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Effect of Some Food Additives on Carp Fish Nugget Quality During Frozen Storage

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ABSTRACT

The effects of locust bean gum, xanthan, pectin and turmeric on proximate composition, cooking quality, physicochemical, microbiological, and sensory properties of common carp fish nuggets stored for three months at -18°C were studied. The results showed that moisture contents of T1 (control), T2 (locust), T3 (xanthan), and T4 (pectin) pre-fried common carp fish nuggets were significantly decreased at the end period of the frozen storage. On the other hand, crude protein, lipids, and ash contents of (T1, T2; T3, and T4) pre-fried common carp fish nuggets were significantly increased at the same period of the frozen storage. Cooking loss percentages of the nugget treatments during frozen storage were significantly increased at the end of the frozen storage. The highest values of cooking loss were found in T1 (control), followed by T3 (xanthan), T4 (pectin), and T2 (locust). On the contrary, cooking yield recorded higher values in T2 (locust), compared to T4 (pectin), T3 (xanthan), and T1 (control), recording less values, respectively. The water holding capacity values were significantly decreased at the end of three months of frozen storage. TVBN, TMA, and TBA contents of T1 (control), T2 (locust), T3 (xanthan), and T4 (pectin) pre-fried common carp fish nuggets were reached at the end of frozen storage. For the microbiological quality of treated fish nuggets with respect to the highest effect, it was obtained for locust (T2), followed by pectin (T4) and xanthan (T3), which reduced the microbial growth. The obtained results showed that thickening agents were significantly improved regarding color, tenderness, juiciness, taste, flavor, and overall acceptability of fish nuggets, compared to the control samples, also there was a gradual decrease in sensorial values during the freezing storage.

INTRODUCTION

Fish nugget is one of the modern food, made from ground fish meat with the addition of spices and formed, then covered with a coating (coating and breading), followed by frying **(Rario, 2015)**. Fish nuggets are considered one of the most favorite convenient food products worldwide due to the higher nutritional value, attractive organoleptic properties, safety for consuming, moderate price and ready- eat fish products **(Barbut, 2012).** Fish nugget production is one of the fish processing techniques that can increase the value and reduce the postharvest loss in the fishing industry **(Oppong, *et al*.,**

2021). Fried foods are tasty with unique flavor-texture combination and their attractive appearance, which is responsible for the great acceptance of these foods **(Da Silva and Moreira 2008)**.

Many studies have been conducted on fish nuggets to improve its quality and extend its shelf life, e.g. the addition of dextrin into batter formulation, and using a package containing a subsector material to improve the crunchiness of hake fish nuggets for microwave final cooking **(Albert *et al*., 2009)**. The crust qualities of *Coryphaena hippurus* fish nuggets by either 5 min deep-fat frying or 3.5min microwave frying were evaluated by **Chen, *et al*. (2009)**. Moreover, the effects of soy and corn flour (5 and 10% w/w) added to the batter formulation on the quality of deep fat-fried shrimp nuggets were evaluated in the study of **Nasiri, *et al*. (2012)**. **Jayasinghe, *et al*. (2013)** used lentil, chickpea and cowpea grains as extenders with their flour in preparation of tilapia fish nuggets. **Jamshidi and Shabanpour (2013)** studied the effect of hydroxypropyl methylcellulose (HPMC) added to predust and batters of Talang queen fish (S. *commersonnianus*) nugget on the quality and its shelf life during four months of frozen storage. **Rario (2015)** determined the characteristics of the organoleptic quality of catfish (*Pangasius pangasius*) nuggets. **Moosavi-Nasab, *et al*. (2019)** prepared surimi from *S. commersonnianus* and used it for nugget formulation. **Bonfim *et al*., (2019)** examined the possibility of partial replacement of coating flour by fish (*Priacanthus arenatus*) waste flour during the processing of pre-fried and fried fish nuggets. **Rajkowski *et al.* (2013)** tested catfish nuggets for aerobic plate count, *Enterobacteriaceae*, and *Escherichia coli/coliform*, using petrifilms.

Thus, the objectives of this study was to compare the effects of locust bean gum, xanthan, pectin and turmeric on chemical composition, cooking properties, physicochemical, microbiological and sensory quality properties of pre-fried common carp nuggets stored for three months at -18±1ºC.

