World Journal of Fish and Marine Sciences 5 (4): 382-391, 2013
ISSN 2078-4589

DOI: 10.5829/idosi.wjfms.2013.05.04.7361

The Effect of Hydroxypropyl methylcellulose (HPMC) Gum Added to Predust and Batters of Talang Queen fish (*Scomberoides commersonnianus)* Nuggets on the Quality and Shelf Life during Frozen Storage (-18°C)

Aniseh Jamshidi and Bahareh Shabanpour

Department of Fisheries, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Golestan, Iran

Abstract: In the present study the effect of Hydroxypropyl methylcellulose (HPMC) added to predust and batters of Talang queen fish *(Scomberoides commersonnianus)* nugget on the quality and its shelf life during four months of frozen storage were evaluated. The treatments consisted of control (without HPMC in coating), A (with 2%HPMC in pre-dust), B (with 2%HPMC in batter) and C (with 1% HPMC in pre-dust and 1%HPMC in batter). The par-and final frying of the fish nuggets were analyzed from viewpoint of proximate composition (moisture, lipid content, total crude protein and ash) at the first time and the par-frying nuggets from viewpoint of chemical parameters (thiobarbituric acid and free fatty acid), microbial (total count, mesophilic and psychrotrophic), color, pH and sensory evaluation periodically (each month). The amount of total crude protein, ash and pH were the same as in various treatments of par- and final frying fish nuggets ($p \leq 0.05$), whereas, the amount of moisture and lipid showed significant difference, in way that, sample B with 2%HPMC in batter, showed highest moisture retention and lowest lipid content ($p \leq 0.05$) compared to other samples. During four months storage lightness and yellowness indexes, mesophilic count and overall acceptability reduced and pH, thiobarbituric acid and free fatty acid increased significantly ($p \leq 0.05$). The obtained results of the study indicated that the use of HPMC in coated products had no effect on the shelf life and the best result for moisture retention and reduced oil uptake was shown obtained in sample B with adding 2% HPMC in batter.

Key words: Hydroxypropyl Methylcellulose (HPMC) · Fish Nugget · Talang Queen fish (*Scomberoides commersonnianus*) · Deep-Frying · Frozen Storage

INTRODUCTION

With increasing population and industrialization of cities, there is a growing trend of consuming ready to eat products. Among the ready to eat meat products, fish meat products have a special place due to its nutritional value. these products may include fish burgers, fish finger, fish sausages and fish nugget. Fish nugget is a product produced by formation of boneless fish fillets. Fish nuggets undergo production process of pre-dusting, then battering and breading and after being par-fried in hot oil, freezed, packaged and stored [1].

The process of battering and breading provides special functions in food products including improved in appearance of the products, increased texture crispiness, reduced oil uptake during the frying process and increased the shelf life of the coated products [2-4]. These products are often stored and marketed frozen. Generally fish and its products can be exposed to decadence and undesirable changes during the frozen storage. These changes that reduced the shelf life of products [5], can be the result of protein denaturation, lipid oxidation, the activity of endogenous enzymes and metabolic activities of microorganisms [6].

Various protective methods are used in order to delay decay process in ready to eat products. Edible coatings made from materials such as polysaccharide, protein and fats can increased the shelf life of food products and acts as a barrier to soluble and gaseous substances [7].

Corresponding Author: Aniseh Jamshidi, Department of Fisheries, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran.

Cellulose and its derivatives such as methyl cellulose (MC) and hydroxypropyl methyl cellulose (HPMC) which constitute gel-like structure on heating, can be used as edible films in combination of pre-dust and batter in battered and breaded products [4, 8-9]. These compounds have been used in some studies, but the simultaneous application of them in pre-dusting and battering and their role in the quality and shelf life of food products has not been studied.

Talang queen fish belongs to *Carangidae* family with average length 90cm which is mostly consumed in fresh, frozen, dried and salted form. Due to its appropriate cost, tight texture and tasty flavor we can produce battered and breaded products from this kind of fish and put it more in household food basket.

The aim of the present study was to evaluate the effects of HPMC added to the pre-dust and batter of Talang queen fish nuggets on the quality and shelf life of par-fried product during frozen storage.

MATERIALS AND METHODS

Food Matrix, Battered and Breaded Talang Queen Fish Nuggets: Talang queen fish (*Scomberoides commersonnianus*) were caught on 21 Nov 2010 and stored in the ice for one day and moved to local market. Then the fishes were bought from the local market and frozen at -18 °C for one day. After thawing, the fishes were beheaded, gutted, washed and filleted by hand. The flesh achieved was 49.08%. The fillets were cut with a sharp knife into rectangular-shaped portions (fish nuggets) in measures of 30±1, 50±1 and 20±1 and weights of 27±3 g and then they were packaged and stored in a freezer at -20 °C for three days until processing stage.

