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NILE PERCH FISH NUGGETS: PARTIAL REPLACEMENT OF FISH FLESH WITH SESAME HULLS AND SUNROOT — QUALITY ASSESSMENT AND STORAGE STABILITY

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Keywords: *Nile perch, sesame hulls, sunroot, quality properties, sensory evaluation*

Abstract
This study aimed to produce Nile perch fish nuggets by replacing a part of fish flesh with different concentrations of sesame hulls and sunroot to reach the optimal recipe. Chemical, microbiological, and sensory characteristics of nuggets were evaluated during 3 months of frozen storage at –18 °C. According to the obtained data on the chemical composition of raw materials, Nile perch flesh had the highest content of protein (20.21%), sesame hulls contained the highest amount of fat (13.54%), fiber (17.24%) and ash (16.11%), while sunroot tubers had the highest amount of carbohydrates (15.76%). Based on the sensory score, the acceptable replacement ratio for fish nuggets prepared with sunroot (T1) and sesame hulls (T2) was 10% and 7.5%, respectively. Thiobarbituric acid (TBA) analysis at zero time shows that the T1 samples had the minimum value compared to the T2 and control samples. During storage, the TBA levels increased slightly in all samples, but after three months T1 also showed the lowest value. The total plate count (TPC) and psychrophilic bacterial (PSY) count in the samples were affected by the period of frozen storage at –18 °C. The initial TPC and PSY loads were 2.32 and 2.02 log cfu/g for control; 2.24 and 1.72 log cfu/g for T1; 2.30 and 1.47 log cfu/g for T2, respectively. During storage, the values of TPC and Psy slightly decreased. In conclusion, this study succeeded in the replacement of Nile perch fish with sesame hulls and sunroot as new sources to improve the nutritional value and quality characteristics of fish nuggets.

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Introduction

In recent years, the consumption of breaded and battered foods, particularly seafood, fish, poultry, vegetables, and cheese has increased significantly [1,2]. Fish and its products have polyunsaturated fatty acids that are good for health, high-quality proteins that are easy to digest, and other nutrients like minerals and vitamins that are also important for human nutrition [3]. Dietary fiber plays a significant role in the preparation of fish mince-based products due to its fat-binding capacity, water-holding capacity, gelling characteristics, texturizing, viscosity, etc. [4,5]. Koh et al. [6] state that incorporation of the appropriate amount and type of soluble-fiber polysaccharides into a recipe may improve the eating quality of processed fish products by taking advantage of their multidimensional functionality as instrumental/sensory texture modifiers. Accordingly, the addition of a suitable fiber source is sought to enhance the functional qualities of products based on fish mince.

Due to the busy lifestyle of the most urban population, there is an ongoing demand for nutritional, quick to prepare, and appetizing food products. Therefore, it is necessary to produce diverse, value-added, and convenient fish products based on fish mince. Consequently, it is a good raw material for the creation of value-added products, such as cooked products (for example, sausages), as well as mince-based fish nuggets, burgers, fingers and fish balls [7,8,9]. In general, fish does not contain carbohydrates including dietary fibers and different sugars, therefore, the use of plants as a source of carbohydrates (including dietary fiber and various important sugars) in food as functional components is thought to increase the product stability, texture, and nutritional value, as well as reduce total production costs [10,11].

Sesame hulls are a byproduct of sesame seeds (*Sesamum indicum* L.), which include substantial amounts of oxalic acid, calcium, crude fiber, and other minerals. Once the seed is correctly dehulled, the oxalic acid concentration is decreased from approximately 3% to less than 0.25% of the

seed weight [12]. During the oil extraction of sesame seeds and the production of sesame hulls, 12.0% to 13.6% of the initial seed weight is lost, and a large proportion of small, undamaged seeds escape the hulling process [13]. The chemical composition of sesame hulls differs amongst extraction facilities as a result of the various oil extraction procedures. Sunroot belongs to the *Asteraceae* family. Kays and Nottingham [14] reported nearly 100 common names in different languages. The most commonly used English names are Jerusalem artichoke, woodland sunflower, earth apple, and sun-choke. It is considered a good source of carbohydrates (containing a high amount of inulin (8–13%) that is considered a prebiotic). When sunroot is stored for some time, inulin will convert into fructose. Therefore, it has a sweet taste because of fructose [14,15]. Also, sunroot contains a high amount of phenolic compounds such as coumarins, poly acetylenic derivatives and sesquiterpenes with high antioxidant capacity [14]. Sunroot contains 15% carbohydrate, 1 to 2% protein and 80% water, no fat and little starch.