MATERIALS AND METHODS

Materials

Fifty kg of fresh common carp (*Cyprinus carpio* L.) fish samples were obtained from Manzala aquatic farm belonging to GAFAD, Egypt during December 2019. They were immediately transported using ice box within one hour to Fish Processing and Technology Laboratory, El-Kanater El-Khairia Fish Research Station, National Institute of Oceanography and Fisheries, Egypt. The mean values ± STDEV of total lengths and weights of the collected fish samples were recorded (44±6.11 cm and 4.45±0.51 kg), respectively. Afterwards, samples were washed using tap water, beheaded, removed of scales, fins, skin, viscera and large bones, then filleted, rewashed and drained. The yield of flesh achieved by hand-filleting was 45.50%. Fish fillets were soaked in saturated brine solution (26% of sodium chloride) containing 0.02% of acetic acid for 1- 2min at ambient temperature, washed with tap water and drained. Treated fillets were trimmed to obtain cubic shape for coated nuggets, which were prepared from dorsal muscles.

Preparation of common carp fish nuggets

Common carp fish nuggets were processed according to the method reported by **Abdel Aziz (2013)**, with some modifications using the recipes displayed in Table (1).

Table 1. Fish nuggets recipes for the current study

Treatments	T1	T2	T3	T4
Ingredient	%			
Minced fish	88.36	88.36	88.36	88.36
Eggs	1.50	1.50	1.50	1.50
Chopped onion	3.50	3.50	3.50	3.50
Edible salt	0.28	0.28	0.28	0.28
Black pepper	0.22	0.22	0.22	0.22
Cumin	0.33	0.33	0.33	0.33
Thyme	0.22	0.22	0.22	0.22
Ginger	0.22	0.22	0.22	0.22
Cardamom	0.22	0.22	0.22	0.22
Cubeb	0.22	0.22	0.22	0.22
Bread crumb	2.31	2.31	2.31	2.31
Starch	2.62	2.62	2.62	2.62
Turmeric	0.00	1.00	1.00	1.00
Locust bean	0.00	1.00	0.00	0.00
Xanthan	0.00	0.00	1.00	0.00
Pectin	0.00	0.00	0.00	1.00

T1 = Control, T2 = Locust beean gum, T3= Xanthan gum and T4= Pectin.

Fish nuggets (T1, control; T2, locust beean gum; T3, xanthan gum and T4, pectin) were shaped into equal cubic pieces, dipped in beaten egg, separately rubbed with wheat flour and bread crumb. Fish nuggets were cooked by deep frying, using electrical fryer pan (Moulinex brand) in sun flower oil that was preheated at 170^{o}C for 30sec., drained in basket to remove excess oil and cooled at room temperature (25±2°C). Finally, all batches were separately packaged in polyethylene bags and stored at -18±1°C for 3 months. The samples were analyzed immediately after processing and monthly during storage period for chemical, physical, microbiological and sensory quality characteristics.

Analytical methods

Proximate chemical composition and cooking characteristics analysis

Moisture, crude protein, lipid and ash were determined according to **AOAC (2012)**. The cooking yield and cooking loss of the processed fish products samples were determined according to the method of **Niamnuy *et al.* (2008)**. Water holding capacity (WHC) was determined according to **Hennigar *et al.* (1988)**. The pH value was measured as described by **Egbert *et al.* (1992)**. Total volatile basic nitrogen (TVB-N) contents were determined according to **AOAC (2012)**, trimethylamine nitrogen (TMA-N) contents were determined as mentioned by **Pearson (1976)** and thiobarbituic acid (TBA) values were determined according to **Siu and Draper (1978)**.

Microbiological and sensory analysis

The total bacterial count (TBC) was determined according to **ISO (2003)** by using nutrient agar medium as described by **Oxoid (2006)**. Aerobic spore former bacteria were determined according to the method described in **APHA (2001)**. The *E. coli* was determined by using violet red bile lactose (VRBL) agar medium according to **ISO (2001)**. *Salmonella and shigella* bacteria counts were determined according to **ISO (2002)** by using commercial S.S Agar (Salmonella and shigella agar) medium **(Oxiod CM 0099, OXIOD)**, incubated at 37±1ºC for 48h. Yeast and mold counts were determined in accordance with **ISO (2008)**. Sensory evaluation was assessed according to the procedure of **Teeny and Miyaauchi (1972)**.