Wheat flour was used as the pre-dust and for different patterns the percentage of blending of wheat flour and hydroxypropyl methylcellulose (HPMC, Methocel E4M, Sigma Co) for pre-dust was mentioned in Table 1. The batter formula was utilized according to the Chen *et al.* [9] formula which consists of wheat flour, cornstarch, gluten, leavening, HPMC and salt (Table 2). Breadcrumb was purchased from an Iranian Solar Co, Ltd. In this study the amount of 2% HPMC was added to the pre-dust and batters formula for patterns A and B respectively and then chopped in 1% HPMC in the pre-dust and 1% HPMC in the batter for pattern C.

The batters of each patterns were prepared in three separated replications and dry ingredients of every batter was thoroughly pre-blended and mixed with water at 10 °C in ratios of 1:1/5 (water to solid ratio) for 2 minutes. The chopped portions of Talang queen fish after being thawed at room temperature and being pre-dusted with wheat flour for control and blended with wheat flour and HPMC for A to C patterns, were immersed in the batters and after being dripped for 1 minute were breaded with conventional breading crumbs. The battered and breaded Talang queen fish nuggets were par-deep-fried in sunflower oil at 190°C for 30 second

Table 1: Ingredients in pre-dust of Talang queen fish nuggets

Ingredients (%)	Control	Pattern A	Pattern B*	Pattern C
Wheat flour	100	98	100	99
Hydroxypropyl methylcellulose	0	2	0	1

*Pattern B have 2% HPMC in batter, thus the pattern was without HPMC in pre-dust.

Table 2: Ingredients in batters formula of Talang queen fish nuggets

	Patterns			
Ingredients (%)	Control	A*	B	C
Wheat flour	55	55	53	54
Cornstarch	30	30	30	30
Gluten	10	10	10	10
Leavening	2	2	2	2
HPMC	-	-	2	1
Salt	3	3	3	3

*Pattern A have 2% HPMC in pre-dust, thus the pattern was without HPMC in batter.

(Moulinex Toucan Automatic fryer, Portugal) and after each batch of frying, the internal pan of the fryer was washed and dried. After being allowed to cool at room temperature, the nuggets were packaged in Ziploc bags and stored at -20 °C for 3 days. The analysis was performed in both par-fried and final fried nuggets at 180 °C for 2 minutes. The fried samples were cooked without thawing.

Proximate Composition: Fat, moisture, crude protein and ash of fish nuggets were determined by standard procedures of Association of Official Analytical Chemists [10].

The pH Measurement: The pH measurement was carried out using a pH Lat Stirrer Metrohm model 728 pH meter. Fish nugget (5 g) was homogenized thoroughly with 45 ml of distilled water and the homogenate was subjected to pH determination in a room temperature according to the method of Das *et al*. [11].

Determination of Thiobarbituric Acid: According to method of Kilinc *et al*. [12], 10 g of sample was homogenized with 97.5 ml distilled water and 2.5 ml 4 N HCl solution, three drops of anti-foam and some boiling stones were added. The blend was heating up in balloons 50 ml and the extract was obtained within 10 minutes of boiling time. 5 ml of the extract with 4 ml TBA reagent (0.02 M of the 2-thiobarbituric acid in 90% acetic acid) were blended and heated in a boiling water bath for 30 minutes and then cooling in water tap for 10 minutes, the absorbance was measured at 538 nm against blank.

Free Fatty Acid: The amounts of free fatty acids were measured according to the method of Egan *et al*. [13].

Microbiological Analyses: 10 g of Samples of fish nuggets were taken and mixed with 90 ml of 0.1% peptone water and crushed in a mortar for one min. Serial dilutions from the microbial extracts were prepared in 0.1% peptone water. Psychrotrophic, mesoophilic bacteria and aerobic total counts were determined by using pour plate method, with using Plate Count Agar as the medium. Plates were incubated at 30°C for 24-48 h and for 2 days at 37 °C for total count and mesophilic bacteria respectively and for psychrotrophic count was incubated in 10 °C for 7 days [12-14]. Microbial counts were expressed as log CFU/g.

Color Measurements: Samples color with six replication was measured with a Lovibond (Lovibond CAM-system, England 500). The parameters determined were L* for an approximate of lightness between black and white within the range of 0-100, (+a*) for redness or (-a*) for greenness and (+b*) for yellowness or (-b*) for blueness [15].

Sensory Evaluation: The evaluation of sensory quality of fish nuggets was carried out by fifteen students of Gorgan University of Agricultural Sciences and Natural Resources. The fish nuggets were final fried in sunflower oil for 2 minutes. The panelists were scored for color, flavor, texture and overall acceptability on an 8-point hedonic scale sensory evaluation (1: dislike extremely to 8: like extremely) [11].

Statistical Analysis: The statistical analysis of the data was performed through using one-way analysis of variance (ANOVA).The results were processed by SPSS 17.0 analysis. Test of significant differences between groups was determined by Duncan's multiple range test calculated at $p \leq 0.05$. Non-parametric Kruskal-Wallis tests for analysis of sensory data (for multiple group comparisons) and Mann-Whitney (for comparison with other groups) were used. The graphs were plotted in Excel software.

