/100g sample at zero time and it reached 19.51 mg/100g sample after 6 months of frozen storage. On the other hand, in carp burger TVBN values increased and recorded 17.43, 17.71, 18.27and 18.83 mg/100g sample from zero time, 2, 4 and six months, respectively.

From data mentioned in this Table, TSN and SPN values decreased as storage time prolong, TSN content decreased during frozen storage might be mainly due to the escape of some nitrogen with the separated drip during thawing of frozen fish samples. While value of NPN increased being 0.321 and 0.344 mg/100g for tuna and carp nuggets, respectively.

Data in Table 3 showed also the effect of frozen storage on TVBN content of both tuna and carp nuggets, it can be seen that TVBN content decreased during storage being 19.97 and 19.12 mg/100g for tuna and carp nuggets after 6 months, respectively. These results are in harmony with Tokur et al. (2006) who reported that TVBN content is not stable during storage and could be changed according to storage temperature.

Data presented in Table 3 showed that TSN and SPN values decreased as storage time prolong time, SPN content decreased during frozen storage; this is thought to be because of the nature of sarcoplasmic proteins, which are easily dissolved in water. Sarcoplasmic protein decreases with the degradation of fish muscle tissue (Gandotra et al., 2012). While NPN increased from 0.243 to 0.369 mg/100g and 0.187 to 0.307 mg/100g for tuna and carp fingers, respectively.

Data in this table showed also the effect of frozen storage on TVBN content of both tuna and carp fingers, it can be seen that TVBN content decrease during storage being 17.91 and 18.96 mg/100g for tuna and carp fingers after 6 months, respectively.

Effect of frozen storage for six months on cooking loss and cooking yield of tuna and carp products

Cooking loss was defined as the amount of fluid lost from food. Data in Table 4 showed effect of frozen storage on cooking loss and cooking yield of tuna and carp burger. It was observed that during storage period, cooking loss was increased and vice versa, cooking yield was decreased. However, when compared to the initial cooking loss of fresh samples (zero time), the increase in cooking drip loss of processed samples after 6 months of storage was nominal, values were 19.85 being 21.92 % for tuna fish burger, 19.92 being 21.34% for carp burger. The increase in cooking loss during both tuna and carp burger storage may be due to the disintegration of muscle protein, subsequently denaturation, and this condition may be explained by the fact that protein is the main substance that binds meat and meat products to water. From another hand, the loss in burger after cooking might be affected by several factors such as water holding capacity and the type of ingredients used in formulation.

TABLE 3. Effect of frozen storage on protein fractions of tuna and carp products for six months.

Fish Products	Storage period (months)	NPN (mg/100g sample)	SPN (mg/100g sample)	TSN (mg/100g sample)	TVBN (mg/100g sample)
Tuna Burger	0	0.237±0.004[f]	0.675±0.004[a]	0.912±0.004[a]	21.74±0.050[a]
	2	0.258±0.007[e]	0.613±0.006[b]	0.871±0.005[b]	18.04±0.080[f]
	4	0.306±0.007[c]	0.486±0.002[d]	0.792±0.007[c]	18.98±0.120[c]
	6	0.345±0.004[a]	0.395±0.0.06[e]	0.740±0.006[d]	19.51±0.140[b]
Carp Burger	0	0.182±0.006[h]	0.548±0.006[c]	0.730±0.006[e]	17.43±0.060[h]
	2	0.223±0.003[g]	0.479±0.006[d]	0.702±0.006[f]	17.71±0.030[g]
	4	0.291±0.010[d]	0.324±0.003[f]	0.615±0.004[g]	18.27±0.060[e]
	6	0.328±0.007[b]	0.243±0.006[g]	0.571±0.006[h]	18.83±0.060[d]
Tuna nuggets	0	0.260±0.005[f]	0.639±0.007[a]	0.865±0.004[a]	22.66±0.120[a]
	2	0.272±0.005[e]	0.582±0.007[b]	0.824±0.005[b]	18.47±0.050[b]
	4	0.287±0.006[d]	0.483±0.005[c]	0.770±0.006[c]	19.21±0.050[c]
	6	0.321±0.005[b]	0.391±0.005[d]	0.712±0.009[d]	19.97±0.080[d]
Carp nuggets	0	0.184±0.005[h]	0.522±0.007[e]	0.706±0.007[d]	18.15±0.080[d]
	2	0.229±0.004[g]	0.452±0.006[f]	0.683±0.006[e]	18.62±0.070[e]
	4	0.299±0.006[c]	0.293±0.005[g]	0.592±0.004[f]	18.88±0.13[f]
	6	0.344±0.005[a]	0.205±0.007[h]	0.549±0.005[g]	19.12±0.070[g]
Tuna fingers	0	0.243±0.002[f]	0.695±0.007[a]	0.938±0.005[a]	22.9±0.060[a]
	2	0.275±0.004[d]	0.624±0.004[b]	0.899±0.006[b]	19.05±0.090[b]
	4	0.326±0.005[b]	0.499±0.007[c]	0.825±0.004[c]	18.65±0.090[c]
	6	0.369±0.003[a]	0.399±0.006[d]	0.768±0.007[d]	17.91±0.070[e]
Carp fingers	0	0.187±0.006[g]	0.560±0.006[e]	0.747±0.006[e]	17.86±0.130[e]
	2	0.240±0.003[f]	0.475±0.003[f]	0.715±0.004[f]	17.97±0.090[e]
	4	0.263±0.006[e]	0.378±0.007[f]	0.641±0.007[g]	18.40±0.050[d]
	6	0.307±0.004[c]	0.286±0.005[g]	0.593±0.006[h]	18.96±0.080[b]