In light of these facts, the purpose of this investigation was to determine the influence of replacing a portion of Nile perch flesh with sesame hulls powder and sunroot puree on the improvement of nutritional quality, cooking properties, technical functionality, and shelf life of Nile perch mince-based nuggets.

Materials and methods

Raw materials

Nile perch flesh (*Lates niloticus*), pepper, cardamom, garlic paste, salt, and lime juice were obtained from a local market in Giza, Egypt. Sunroots were obtained from the Vegetable Department, Faculty of Agriculture, Cairo University, Egypt. Sesame hulls were obtained from Halawa El Rashidi El Mizan factory in 6th of October city, Egypt. All chemicals used for the analysis were bought from Sigma Aldrich Chemical Company, United Kingdom.

Sesame hulls and sunroot preparation

Sesame hulls were oven-dried (Shel-lab, Cornelius, OR, USA) at 50 °C for 24 hours and then ground in an analytical mill (Cole-Parmer, Vernon Hills, IL, USA) to obtain powder with a particle size of 1 mm. Unblemished sunroot tubers were selected, washed, dried with tissue paper, and cut into small cubes. The small cubes were transformed to puree by a mixer (PHILIPS, HR1865–700W, China).

Nile perch fish nuggets preparation

During this study, fish flesh was replaced with different concentrations of sesame hulls (2.5%, 5%, 7.5%, 10%, 15%, and 20%) or sunroot (2.5%, 5%, 10%, and 15%) to reach the optimal recipe. After optimization, the final recipes for Nile perch fish nuggets with sesame hulls and sunroot as well as the control sample were as follows:

- control sample: 100 g minced Nile perch flesh, 1.175 g pepper, 0.055 g cardamom, 4.62 g garlic paste, 1.175 g salt, 0.5ml lime juice;
- Nile perch fish nuggets with 10% of sunroot (T1): 90 g minced Nile perch flesh, 10 g sunroot puree, 1.175 g pepper, 0.055 g cardamom, 4.62 g garlic paste, 1.175 g salt, 0.5 ml lime juice;
- Nile perch fish nuggets with 7.5% of sesame hulls (T2): 92.5 g minced Nile perch flesh, 7.5 g sesame hulls powder, 1.175 g pepper, 0.055 g cardamom, 4.62 g garlic paste, 1.175 g salt, 0.5ml lime juice.

All components for each sample were mixed well, formed into nugget shape and covered by wheat flour then liquid egg, and finally rusk. All samples were stored at –18 °C for further analysis.

Storage conditions

Nile perch fish nugget samples were packed in polypropylene bags and stored at –18 °C for three months. The chemical and microbiological profiles of all samples were determined every month for three months.

Methods of analysis

The moisture and ash content were determined according to Baioumy et al. [16]. The protein and fat content were determined according to AOAC [17]. The pH was measured in the slurry prepared by blending nuggets and distilled water with a 1:2 ratio. A digital pH meter (model 420A, Orion Benchtop pH meter, Allometrics Inc.) was calibrated before use.

The water holding capacity (WHC) of the samples was determined using the filter paper press technique according to Daum-Thunberg et al. [18]. A fish nugget sample (0.3 g) was put under ashless filter paper (Whatman, No. 41) and pressed for 10 min using 1 kg weight. Two zones were formed on the filter paper and their surface areas were measured by a planimeter. The outer zone resulted from the water separated from the pressed tissues thus indicating the WHC value and the internal zone was due to the fish pressing indicating the plasticity. WHC was calculated by subtracting the area of the internal zone from that of the outer zone. Data were presented as cm^2.

Thiobarbituric acid (TBA) values of fish nuggets were measured according to Sallam et al. [19] with a slight modification. One milliliter of the homogenized sample was mixed with 2 ml of the stock solution (prepared as follows: 0.37% TBA, 15% TCA, and 0.25 N HCL were slowly heated to 75 °C in a water bath to facilitate the dissolution of thiobarbituric acid). After that, the mixture was heated in a boiling water bath for 15 min to develop pink color. After cooling with tap water and centrifuging at 2000 rpm for 15 min, the absorbance was measured at 532 nm (Unico UV-2000, Dayton, NJ, USA). The TBA value was expressed as mg malonaldehyde/kg of nuggets.