RESULTS

Raw Talang queen fish contains 19.84 ± 0.34 protein, 75.92 ± 0.32 moisture, 2.03 ± 0.77 fat and 5.23 ± 0.39 ash. The process of nuggets production had a significant effects on protein, ash, moisture and fat content ($p \leq 0.05$). Higher amounts of protein and fat was found in the fish nuggets and the higher amounts of moisture and ash was observed in the raw meat of fish. Approximate composition content of par-frying and final frying and the amount of pH of Talang queen fish nuggets are shown in Table 3.

The obtained results of the amount of pH in par-fried fish nuggets, showed no significant difference among treatments ($p \leq 0.05$) but during the storage time, the increase of pH values was observed in all samples ($p \leq 0.05$) (Fig. 1). No difference observed among the values of pH, but during the storage time there was a growing trend in amount of pH.

Table 3: Protein, ash, moisture, fat and pH content in par-frying Talang queen fish nuggets

	Samples	Protein	Ash	Moisture	Fat	pH
Par-frying	Control	46.84±1.07^{a}	1.84±0.3^{a}	54.32±1.43^{c}	7.21±0.46^{cd}	6.73±0.1^{a}
	A	44.30±1.23^{ab}	2.05±0.35^{a}	56.61±0.37^{ab}	4.85±0.32^{e}	6.8±0.12^{a}
	B	43.47±2.12^{ab}	2.05±0.29^{a}	60.15±0.86^{a}	3.52±0.32^{f}	6.74±0.01^{a}
	C	40.41±2.16^{ab}	1.79±0.15^{a}	58.13±0.32^{ab}	4.62±0.35^{ef}	6.8±0.01^{a}
Final frying	Control	40.16±1.51^{ab}	1.47±0.13^{a}	47.98±1.01^{f}	9.13±0.59^{a}	6.77±0.1^{a}
	A	38.22±2.33^{b}	1.82±0.1^{a}	53.31±1.49^{e}	7.15±0.37^{b}	6.73±0.01^{a}
	B	39.60±3.31^{ab}	1.87±0.15^{a}	55.22±0.68^{d}	5.47±0.26^{d}	6.83±0.17^{a}
	C	41.04±2.25^{ab}	1.59±0.12^{a}	52.41±0.64^{e}	6.94±0.44^{bc}	6.8±0.12^{a}

Mean values with different superscripts at the same column are significantly different among samples at first time (P<0.05).

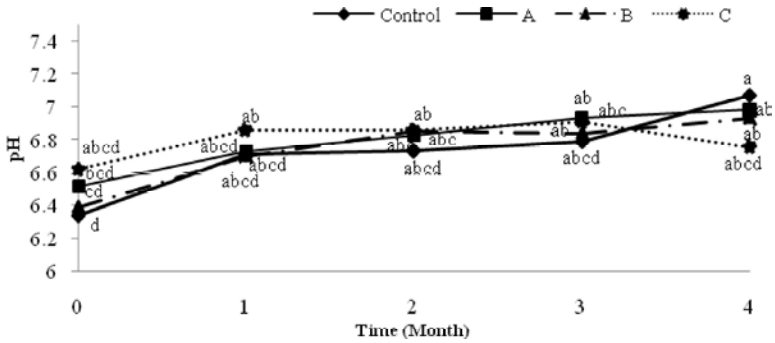

Fig. 1: Changes in pH in Talang queen fish nuggets during 4 month storage in freezer: control (without HPMC in coating), A (with 2%HPMC in pre-dust), B (with 2% HPMC in batter) and C (with 1% HPMC in pre-dust and 1% HPMC in batter).
Bars represent standard deviation from triplicate determinations.

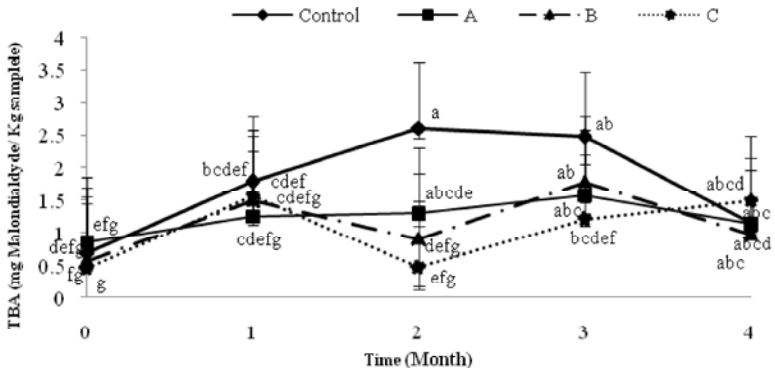

Fig. 2: Changes in TBA content in Talang queen fish nuggets during 4 month storage in freezer: control (without HPMC in coating), A (with 2%HPMC in pre-dust), B (with 2%HPMC in batter) and C (with 1% HPMC in pre-dust and 1%HPMC in batter).
Bars represent standard deviation from triplicate determinations

The amount of thiobarbituric acid among different treatments were showed no significant effects ($p \leq 0.05$) (Fig. 2), but all treatments were demonstrated a significant increase ($p \leq 0.05$) during the storage time.