Statistical analysis

Data were expressed as the mean values of three replicates, and standard deviations were statistically analyzed by performing the analysis of variance technique (ANOVA), using the statistical analysis system according to **SAS (2008)**. Differences among means were compared using Duncan's multiple range test (1955) at significant level 95% ($P \leq 0.05$).

RESULTS AND DISCUSSION

Proximate composition of fish nuggets

Proximate composition of frozen common carp fish nuggets are shown in Fig. (1). Generally, it could be noticed that moisture and carbohydrate contents were significantly decreased; while, crude protein, lipids and ash contents were significantly increased during the frozen period. On the other hand, thickening agents significantly increased the moisture content in pre-fried common carp fish nuggets treated samples, compared to the control at the beginning time of the storage period.

The moisture content (%) tended to have a downward pattern of change since it started by 53.48, 55.97, 55.63 and 55.75% for T1 (control), T2 (locust), T3 (xanthan) and T4 (pectin), respectively, for pre-fried common carp fish nuggets at zero time, while it significantly decreased to 48.86, 51.86, 49.77 and 51.84%, respectively, at the end of frozen storage. Consequently, these results indicate a reversible relation between moisture content and frozen storage period. Additionally, this decrease in moisture content might be due to the decrease in their water holding capacity and to cell damage caused by the ice crystals formed during freezing **(Reddy *et al*., 2012)**.

Results of the present work (Fig. 1) show that, pre-fried common carp fish nuggets produced by different treatments led to a similar trend in the tested samples, and the highest reduction in moisture content was observed in the control, followed by xanthan. The lower reduction in moisture content was noticed in locust and pectin. These results are in accordance with those obtained by **Jeon *et al*. (2002)**.