Cooking loss (%) of nugget samples (40 g) was determined by their weighing before and after the cooking process by deep-fat frying. Samples were removed, drained, lightly blotted, and weighed. Cooking loss (%) was calculated as weight loss due to cooking divided by the initial

weight of raw samples. The calculation was carried out as% on a wet weight basis. Oil uptake of nugget samples was determined by weighing before and after the frying process with the use of immersion of these samples in the oil. Oil uptake% was calculated by the following equation:

$$\text{Oil uptake\%} = \frac{\text{weight after frying} - \text{weight before frying}}{\text{weight before frying}} \times 100 \quad (1)$$

The color values [L* (lightness), a* (redness), and b*(yellowness)] of each sample were measured using a colorimeter (Model CR-200; Konica Minolta, Japan) as described by Abedelmaksoud et al. [20].

The total plate and psychrophilic bacterial counts were determined as follows: 1 ml of each sample was transferred into 9 ml of the 0.1% peptone water or 0.85% physiological saline solution (sterile) and homogenized with a blender for 2 min. From the 10^{-1} dilution, other decimal dilutions were prepared. Plate count agar was used as a medium, and plates were incubated at 35 °C for 48 ± 2 h for the total plate count [21] and in the refrigerator at 5 ± 2 °C for 10 days for the psychrophilic plate count [22].

Sensory evaluation of nuggets included color, odor, flavor, texture, and overall acceptability. Samples were evaluated using a 10-point hedonic scale to establish the optimal recipe for producing fish nuggets with high eating quality attributes. The panelists were asked to evaluate the quality characteristics of the samples based on the following criteria: 0–2 = extremely dislike, 3–4 = slightly dislike, 5–6 = average, 7–8 = like considerably, and 9–10 = outstanding.

Using analysis of variance (ANOVA) XLSTAT software version 2014, 5.03 (Addinsoft, New York, NY, USA) in three repetitions, experimental results were evaluated and expressed as the mean ± standard error of the mean. Differences between sample means with a *p-value* ≤ 0.05 were considered to be significant.

Results and discussion

Chemical composition of Nile perch flesh, sesame hulls and sunroot

Table 1 indicates the chemical composition of Nile perch flesh, sesame hulls powder and sunroot puree. According to the results, the sample of Nile perch flesh had the highest protein content (20.21%) followed by sesame hulls (10.52%) and sunroot (2.10%).

Table 1. Chemical composition of Nile perch flesh, sesame hulls and sunroot (g/100g sample)

Parameters %	Nile perch flesh	Sesame hulls	Sunroot
Crude protein	20.21 ± 0.21^a	10.52 ± 0.32^b	2.10 ± 0.17^c
Crude fat	0.54 ± 0.16^b	13.54 ± 0.23^a	0.22 ± 0.15^c
Crude fiber	—	17.24 ± 0.22^a	3.24 ± 0.12^b
Ash	0.61 ± 0.19^c	16.11 ± 0.23^a	0.8 ± 0.13^b
Total carbohydrates	—	12.53 ± 0.21^b	15.76 ± 0.32^a
Moisture	78.64 ± 0.33^b	47.3 ± 0.36^c	81.12 ± 0.41^a

The letters (a, b, and c) represent the statistically significant changes between treatments (p ≤ 0.05).

The fat content was the highest in sesame hulls (13.54%) followed by Nile perch (0.54%) and sunroot (0.22%). The sesame hull sample showed the highest crude fiber and ash content (17.24% and 16.11%) compared to the sunroot (3.24% and 0.80%) and Nile perch flesh (0% and 0.61%) samples, respectively. There were no carbohydrates in Nile perch flesh, while the content of carbohydrates in sunroot and sesame hulls was 15.76% and 12.53%, respectively. Table 1 also shows that the moisture content was high in both sunroot (81.12%) and Nile perch flesh (78.64%) samples compared to sesame hulls (47.3%).

In this respect, Okeyo et al. [23] reported that the protein, lipid, ash and moisture contents in Nile perch edible tissue varied between 19.8 and 17.7%; 0.59 and 0.63%; 0.55 and 0.63%; 78.5 and 79.5%, respectively. Also, the chemical composition values (protein, lipid, fiber and ash contents) of sunroot agree with Kays and Nottingham [14] and those of sesame hulls agree with Nikolakakis et al [23] and Bonos et al. [24].