Chemical experiments to determine the amount of free fatty acids in the Talang queen fish nuggets has failed at initial of period. Measuring the amount of free fatty acids in the different treatments of par-fried nuggets do not showed significant difference among treatments ($p \leq 0.05$) (Fig. 3). Changes in the amount of free fatty acids showed an increasing trend over time.

During the storage times not psychrotrophic bacteria observed in all treatments. Total bacteria count in par-fried fish nuggets showed a significant difference during

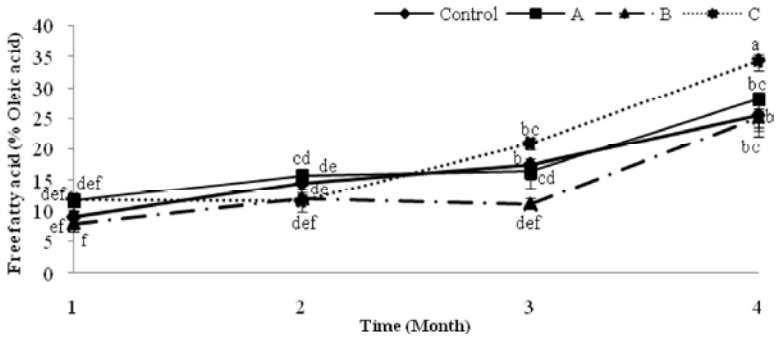

Fig. 3: Changes in FFA content in Talang queen fish nuggets during 4 month storage in freezer: control (without HPMC in coating), A (with 2%HPMC in pre-dust), B (with 2% HPMC in batter) and C (with 1% HPMC in pre-dust and 1%HPMC in batter).
Bars represent standard deviation from triplicate determinations.

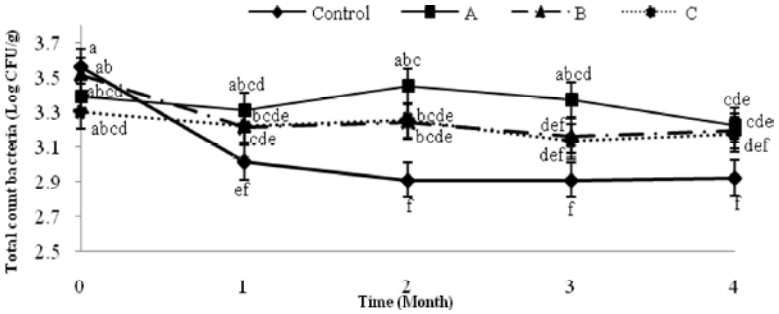

Fig. 4: Changes in total count bacteria in Talang queen fish nuggets during 4 month storage in freezer: control (without HPMC in coating), A (with 2%HPMC in pre-dust), B (with 2%HPMC in batter) and C (with 1% HPMC in pre-dust and 1%HPMC in batter). Bars represent standard deviation from triplicate determinations.

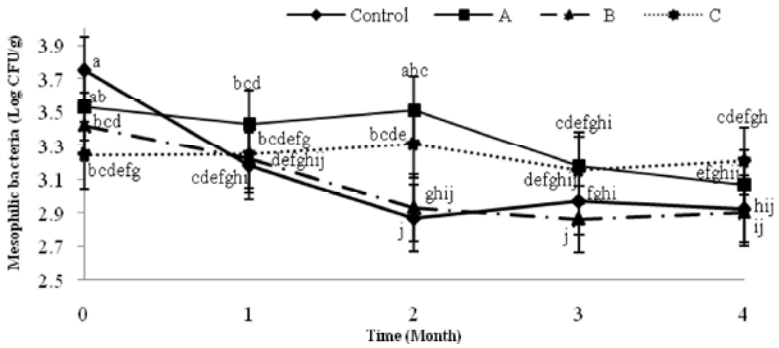

Fig. 5: Changes in mesophilic bacteria in Talang queen fish nuggets during 4 month storage in freezer: control (without HPMC in coating), A (with 2%HPMC in pre-dust), B (with 2%HPMC in batter) and C (with 1% HPMC in pre-dust and 1%HPMC in batter). Bars represent standard deviation from triplicate determinations.

the storage time ($p \leq 0.05$) (Fig. 4). According to Fig. 5 the number of mesophilic bacteria among different treatments and during storage times in par-fried nuggets showed a significant difference ($p \leq 0.05$) and the number of mesophilic bacteria decreased (Fig. 5).

Changes in color characteristics of par-fried fish nuggets during the storage time is presented in Table 4 showing that there are different results in lightness, redness and yellowness among the treatments. According to the results, treatment C showed less lightness and higher redness compared to other treatments. During the storage time the lightness and yellowness indexes showed a significant decrease in all treatments ($p \leq 0.05$), while the redness index did not show any significant changes ($p \leq 0.05$).