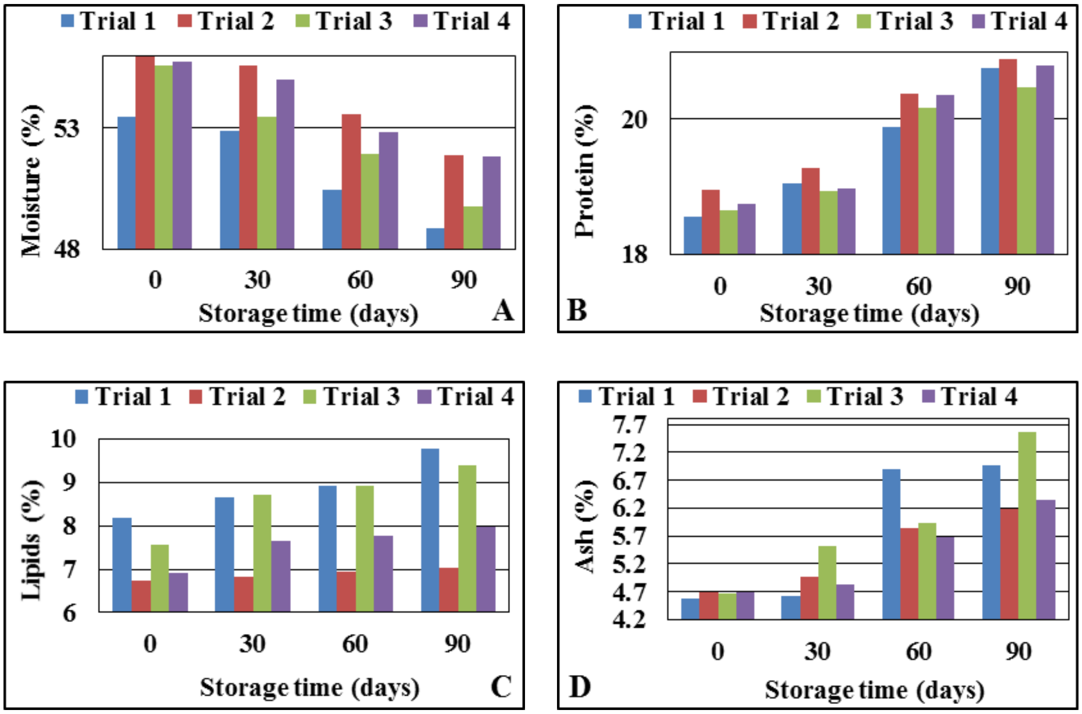

Fig. 1. Proximate composition of frozen common carp fish nuggets

Crude protein contents of pre-fried common carp fish nuggets were 18.56, 18.96, 18.65 and 18.74%, for T1, T2, T3 and T4, respectively, at zero time, while it significantly increased to 20.76, 20.88, 20.47 and 20.79 %, respectively, at the end of frozen storage (Fig. 1); the increase in the protein content may be attributed to the decrease in moisture (Talab, 2014).

Crude lipids contents of T1 (control), T2 (locust), T3 (xanthan) and T4 (pectin) pre-fried common carp fish nuggets were 8.17, 6.75, 7.56 and 6.92%, respectively, at zero time, while it significantly increased to 9.76, 7.04, 9.38 and 7.96 %, respectively, at the end of frozen storage, as seen in Fig. (1). The increase in lipid content may be attributed to the decrease in moisture **(Saguy & Dana, 2003; Talab, 2014)**.

Moreover, changes in ash content of pre-fried common carp fish nuggets through storage at -18°C for 3 months as influenced by the addition of different components and frozen storage are given in Fig. (1).

Crude ash contents (T1, T2, T3 and T4) of pre-fried common carp fish nuggets were 4.57, 4.69, 4.66 and 4.68%, respectively, at zero time, while it significantly increased to 6.97, 6.19, 7.56 and 6.35%, respectively, at the end of frozen storage. The increment rates in ash content of the tested fishery products were different, but the highest increment was found in xanthan, followed by control, respectively. The increase in ash content was mainly due to the salt addition, the other minerals found in recipe components including minerals during formulating process. Additionally, the increase in ash content during storage may be attributed to the decrease in moisture **(Zaitsev *et al.*, 1969; Kilinc *et al.*, 2008)**.

On the other hand, the addition of thickening agents during the processing of fish nuggets led to reduction in lipid & carbohydrates compared to control samples, while it led to increase in protein and ash values. Similar results were reported in the study of **Jayasinghe *et al*. (2013)**, who detected a significant increase in protein and energy values of tilapia fish nuggets after incorporation of legume flour as extenders, and they pointed out this increase to the added materials, which may contain relatively an amount of protein. While, the increase in the protein, ash contents and the reduction in lipid, carbohydrates of fish nuggets may be attributed to the decrease in moisture content **(Ordonez-Ramos, *et al*., 2012; Talab, 2014)**.

Cooking characteristics of fish nuggets

Fig. (2) shows the effect of thickening agents on cooking characteristics of pre-fried common carp fish nuggets stored at -18±1°C for 3 months. Cooking loss percentages of control, locust, xanthan and pectin pre-fried common carp fish nuggets were 15.55, 15.13, 14.33 and 12.82%, respectively, at zero time, while they significantly increased to 24.92, 17.21, 21.35 and 19.41%, respectively, at the end of frozen storage. On the other hand, the highest values of cooking loss were found in the control, followed by xanthan, pectin and locust.