Mean values ± standard deviation (n=3). Means of sample having the same letter(s) within a column are not significantly different ($p<0.05$).

On the other hand, values of cooking yield were decreased during storage being (78.08and 78.66) for tuna and carp burger. Data in Table 4 showed also effect of frozen storage on cooking loss and cooking yield of tuna and carp nuggets. It was noted that cooking loss has increased during the storage cycle and cooking yield has decreased vice versa. However, the increase in cooking drip loss of samples after 6 months of frozen storage, relative to the initial cooking loss of fresh samples (zero time), was nominal, values were 20.45 being 21.98% for tuna nuggets and 20.68 being 22.04% for carp nuggets.

TABLE 4. Effect of frozen storage for six months on cooking loss and cooking yield of tuna and carp products.

Fish Products	Storage period (months)	Cooking loss (%)	Cooking yield (%)
Tuna burger	0	19.85±0.110[e]	80.15±0.070[a]
	2	20.68±0.070[d]	79.32±0.090[b]
	4	21.25±0.110[b]	78.75±0.140[d]
	6	21.92±0.090[a]	78.08±0.110[e]
Carp burger	0	19.92±0.070[e]	80.08±0.130[a]
	2	20.71±0.130[d]	79.29±0.060[b]
	4	20.92±0.110[c]	79.08±0.110[c]
	6	21.34±0.070[b]	78.66±0.150[d]
Tuna nuggets	0	20.45±0.080[d]	79.55±0.070[a]
	2	20.65±0.160[cd]	79.35±0.120[ab]
	4	21.12±0.0.230[b]	78.88±0.070[c]
	6	21.98±0.110[a]	78.02±0.140[e]
Carp nuggets	0	20.68±0.070[c]	79.32±0.120[b]
	2	20.86±0.090[c]	79.14±0.110[b]
	4	21.36±0.090[a]	78.64±0.140[d]
	6	22.04±0.110[a]	77.96±0.170[e]
Tuna fingers	0	20.56±0.120[e]	79.44±0.080[a]
	2	20.83±0.130[cd]	79.17±0.140[bc]
	4	21.24±0.120[b]	78.76±0.130[d]
	6	21.96±0.080[a]	78.04±0.150[e]
Carp fingers	0	20.74±0.120[de]	79.26±0.090[ab]
	2	21.02±0.140[c]	78.98±0.170[c]
	4	21.28±0.090[b]	78.72±0.130[d]
	6	22.14±0.140[a]	77.86±0.090[e]

Mean values ± standard deviation (n=3). Means of sample having the same letter(s) within a column are not significantly different ($p<0.05$).

Kassem & Emara (2010) indicated that during cooking, the weight loss was mostly due to moisture evaporation and dripping of melted fat. While cooking yield values were declined being 78.02 and 77.96% in tuna and carp nuggets.

Data in Table 4 showed effect of storage on cooking loss and cooking yield of tuna and carp fingers. It was noted that during the storage period, cooking loss increased and vice versa, cooking yield decreased. Nevertheless, the rise in sample cooking drip loss after 6 months of storage compared to the initial cooking loss of fresh samples (zero time) was nominal; values were 21.96 and 22.14% for tuna and carp fingers, respectively, after six months of storage. While values of cooking yield were 79.44 being 78.04 % for tuna fingers, 79.26 being 77.86 % for carp fingers.