Sensory evaluation of Nile perch fish nuggets with different concentrations of sunroot and sesame hulls

The obtained results presented in Table 2 and Figure 1 show the sensory score (aroma, texture, color, and overall acceptability) of Nile perch fish nugget samples at different concentrations of sesame hulls (2.5%, 5%, 7.5%, 10%, 15%

Table 2. Sensory evaluation of the Nile perch fish nuggets prepared with different concentrations of sunroot and sesame hulls

Sample	%	Color	Texture	Taste	Odor	Overall Acceptability
Control	—	8.8 ± 0.21^a	8.7 ± 0.12^a	8.7 ± 0.16^a	8.7 ± 0.22^a	8.7 ± 0.25^a
Sunroot	2.5	8.8 ± 0.23^a	8.7 ± 0.25^a	8.7 ± 0.12^a	8.7 ± 0.27^a	8.7 ± 0.25^a
	5	8.8 ± 0.21^a	8.6 ± 0.29^a	8.6 ± 0.27^a	8.6 ± 0.22^a	8.6 ± 0.13^a
	10	8.6 ± 0.23^a	8.6 ± 0.26^a	8.5 ± 0.15^a	8.6 ± 0.28^a	8.6 ± 0.11^a
	15	7.7 ± 0.22^b	7.5 ± 0.16^b	6.5 ± 0.45^b	7.8 ± 0.22^b	7.1 ± 0.26^b
Sesame hulls	2.5	8.2 ± 0.24^a	8.0 ± 0.28^a	8.2 ± 0.24^a	8.2 ± 0.23^a	8.2 ± 0.14^a
	5	8.1 ± 0.26^a	7.9 ± 0.16^a	8.1 ± 0.23^a	8.2 ± 0.21^a	8.2 ± 0.21^a
	7.5	8.0 ± 0.15^a	7.8 ± 0.24^a	8.0 ± 0.27^a	8.1 ± 0.24^a	8.2 ± 0.23^a
	10	7.3 ± 0.19^b	7.1 ± 0.12^b	7.4 ± 0.15^b	7.5 ± 0.10^b	7.3 ± 0.12^b
	15	6.5 ± 0.25^c	6.7 ± 0.21^c	6.5 ± 0.27^c	6.6 ± 0.29^c	6.7 ± 0.14^c
	20	5.8 ± 0.23^d	5.6 ± 0.24^d	5.8 ± 0.28^d	6.4 ± 0.26^c	5.7 ± 0.25^d

The letters (a, b, and c) represent the statistically significant differences between treatments (p ≤ 0.05).

and 20%) and sunroot (2.5%, 5%, 10% and 15%) compared to the control sample. The results show that the sensory score of fish nuggets with sunroot was acceptable up to the 10% replacement ratio, and beyond this ratio, a big change in texture and taste, as well as overall acceptability of fish nuggets, was observed.

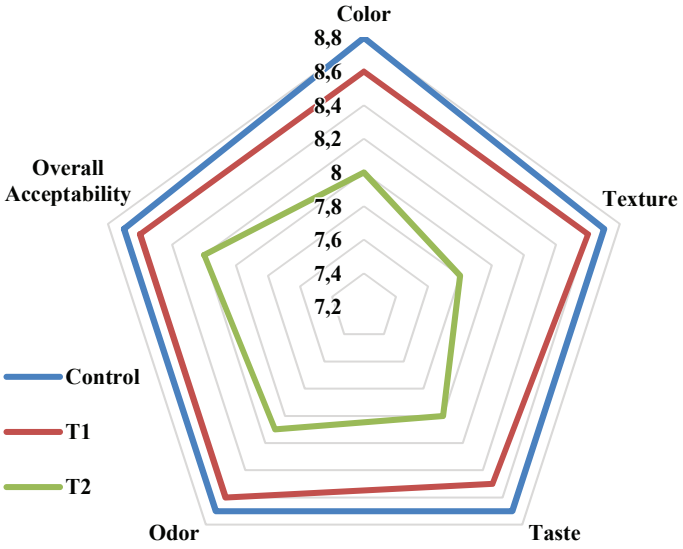

Figure 1. Sensory evaluation of Nile perch fish nuggets with the best concentrations of sunroot (10%) (T1) and sesame hulls (7.5%) (T2)

On the other hand, regarding the sensory evaluation of fish nuggets with sesame hulls, the acceptable replacement ratio reached 7.5%. This percent (7.5%) of sesame hulls was less than the level of fish replacement with sunroot because a higher percentage led to more changes in texture and taste that were rejected by the test panel. Based on the sensory evaluation, 10% of sunroot and 7.5% of sesame hulls were considered to be the best concentrations in the recipes of fish nuggets (Table 2 and Figure 1).