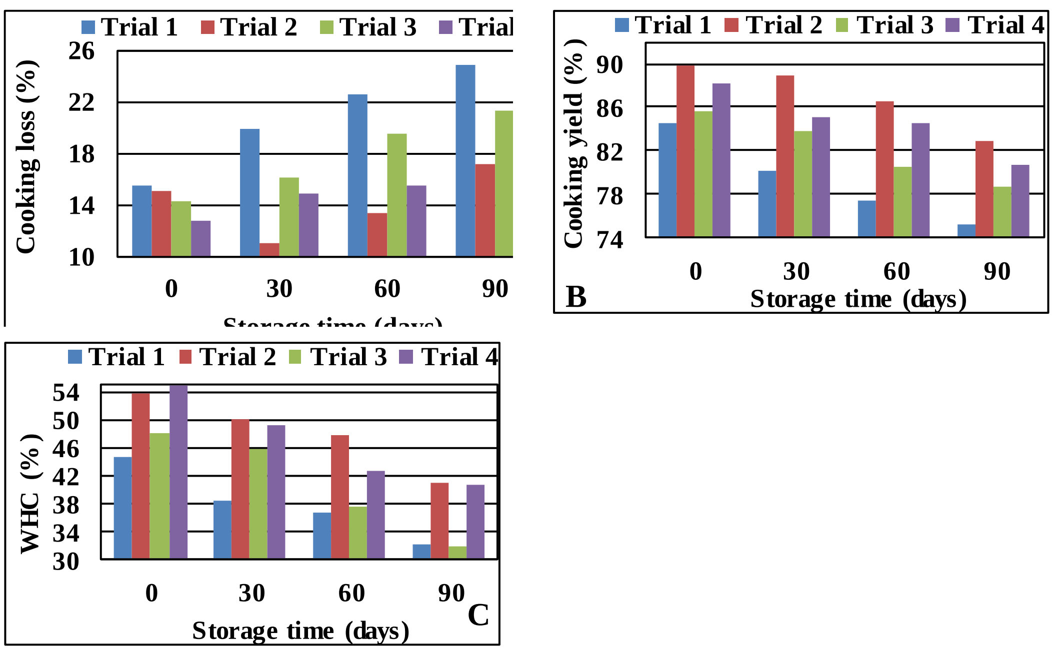

Fig. 2. Cooking loss (%), cooking yield (%) and water holding capacity of fish nuggets

Cooking yield has been reported as the most important criteria to predict behavior of meat products during cooking **(Pietrassik & Duda, 2000)**. It is usually related to the ability of the protein matrix to retain water and bind fat **(Rocha-Garza & Zayas, 1996)**. On the contrary, cooking yield recorded higher values in locust, followed by pectin, xanthan and control. The values of cooking yield for T1, T2, T3 and T4 were 84.45, 89.87, 85.67 and 88.18%, respectively, at zero time, which significantly decreased to 75.08, 82.79, 78.65 and 80.59%, respectively, at the end of three months of frozen storage. Cooking yield is related to fat and water retention **(Aleson- Carbonell *et al.*, 2005)**; the lowest cooking yield was attributed to the highest fat separation and water release during cooking **(Bozkurt & Icier, 2010)**.

The water holding capacity (WHC) of pre-fried common carp fish nuggets samples containing different additives of the aforementioned ones during frozen storage at -18°C for 3 months are given in (Fig. 2). The values of water holding capacity for treatments (T1, T2, T3 and T4) were 44.66, 53.61, 47.94 and 54.90%, respectively, at zero time, which significantly decreased to 32.14, 40.99, 31.86 and 40.63%, respectively, at the end of three months of the frozen storage.

Water holding capacity showed a different trend for the effect of thickening agents, where pectin was the highest value, followed by locust, xanthan and control. It could be noticed that the WHC of all samples progressively decreased with the increase of the outer zones, resulting from the secretion of water from samples throughout the storage period. The xanthan sample had the lowest WHC values after 3 months of frozen storage (31.86%), compared to other samples containing different substances. However, pre-fried common carp fish nuggets samples including the control and locust were recorded as the semi stability of WHC during frozen storage, they reached the loss in WHC after 3 months with 12.52 and 12.62%, respectively.

Physicochemical quality properties of fish nuggets

Effect of thickening agents on pH of frozen fish nuggets are shown in Fig. (3). The pH level increased gradually during storage for all formulas; the pH value of control, locust, xanthan and pectin pre-fried common carp fish nuggets at zero time were 5.53, 6.39, 6.50 and 6.42, respectively, and reached values of 5.44, 6.29, 6.15 and 6.20 at the end of frozen storage, respectively. The decline in pH value during storage was attributed to the formation of lactic acid from glycogen as a result of autolysis **(Aycicek *et al*., 2004; Kilinc *et al*., 2008)**.

Data showed that the highest pH values were obtained for pre-fried common carp fish samples containing xanthan, followed by pectin at the initial time of storage. Whereas, the high reduction rate in the pH values was found in the same samples at the end of storage period. On the other hand, the pre-fried common carp fish samples including the control and locust were more stable for the change in the pH during the storage period.