Table 4: Effects of HPMC on color of par-frying Talang queen fish nuggets

		Times (Month)				
	Samples	0	1	2	3	4
Lightness	Control	58.8±0.71^{cde}	67.66±0.87^{a}	55.64±0.77^{def}	49.58±0.4^{gh}	57.38±0.5^{cde}
	A	59.47±1.02^{cdef}	62.68±1.51^{abc}	54.37±0.22^{defg}	51.04±0.31^{fgh}	58.82±0.46^{def}
	B	61.57±0.92^{bc}	66.01±0.73^{ab}	53.92±0.42^{efg}	51.45±0.72^{fgh}	59.1±1.19^{cde}
	C	59.9±0.58^{cd}	57.48±1.17^{cde}	54.77±0.94^{defg}	49.49±0.32^{h}	59.03±1.02^{cde}
Redness	Control	12.89±0.58^{ab}	12.53±0.22^{ab}	12.09±0.24^{b}	14.23±0.33^{a}	13.01±0.27^{ab}
	A	12.88±0.29^{ab}	13.03±0.23^{ab}	12.17±0.22^{ab}	12.27±0.34^{ab}	12.66±0.28^{ab}
	B	11.79±0.12^{b}	11.73±0.38^{b}	11.3±0.3^{b}	11.73±0.51^{b}	11.74±0.26^{b}
	C	11.78±0.18^{b}	11.41±0.69^{b}	10.92±0.6^{b}	11.81±0.43^{b}	12.02±0.12^{b}
Yellowness	Control	23.09±0.62^{abcdef}	20.04±0.19^{f}	22.88±0.62^{abcdef}	25.04±0.54^{ab}	25.22±0.59^{a}
	A	23.44±0.77^{abcde}	22.72±0.43^{abcde}	23.58±0.31^{abcde}	23.22±0.45^{abcde}	24.88±0.49^{abc}
	B	22.91±0.46^{abcdef}	20.78±0.52^{ef}	23.66±0.34^{abcde}	21.68±0.38^{cdef}	21.64±0.72^{def}
	C	21.87±0.51^{bcdef}	21.28±0.27^{def}	22.46±0.52^{abcdef}	22.61±0.28^{abcdef}	24.44±0.74^{abcd}

Mean values with different superscripts at the same column are significantly different among samples during the storage time (P<0.05).

Table 5: Sensory evaluation of Talang queen fish nuggets after frying

		Times (Month)				
Sensory Evaluation	Samples	0	1	2	3	4
Color	Control	7.57±0.2^{a}	7.57±0.19^{a}	7.14±0.23^{ab}	7.43±0.18^{a}	7±0.22^{abc}
	A	7±0.22^{abc}	7.14±0.29^{ab}	6.14±0.16^{bcd}	5.29±1.04^{d}	6.71±0.18^{abc}
	B	7±0.22^{abc}	6.57±0.25^{abc}	6.43±0.32^{abcd}	5.85±0.7^{cd}	6.71±0.18^{abc}
	C	7.29±0.29^{ab}	6.85±0.23^{abc}	6.57±0.32^{abc}	6.57±0.43^{abc}	5.85±0.26^{cd}
Texture	Control	7.71±0.18^{a}	7.14±0.25^{abc}	6.14±0.59^{bcd}	7.29±0.34^{ab}	6.71±0.18^{abcd}
	A	7.14±0.26^{abc}	7.29±0.29^{ab}	5.86±0.44^{d}	6.71±0.55^{abcd}	6.86±0.34^{abcd}
	B	7.71±0.18^{a}	6.86±0.23^{abcd}	5.86±0.27^{d}	6.29±0.68^{bcd}	6±0.31^{cd}
	C	7.29±0.29^{ab}	7±0.29^{abcd}	6.86±0.12^{abcd}	6.14±0.55^{bcd}	6.14±0.26^{bcd}
Flavor	Control	7.71±0.18^{a}	6.43±0.33^{bcdef}	6.43±0.32^{bcdef}	5.86±0.26^{defg}	5.29±0.42^{g}
	A	7.14±0.26^{ab}	6.71±0.26^{abcde}	6.14±0.37^{bcdefg}	6.57±0.23^{bcde}	6.14±0.26^{bcdefg}
	B	7±0.22^{abc}	6.43±0.37^{bcdef}	5.86±0.33^{defg}	5.43±0.2^{fg}	5.71±0.36^{fg}
	C	7±0.31^{abc}	6.86±0.23^{abcd}	6.43±0.19^{abcdef}	6±0.31^{cdefg}	5.43±0.2^{fg}
Overall acceptability	Control	7.71±0.18^{a}	7.25±0.37^{ab}	6.71±0.41^{abcd}	6.3±0.52^{bcd}	6±0.31^{cd}
	A	7.14±0.26^{abc}	7.3±0.23^{ab}	6.14±0.48^{bcd}	6.86±0.4^{abcd}	6.43±0.3^{bcd}
	B	7.71±0.18^{a}	6.57±0.18^{abcd}	6.43±0.27^{bcd}	5.86±0.55^{d}	6.14±0.26^{bcd}
	C	7±0.22^{abcd}	6.71±0.16^{abcd}	7±0.19^{abcd}	6.14±0.26^{bcd}	6.14±0.4^{bcd}

Mean values with different superscripts at the same column are significantly different among samples during the storage time (P<0.05).