Effect of frozen storage for six months on texture indices of tuna and carp products

Effect of frozen storage of tuna and carp fish burger in texture indices is presented in Table 5, from presented data, it could be observed that, there were a slight decrease in (PWC) and (PWFC) as duration of time of frozen storage increase, this decrease accompanied by increase in (WPC) values. Protein water coefficient (PWC) values for tuna and carp fish burger samples after six months of storage were 0.665 and 0.517%, respectively. While protein water fat coefficient (PWFC) values of the same studied samples after six months of storage were 0.406

and 0.300%, respectively. Also, water protein coefficient (WPC) values for tuna and carp fish burger samples after six months of storage were 1.50 and 1.93%, respectively. These results are in agreement with Tsoladze (1997), who indicated that protein water coefficient (PWC) and protein water fat coefficient (PWFC) used as indicator for texture and tenderness, tenderness of fresh meat and meat products increased with decreased of (PWC) and (PWFC) as vice versa.

Changes in texture indices of tuna and carp nuggets during storage were estimated as shown in Table (5), from data presented in this table, it could be observed that (PWC) and (PWFC) decreased during storage being (0.643and 0.505) and (0.390and 0.291) for tuna and carp nuggets, respectively, after six months of storage, while water protein coefficient (WPC) values were increased being 1.55 and 1.97% for tuna and carp nuggets, respectively, after six months of storage.

sample having the same letter(s) within a column are not significantly different (p<0.05).

Changes in tuna and carp fingers texture indices during storage were calculated as shown in the Table 5, from the details contained in this Table, it could be observed that (PWC) and (PWFC) decreased during storage being 0.689 and 0.549 % and 0.426 and 0.330 % for tuna and carp fingers, respectively, after six months of storage. While water protein coefficient (WPC) values were increased being 1.44 and 1.81 % for tuna and carp fingers, respectively, after six months of storage.

TABLE 5. Effect of frozen storage for six months on texture indices of tuna and carp products.

Fish Products	Storage period (months)	PWC %	WPC %	PWFC %
Tuna Burger	0	0.933±0.006^{a}	1.07±0.050^{g}	0.627±0.005^{a}
	2	0.838±0.007^{b}	1.19±0.040^{f}	0.554±0.004^{b}
	4	0.718±0.008^{d}	1.39±0.070^{d}	0.459±0.008^{d}
	6	0.665±0.005^{f}	1.50±0.040^{c}	0.406±0.005^{f}
Carp Burger	0	0.766±0.003^{c}	1.30±0.020^{e}	0.495±0.006^{c}
	2	0.699±0.007^{e}	1.43±0.050^{cd}	0.433±0.005^{e}
	4	0.570±0.006^{g}	1.75±0.040^{b}	0.339±0.003^{g}
	6	0.517±0.009^{h}	1.93±0.080^{a}	0.300±0.005^{h}
Tuna nuggets	0	0.882±0.006^{a}	1.12±0.040^{g}	0.611±0.004^{a}
	2	0.816±0.006^{b}	1.22±0.050^{f}	0.533±0.005^{b}
	4	0.698±0.006^{d}	1.43±0.030^{d}	0.439±0.005^{d}
	6	0.643±0.005^{f}	1.55±0.040^{c}	0.390±0.005^{f}
Carp nuggets	0	0.748±0.007^{c}	1.33±0.030^{e}	0.477±0.006^{c}
	2	0.683±0.006^{e}	1.46±0.020^{d}	0.418±0.006^{e}
	4	0.542±0.005^{gh}	1.84±0.050^{b}	0.318±0.007^{g}
	6	0.505±0.004^{h}	1.97±0.030^{a}	0.291±0.002^{h}
Tuna fingers	0	0.964±0.003^{a}	1.03±0.020^{g}	0.680±0.008^{a}
	2	0.865±0.003^{b}	1.15±0.030^{f}	0.579±0.002^{b}
	4	0.747±0.005^{d}	1.33±0.030^{d}	0.446±0.004^{e}
	6	0.689±0.003^{f}	1.44±0.030^{c}	0.426±0.005^{f}
Carp fingers	0	0.796±0.005^{c}	1.25±0.050^{e}	0.520±0.003^{c}
	2	0.731±0.006^{e}	1.36±0.030^{d}	0.459±0.003^{d}
	4	0.617±0.008^{g}	1.61±0.070^{b}	0.374±0.004^{g}
	6	0.549±0.004^{h}	1.81±0.030^{a}	0.330±0.008^{h}

Mean values ± standard deviation (n=3).

Means of sample having the same letter(s) within a column are not significantly different (p<0.05)

Conclusion

Assessment results of the products processed from tuna and carp fish introduce very good records in their quality characteristics when freshly prepared. In addition, the results also show good properties in frozen tuna and carp products concerning some chemical, physiochemical and texture indices through 6 months of frozen storage at - 18 °C with slight changes in some parameters but it was within recommended safe levels. It could be concluded that products processed from tuna and carp fish showed high quality characteristics in freshly prepared and after frozen storage. So, it could be recommended that commercial production of these tuna and carp products will achieve a good marketing.

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