Results in Fig. (3) reveal that, the TVB-N, TMA and TBA contents of control, locust, xanthan and pectin pre-fried common carp fish nuggets at zero time were 15.47, 14.71, 15.57 and 15.62mg/ 100g; 3.12, 2.36, 2.84 and 2.49 mg/ 100g and 1.04, 0.83, 0.97 and 0.87mg MDA/kg, respectively. While, these values reached 24.96, 18.42, 19.35 and 18.94mg/ 100g; 6.84, 3.42, 4.66 and 3.78mg/ 100g and 2.95, 2.39, 2.73 and 2.45mg

MDA/kg, respectively, at the end of frozen storage. The TVB-N content increased during the storage of different pre-fried common carp fish nuggets samples.

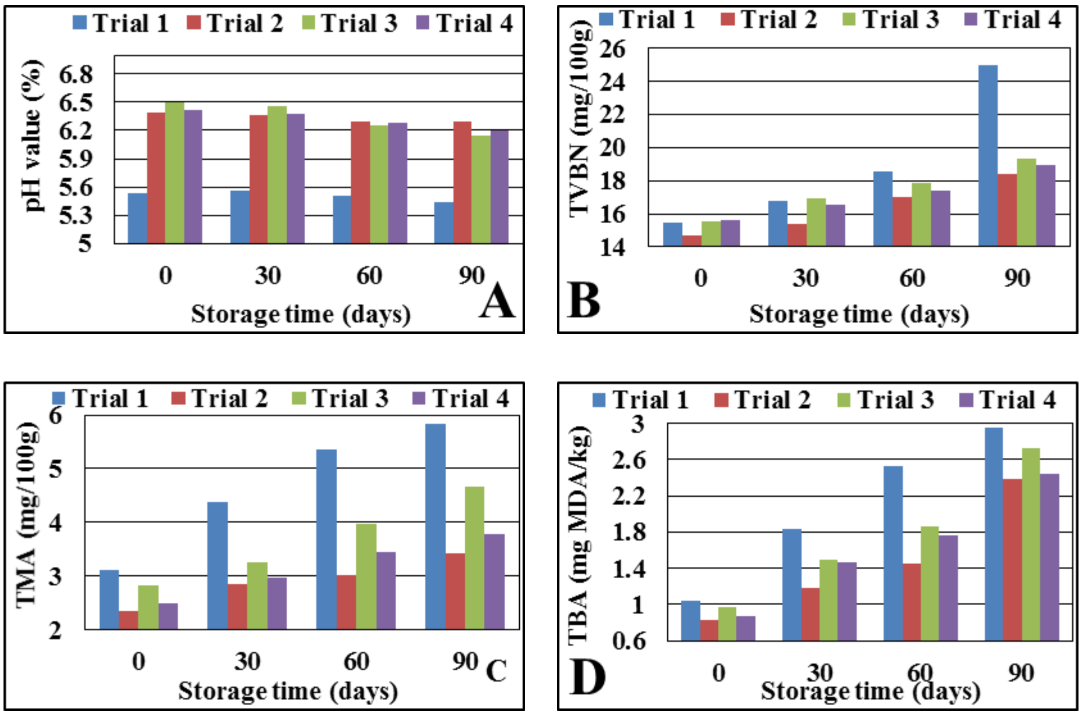

Fig. 3. Physicochemical properties of frozen common carp fish nuggets

Results also revealed that the control sample recorded the highest increase in TVB-N content, with a value of 24.96mg/ 100g after 3 months, compared to the other samples. The increase in TVB-N during the frozen storage of fish nuggets samples might be attributed to the breakdown of nitrogenous substances by microbial activity. On the other hand, the initial and the final TVB-N values of all samples did not exceed the upper acceptability limit after 90 days of the frozen storage. This fact was indicative of either a faster reduction of bacterial population or decreased capacity of bacteria for oxidative domination of non-protein nitrogen compounds **(Fan *et al.*, 2009)**.