The study of the results of sensory evaluation during four months of storage par-fried fish nuggets and final frying them, did not show any significant difference in factors of color, texture and flavor, among all treatments and during the storage time in the freezer ($p \leq 0.05$) and only the overall acceptability factor showed a significant difference during the storage time ($p \leq 0.05$). (Table 5).

DISCUSSION

In this study, the sliced fillets of Talang queen fish were used as a food matrix. After removing the dark meat, fish fillet yield was calculated as 49.08%. Talang queen fish fillets had less protein and fat and more moisture and ash compared to produced fish nuggets. In terms of pH value no significant difference observed between the fillets and the produced nuggets. The increased amounts of protein in the nuggets was due to using herbal protein and starch in the formulation of batter. Due to production process and different stages of par-frying and final frying, the fish nuggets showed higher fat and less moisture content (Table 3).

Common coatings of food can be formed from 0.25 to 1.5 percent by weight of HPMC, 60 to 80 percent by weight of water and about 20 to 40 percent by weight of other ingredients in the mixture of batter [16].

The amount of protein, pH and ash in different treatments of par-fried and final fried fish nuggets were similar, but the amount of moisture and fat were significantly different among treatments. B treatment with 2% HPMC in batter formula showed the least amount of oil and the highest moisture content. Treatments A and C had also lower oil and higher moisture content compared to control treatment. The main factor influencing the oil absorption is ingredients of batter. Studies showed that small amounts of hydrocolloids (usually one percentage of the dry weight of batter formulas) can reduce oil absorption due to the ability of hydrocolloids to form gels and their natural hydrophilic properties that enable them to absorb less oil and retain more moisture in the products during frying process [1-17].

Gelatinization of HPMC due to temperature of cooking process showed more effective role in the batter of treatment B than its function in the pre-dust and batter of treatment C and the pre-dust of treatment A. Probably adding 2% HPMC to the batter of treatment B, in the presence of water available in the batter, formed a stronger gelatinization layer and film which led to the least amount of fat absorption. The results of this section match the obtained results of studies done by Chen *et al.* [9] and Albert *et al*. [18].

HPMC films in treatment C at the frying temperature were formed in the pre-dust and batter layers and prevented oil absorption, but due to the low percentage of HPMC added to these layers (one percent) compared to treatment B (two percent), they showed lower performance to maintain moisture and reduce the absorption of oil. Previous studies showed that there is a positive relationship between the moisture loss and oil uptake during the frying process. Foods with high moisture indicated lower oil absorption [19-20].

According to the study done by Chen *et al*. [9] reduction of moisture and oil absorption occurs mainly in the coating. In comparison with batter and bread flour, pre-dust plays a minimal role in produced coating, thus under heating temperature, formed gel by HPMC in treatment A which have been added in the pre-dust formed a region away from the coating had no effective role in reducing oil absorption or increasing moisture retention. The obtained results of treatment A match the results of Nguyen [3]. Nguyen reported that methyl cellulose added to the pre-dust of chicken nuggets has no significant effects on oil absorption.

Except treatments B that did not show any significant changes in pH, the pH value in other treatments was increased and the control treatments greatly increased compared to other treatments. Increased production of volatile bases such as ammonia, trimethyl amine and other compounds is the result of enzymatic activity of bacteria and endogenous enzymes [21]. Nguyen [3] showed that MC added to pre-dust of chicken nuggets, within six months of storage has no effect on amount of pH which is contrary to the results of the present study. The increasing amount of pH during storage time is consistent with the results of the study done by Das *et al*. [11].

Coating process and added HPMC to the different regions of coating demonstrated positive effects on the amount of thiobarbituric acid, but generally the amount of thiobarbituric acid increased significantly over the storage time in all treatments and the sharp increase observed in the control compared to other treatments. At the end of the storage time, not observed a significant difference observed among all treatments. The production of volatile metabolites of lipid oxidation in the presence of oxygen resulted in increased amount of TBA of treatments during the storage [7-22]. Tokur *et al*. [5] reported that the amount of TBA in fish finger produced from mince and washed mince mirror carp increased during the storage time. According to the results of the study Nguyen [3] application of MC in coating of chicken nuggets between the first and the third months of storage had no effect on the amount of thiobarbituric acid, but in the six month of storage time the amount of thiobarbituric acid increased.

Studying free fatty acids over four months of storage in freezer in all treatments of par-fried nuggets showed a growing trend in the amount of free fatty acids. As a results of free fatty acid, adding HPMC to the coating had no effect on delaying lipid hydrolysis. Similar results have also been reported by Rezaei *et al*. [23] for rainbow trout during 20 days of storage, the amount of free fatty acids significantly increased.