Physical, chemical and microbiological profiles of Nile perch fish nuggets prepared with 10% of sunroot and 7.5% of sesame hulls

Table 3 and Figure 2 show the physical, chemical and microbiological profiles of Nile perch fish nuggets with 10% of sunroot (T1) and 7.5% of sesame hulls (T2) compared to the control sample. The results show an increase in the ash content in T2, which was attributed to the addition of sesame hulls with the high ash content (see Table 1), and no significant changes in T1 compared to the control sample (1.35%). A decrease in the protein content was observed in T1 (17.12%), while there was no significant decrease in T2 (18.32%) compared to the control sample (18.90%). This decrease may be due to the replacement of Nile perch flesh with sunroot and sesame hulls, which have a lower content of protein than Nile perch flesh. An increase in the total carbohydrate content was recorded in the T1 and T2 samples compared to the control, while no significant differences were found between T1 and T2. This increase in carbohydrates is attributed to the addition of sunroot and sesame hulls, both of which are considered a good source of carbohydrates (as shown in Table 1). A significant decrease in the fat content was recorded in T1 (0.52%), while it increased in T2 (1.77%) compared to the control sample (0.56%). This increase in the fat content for T2 is attributed to the addition of sesame hulls, which have the high fat content (see Table 1).

Table 3. Physical and chemical profiles of Nile perch fish nuggets with 10% of sunroot and 7.5% of sesame hulls

Parameter	Control	T1	T2
Ash, %	1.35 ± 0.21^{b}	1.51 ± 0.12^{b}	3.10 ± 0.23^{a}
Protein, %	18.90 ± 0.35^{a}	17.12 ± 0.14^{b}	18.32 ± 0.13^{a}
Total Carbohydrates, %	1.11 ± 0.15^{b}	4.1 ± 0.17^{a}	4.31 ± 0.16^{a}
Fat, %	0.56 ± 0.18^{b}	0.52 ± 0.17^{b}	1.77 ± 0.14^{a}
Moisture, %	78.12 ± 0.32^{b}	76.72 ± 0.41^{a}	72.50 ± 0.23^{c}
pH	6.52 ± 0.14^{a}	6.64 ± 0.28^{a}	6.26 ± 0.27^{b}

T1 (with 10% of sunroot); T2 (with 7.5% of sesame hulls); the letters (a, b, and c) represent the statistically significant differences between treatments ($p \leq 0.05$).

The water holding capacity (WHC) is an important factor that expresses the ability of protein to bind water. According to the data presented in Figure 2, the WHC of the control, T1 and T2 samples was 1.9, 2 and 2.3 cm^2, respectively. The difference between the samples was attributed to a higher percent of protein in the control sample compared to T1 and T2. On the other hand, the difference between the control and samples T1 and T2 is not big, thus this result is good considering the cost of using plant sources to replace fish.

A significant decrease in oil uptake (%) was observed in T1 (1.65%) and T2 (1.68%) compared to the control sample (1.86%), while an increase in cooking loss (%) was found in both T1 (18.25%) and T2 (17.75%) compared to the control sample (16.6%).