In addition, data showed that, the control sample had the highest increase in TMA-N content, with 6.84mg/ 100g after 3 months, compared to the other samples. The pre-fried common carp fish nuggets samples had good levels of acceptance after the storage period. The increased TMA-N values might be due to the increase of microbial content and enzyme activities, specifically in fresh samples. However, pre-fried common carp fish nuggets samples formulated locust, xanthan and pectin showed more stability of increase in TMA-N content during the frozen storage.

Data presented in Fig. (3) clarify that, the TBA significantly increased (P<0.05) between control samples and treated fish nuggets, and it was obviously characterized in the 2- month frozen storage. According to the above- mentioned and displayed data in Fig. (3) concerning lipid oxidation such as TBA, all the components used in different formulas were with acceptable efficacy to retard lipid oxidation in pre-fried common carp fish nuggets during the frozen storage. Therefore, the locust, xanthan and pectin of investigated substances showed the best ability for preserving the fat quality of the fish nuggets products. The increase in the value of TBA may be due to the increase of lipid content compared to the lipid oxidations, resulting from the action of lipolytic enzymes (lipases and phospholipases) through which fish phospholipids undergo degradation to produce hydroperoxides, aldehydes and ketones, which are responsible for the development of oxidative rancidity (**Raharjo *et al*., 1992**).

Microbiological quality properties of frozen fish nuggets

Table (2) exhibits the microbiological quality properties of frozen common carp fish nuggets stored at -18±1°C for 3 months. TPC, Y&M, SFB and TC counts of control, locust, xanthan and pectin pre-fried common carp fish nuggets at zero time were 3.94, 3.36, 3.87 and 3.76 log cfu/g; 1.96, 1.29, 1.87 and 1.76 log cfu/g; 1.28, 1.02, 1.23 and 1.19 log cfu/g and 1.25, 1.15, 1.19, 1.17 log cfu/g, respectively. While, these values reached 2.87, 2.15, 2.18 and 2.10 log cfu/g; 1.55, 1.02, 1.26 and 1.15 log cfu/g, 1.09, nd, nd, nd log cfu/g and 1.00, nd, nd, nd log cfu/g respectively, at the end of frozen storage.

Table 2. Microbiological quality properties of frozen common carp fish nuggets

Storage period (day)	TPC (log cfu/g)				YMC (log cfu/g)			
	T1	T2	T3	T4	T1	T2	T3	T4
0	3.94	3.36	3.87	3.76	1.96	1.29	1.87	1.76
30	3.76	2.75	3.26	2.95	1.90	1.20	1.76	1.43
60	3.32	2.36	2.88	2.48	1.79	1.12	1.56	1.20
90	2.87	2.15	2.18	2.10	1.55	1.02	1.26	1.15
	SFBC (log cfu/g)				**TCC(log cfu/g)**			
0	1.28	1.02	1.23	1.19	1.25	1.15	1.19	1.17
30	1.23	1.00	1.18	1.10	1.18	1.08	1.13	1.09
60	1.15	≤1	1.03	≤1	1.12	1.00	1.08	1.05
90	1.09	≤1	≤1	≤1	1.00	≤1	≤1	≤1

Note: (**TPC**): Total plate counts; (**YMC**): Yeast and mold counts; (**SFBC**): Spore forming bacterial counts; (**TCC**): Total coliform count; **(T1)**: control sample; (T2): (1% locust bean gum+1% turmeric); **(T3):** (1% xanthan+1% turmeric); **(T4)**: (1% pectin +1% turmeric).

On this basis, the differences among treated samples might be ascribed to the difference in their antimicrobial activity. The highest reduction effect was obtained from the locust, xanthan and pectin, compared to the control, while the general best effect is reduced bacterial growth (total bacterial count, yeast and molds, spores forming bacterial) in fish nuggets obtained from locust. The reduction in microbial counts during frozen storage may be due to the mechanical destroy of bacterial cell due to crystals during freezing and the powerful antimicrobial properties of food additives **(Block, 1992)**.

Sensorial quality properties of fish nuggets

The effect of thickening agents on sensorial quality properties of pre-fried common carp fish nuggets stored at -18±1°C for 3 months are shown in Table (3). The obtained results showed that, thickening agents were significantly improved regarding color, tenderness, juiciness, taste, flavor and overall acceptability of fish nuggets in comparison with control samples; a gradual decrease was detected in sensorial values during freezing storage.