One of the effects of freezing on the products quality is prevention of growth and activity of microorganisms. In the present study, psychrotrophic bacteria were not observed in the par-fried nuggets. Results obtained from counting the total number of bacteria and mesophilic bacteria were also different. The total bacteria count in the control and treatment B decreased during the storage time, while in treatments A and C they remained unchanged. The number of mesophilic bacteria displayed an decreasing trend over time. Normally freezing is able to destroy 50 to 90 percent of bacteria in the fish and fish products. Usually some of bacteria is slowly die down at during the storage time of freezing state and the rate of this decrease will depend on the bacterial species and refrigerator temperature [24].

As seen in Fig. 4, at the beginning of period the total count of bacteria and mesophilic bacteria load were ($\leq 4^{log\ CFU/g}$), that this number of colonies ($\leq 4^{log\ CFU/g}$) indicate that a good quality fillets were used [25]. In study of Elyasi *et al*. [26] on fried fish fingers produced from mince and surimi the total count of bacteria and coliforms showed significant decrease and resulting heat of frying process resulted in the death of microorganisms in the fish fingers.

One of the most important parameters that affect the marketability of coated products is the final color of these products. Lower lightness and higher redness was observed in treatment C. During four months storage, the amount of the lightness and yellowness in Talang queen fish nuggets reduced, but the redness index did not show any changes. Frying process resulted in reduced amount of lightness and yellowness and increased amount of redness in the fish nuggets.

The golden color of fried crusts was due to Millard`s reaction and sugar caramelization at higher temperature of frying treatment [8]. The batter containing HPMC showed lighter crust color [18] because the crusts containing HPMC had higher water holding capacity and thereby less Millard reaction occurred during frying stage [27]. During the frying process various chemical reactions such as denaturation of proteins, starch gelatinization and browning reaction of breading flour occurred in the battered and breaded products and all these reactions cause complex changes in the color [28]. The outward color of the fish nuggets are mostly influenced by the breaded coating and size of its granulations and less dependent on the interior materials and intermediate surfaces.

Although the index of flavor was not significant, all treatments displayed reduced amount of flavor measurement over time. The flavor and overall acceptability indexes decreased in the control and treatment B during the storage. Flavor changes during the storage time is the result of the restoration of trimethyl amine oxide into trimethyl amine and its emergence is the result of passing time and activity of voluntary aerobic bacteria [24-29]. Similar results have also been confirmed by Elyasi *et al*. [26] who showed that there is no difference among indexes of sensory evaluation index of flavor, smell and texture and there is only significant difference in color and the overall acceptability indexes. Tokur *et al*. [5] reported that unwashed fish fingers had more nutritional value, but the panelists preferred washed fish fingers due to desirable flavor.

CONCLUSION

According to the results of the present study, using HPMC in various phases of coated in battered and breaded products is effective in reducing oil absorption. The highest decrease of oil content was observed in the nuggets that contained two percent of the HPMC in the batter. The nuggets containing two percent of HPMC in pre-dust and nuggets with one percent HPMC in pre-dust and one percent of HPMC in the batter reduced the same amount of oil absorption and overall absorbed amount of oil were less compared to the control treatment. Using the HPMC also had a positive effect on retention of moisture products. Obtained results showed that added HPMC to the coated of fish nuggets during the four months of storage in the freezer and then final frying the products, showed no significant effects on the shelf life and fat decay indexes of fish nuggets.

ACKNOWLEDGMENTS

Authors thank the processing laboratory of Gorgan University of Agricultural Sciences and Natural Resources for their help and support and all the people who assisted in this project.

REFERENCES

1. Venugopal, V., 2006. Seafood Processing. CRC Press, pp: 485.
2. Mallikarjunan, P., 2004. Understanding and measuring consumer perception of crispness. Pages 82-103 in Texture in Food. D. Kilcast, ed. Woodhead, Cambridge, UK.
3. Nguyen, B.E., 2009. Effects of methylcellulose on the quality and shelf-life of deep-fat fried and oven baked chicken nuggets. Master Thesis, Faculty of Food Science, Texas Tech University, Texas.
4. Varela, P. and S.M. Fiszman, 2011. Review: Hydrocolloids in fried food. Journal of Food Hyrocolloids, 25: 1801-1812.
5. Tokur, B., S. Ozkutuk, E. Atici, G. Ozyurt and C. Ozyurt, 2006. Chemical and sensory quality changes of fish fingers, made from mirror carp (*Cyprinus carpio*) (Linnaeus, 1758), during frozen storage (-18°C). Journal of Food Chemistry, 99: 335-341.