Table 4 shows an effect of storage time (for 3 months at –18 °C) on TBA, WHC, color values (L*, a* and b*) and microbial load (total plate count and psychrophilic bacterial count) of Nile perch fish nuggets with 10% of sunroot (T1) and 7.5% of sesame hulls (T2) as well as the control sample. An increase in TBA, WHC, a* and b* values, and a decrease in L*, TPC and PSY values with storage time were observed for all samples (control, T1 and T2). Lipid oxidation is a significant component in the deterioration of frozen fish and fishery products, since it severely affects protein functioning and causes discoloration, off-odor, and off-taste [26]. TBA is the secondary lipid oxidation product that was measured each month during the storage period (3 months). The results are presented in Table 4. The lower TBA value was observed in T1 (0.294 mg malonaldehyde/kg) compared with the control (0.327 mg malonaldehyde/kg) and T2 (0.405 mg malonaldehyde/kg) samples ($p < 0.05$). Moreover, an increase in the TBA values was detected as the storage duration was extended ($p < 0.05$). At the beginning of storage, the TBA values for the T1, control, and T2 samples were 0.224 (mg malonaldehyde/kg), 0.241 (mg malonaldehyde/kg), and 0.337 (mg malonaldehyde/kg), respectively. TBA is a crucial

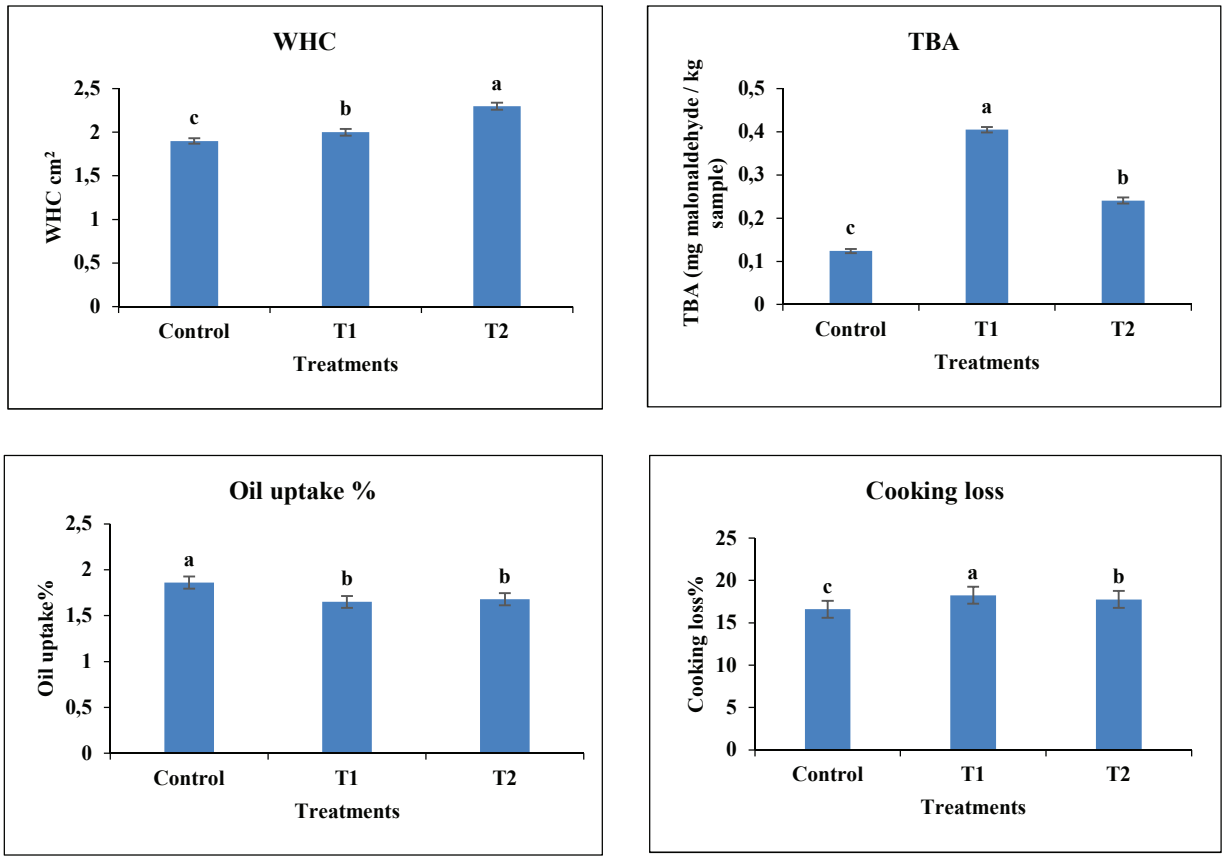

Figure 2. Water-holding capacity (WHC), thiobarbituric acid (TBA), oil uptake and cooking loss of Nile perch fish nuggets with the best concentration of sunroot (10%) (T1) and sesame hulls (7.5%) (T2) compared to the control; the letters (a, b, and c) represent the statistically significant differences between treatments ($p \leq 0.05$)