Table 3. Sensory quality properties of frozen common carp fish nuggets

Storage period (day)	**Color**				**Tenderness**			
	T1	T2	T3	T4	T1	T2	T3	T4
0	8.67^{aD}	9.50^{aA}	9.38^{aB}	9.48^{aA}	8.68^{aD}	9.65^{aA}	9.13^{aC}	9.58^{aB}
30	8.00^{bD}	9.35^{bA}	9.17^{bC}	9.32^{bB}	8.25^{bD}	9.42^{bA}	9.01^{bC}	9.36^{bB}
60	7.59^{cD}	9.08^{cA}	8.85^{cC}	9.01^{cA}	8.01^{cD}	9.22^{cA}	8.77^{cC}	8.98^{cB}
90	7.24^{dC}	8.50^{dA}	8.13^{dB}	8.42^{dB}	7.89^{dD}	8.66^{dA}	8.15^{dC}	8.30^{dB}
	Juiciness				**Taste**			
0	8.77^{aD}	9.44^{aA}	9.06^{aB}	9.25^{bB}	9.28^{aC}	9.60^{aA}	8.80^{aD}	9.45^{aB}
30	8.41^{bD}	9.38^{bA}	8.89^{bC}	9.04^{bB}	9.00^{bC}	9.48^{bA}	8.68^{bD}	9.40^{bB}
60	8.28^{cD}	9.11^{cA}	8.70^{cC}	8.92^{cB}	8.56^{cC}	9.17^{cA}	8.53^{cD}	9.15^{cB}
90	8.06^{dC}	8.89^{dA}	8.65^{dB}	8.80^{dA}	8.32^{dC}	8.95^{dA}	8.85^{dD}	8.86^{dB}
	Flavor				**Over acceptability**			
0	8.98^{aC}	9.65^{aA}	9.45^{aB}	9.58^{aA}	8.66^{aC}	9.35^{aA}	9.18^{aB}	9.24^{aB}
30	8.87^{bC}	9.48^{bA}	9.30^{bB}	9.45^{bA}	8.50^{bC}	9.27^{bA}	9.03^{bB}	9.19^{bA}
60	8.42^{cC}	9.30^{cA}	9.18^{cB}	9.28^{cA}	8.32^{cB}	8.95^{cA}	8.89^{cA}	8.90^{cA}
90	8.25^{dC}	9.16^{dA}	9.05^{dB}	9.12^{dA}	8.15^{dD}	8.78^{dA}	8.46^{dB}	8.55^{dB}

Note: **(T1):** control sample; (T2): (1% locust bean gum+1% turmeric); **(T3):** (1% xanthan+1% turmeric); **(T4):** (1% pectin +1% turmeric); Means followed by different small letters in the same column (effect of storage period) are significantly by Duncan´s multiple tests ($p\leq0.05$); Means followed by different capital letters in the same raw (effect of treatment) are significantly by Duncan´s multiple tests ($p\leq0.05$).

Our results on the effect of thickening agents on sensory quality properties of common carp fish nuggets proved that, the incorporation of thickening agents during processing of fish nuggets caused a significant decrease in the moisture content of pre-fried common carp fish nuggets during frozen storage, and this may be attributed to cell damage caused by the ice crystals formed during freezing **(Reddy *et al*., 2012; Hassanine *et al*., 2017).**

Fish nuggets processed using locust recorded the highest values of color, tenderness, juiciness, taste, flavor and overall acceptability during frozen storage, followed by pectin treatment, then xanthan treatment, compared to control without addition of any thickening agents. Sensory evaluation illustrated that, all added thickening agents used for producing pre-fried common carp fish nuggets had improved the sensorial quality properties of fish nuggets, while the best thickening agents was the mixture of 1% locust bean gum and 1% turmeric followed by a mixture of 1% pectin + 1% turmeric and then a mixture of 1% xanthan and 1% turmeric, respectively.

CONCLUSION

Results showed that, thickening agents significantly improved the color, tenderness, juiciness, taste, flavor and overall acceptability of fish nuggets, compared to the control samples, and there was a gradual decrease in sensorial values during freezing storage. On the other hand, fish nugget prepared using locust bean gum gave the best effect on quality properties.

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