6. Benjakul, S., T.A. Seymour, M.T. Morrissey and H. An, 1997. Physicochemical changes in pacific whiting muscle proteins during iced storage. Journal of Food Science, 62: 729-733.
7. Ojagh, S.M., M. Rezaei, S.H. Razavi and S.M.H. Hosseini, 2010. Effect of chitosan coatings enriched with cinnamon oil on the quality of refrigerated rainbow trout. Journal of Food Chemistr, 120: 193-198.
8. Albert, A., I. Perez-Munuera, A. Quiles, A. Salvador, S.M. Fiszman and I. Hernando, 2009a. Adhesion in fried battered nuggets: performance of different hydrocolloids as predust using three cooking procedures. Journal of Food Hydrocolloids, 23: 1443-1448.
9. Chen, C., P. Li, W. Hu, M. Lan, M. Chen and H. Chen, 2008. Using HPMC to improve crust crispness in microwave-reheated battered mackerel nuggets: water barrier effect of HPMC. Journal of Food Hydrocolloids, 22: 1334-1344.
10. AOAC, 2005. Official methods of analysis (17th ed). Association of Official Analytical Chemists, Washington, DC, USA.
11. Das, A.K., A.S.R. Anjaneyulu, Y.P. Gadekar, R.P. Singh and H. Pragati, 2008. Effect of full-fat soy paste and textured soy granules on quality and shelf-life of goat meat nuggets in frozen storage. Journal of Meat Science, 80: 607-614.
12. Kilinc, B., S. Cakli, T. Dincer and A. Cadun, 2007. Effects of phosphates treatment on the quality of frozen-thawed fish species. Journal of Muscle Foods, 20: 377-391.
13. Egan, H., R.S. Kirk and R. Sawyer, 1997. Pearson's Chemical Analysis of Food. 9th Edition. Longman Scientific and Technical, pp: 609-634.
14. Arashisar, S., O. Hisar, M. Kaya and T. Yanik, 2004. Effects of modified atmosphere and vacuum packaging on microbiological and chemical properties of rainbow trout (*Oncorhynchus mykiss*) fillets. International Journal of Food Microbiology, 97: 209-214.
15. Fagan, J.D., T.R. Gormley and M.U. Mhuircheartaigh, 2003. Effect of freeze-chilling, in comparison with fresh, chilling and freezing, on some quality parameters of raw whiting, mackerel and salmon portions. Journal of Lebensm. Wiss. u. Technology, 36: 647-655.
16. Meyers, M.A. and J.R. Conklin, 1990. Method of inhibiting oil adsorption in coated fried foods using hydroxypropyl methylcellulose. United States Patent, 4(900): 573.
17. Fiszman, S.M. and A. Salvador, 2003. Recent development in coating batters. Journal of Food Science and Technology, 14: 399-407.
18. Albert, A., P. Varela, A. Salvador and S.M. Fiszman, 2009b. Improvement of crunchiness of battered fish nuggets. Journal of Eru Food Research Technology, 228: 923-930.
19. Dana, D. and S. Saguy, 2006. Review: Mechanism of oil uptake during deep-fat frying and the surfactant effect-theory and myth. Journal of Advances in Colloid and Interface Science, 128-130: 267-272.
20. Mellema, M., 2003. Mechanism and reduction of fat uptake in deep-fat fried foods. Journal of Trends in Food Science and Technology, 14: 364-373.
21. Fan, W., J. Sun, Y. Chen, J. Qiu, Y. Zhang and Y. Chi, 2009. Effects of chitosan coating on quality and shelf life of silver carp during frozen storage. Journal of Food Chemistry, 115: 66-70.
22. Chidanandaiah, A., R.C. Keshri and M.K. Sanyal, 2007. Effect of sodium alginate coating with preservatives on the quality of meat patties during refrigerated (4 ± 1°C) storage. Journal of Muscle Foods, 20: 275-292.
23. Rezaei, M., S.F. Hosseini, H. Ershad Langrudi, R. Safari and S.V. Hossein, 2008. Effect of delayed icing on quality changes of iced rainbow trout (*Oncorhynchus mykiss*). Journal of Food Chemistry, 106: 1161-1165.
24. Razavi Shirazi, H., 2005. Seafood technology. Pars Negar press, pp: 325.
25. Ibrahim Sallam, K., 2007. Antimicrobial and antioxidant effects of sodium acetate, sodium lactate and sodium citrate in refrigerated sliced salmon. Journal of Food Control, 18: 566-575.
26. Elyasi, A., E. Zakipour Rahim Abadi, M.A. Sahari and P. Zare, 2010. Chemical and microbial changes of fish fingers made from mince and surimi of common carp *(Cyprinus carpio* L., 1758). International Food Research Journal, 17: 59-64.

27. Akdeniz, N., S. Sahin and G. Sumnu, 2006. Functionality of batters containing different gums for deep-fat frying of carrot slices. Journal of Food Engineering, 75: 522-526.
28. Das, R., D.P. Pawar and V.K. Modi, 2011. Quality characteristics of battered and fried chicken: comparison of pressure frying and conventional frying. Journal of Food Science Technology, DOI 10.1007/s13197-011-0350-z.
29. Suvanich, V., M.L. Jahncke and D.L. Marshall, 2000. Changes in selected chemical quality characteristic of channel catfish frame mince during chill and frozen storage. Journal of Food Science, 65: 24-29.