Table 4. Effect of storage time (three months at –18 °C) on some quality parameters of Nile perch fish nuggets prepared with 10% of sunroot and 7.5% of sesame hulls

Time (Month)	Treatment	TBA (mg malonaldehyde/kg)	WHC ($cm^{2)}$	L*	a*	b*	TPC (log cfu/g)	PSY (log cfu/g)
0	Control	0.241 ± 0.01	1.9 ± 0.1	63.03 ± 0.34	3.58 ± 0.15	20.72 ± 0.35	2.32 ± 0.17	2.02 ± 0.09
	T1	0.224 ± 0.01	2.0 ± 0.1	67.61 ± 0.32	4.34 ± 0.18	20.21 ± 0.33	2.24 ± 0.10	1.72 ± 0.06
	T2	0.337 ± 0.01	2.3 ± 0.1	68.79 ± 0.35	3.94 ± 0.13	19.22 ± 0.30	2.30 ± 0.02	1.47 ± 0.04
1	Control	0.267 ± 0.01	2.1 ± 0.1	58.66 ± 0.26	3.73 ± 0.11	20.77 ± 0.17	2.28 ± 0.05	1.99 ± 0.07
	T1	0.243 ± 0.01	2.1 ± 0.1	63.65 ± 0.22	4.74 ± 0.12	22.44 ± 0.24	2.16 ± 0.06	1.56 ± 0.1
	T2	0.356 ± 0.01	2.4 ± 0.1	67.55 ± 0.31	3.93 ± 0.15	19.81 ± 0.25	2.18 ± 0.09	1.59 ± 0.01
2	Control	0.289 ± 0.01	2.2 ± 0.1	56.78 ± 0.28	4.16 ± 0.12	20.84 ± 0.19	2.27 ± 0.06	1.89 ± 0.11
	T1	0.262 ± 0.01	2.2 ± 0.1	55.92 ± 0.23	5.74 ± 0.16	22.59 ± 0.32	1.95 ± 0.04	1.45 ± 0.09
	T2	0.372 ± 0.01	2.5 ± 0.1	66.78 ± 0.21	3.96 ± 0.12	20.15 ± 0.17	2.02 ± 0.07	1.38 ± 0.08
3	Control	0.327 ± 0.01	2.5 ± 0.1	54.28 ± 0.32	4.21 ± 0.13	21.90 ± 0.15	2.25 ± 0.04	1.81 ± 0.05
	T1	0.294 ± 0.01	2.4 ± 0.1	52.67 ± 0.34	5.53 ± 0.17	20.68 ± 0.22	1.82 ± 0.05	1.23 ± 0.09
	T2	0.405 ± 0.01	2.7 ± 0.1	65.85 ± 0.30	4.06 ± 0.15	20.96 ± 0.18	1.89 ± 0.07	1.28 ± 0.1

* T1 (with 10% of sunroot); T2 (with 7.5% of sesame hulls); TBA: thiobarbituric acid; WHC: water-holding capacity; TPC: total plate count; Psy: psychrophilic bacteria

measure of the quality of fish and fish products. It can be concluded that the sunroot addition in T1 decreased the TBA value due to removing a considerable amount of lipids.

Tokur et al. [27] likewise found an increase in the TBA value of tilapia (*Oreochromis niloticus*) fish burger after eight months. In addition, similar patterns were seen in the TBA values of the Nile tilapia fish burger, tilapia fish cutlet [9], grass carp fish cutlet and fish finger [28], and Nile tilapia nuggets [29]. The rise in TBA may be attributable to the availability of oxygen for oxidation, which is linked to the mechanical chopping of fish meat or the mixing of ingredients [27] or to the packaging. The TBA value is an indicator of lipid oxidation in fish products with the generation of aldehydes and carbonyl-containing compounds. Günşen et al. [30] stated that the TBA value should not be higher than 5 mg malonaldehyde/kg in good quality products. Nevertheless, rancidity had been identified when TBA values exceeded 4 mg malonaldehyde/kg [30]. Also, Connell [31] reported that rancidity develops in fish when TBA levels are above 1–2 mg malonaldehyde/kg. According to Egyptian requirements, the allowed upper limit of TBA as an index of fish quality during storage of fish is

4.5 mg malondialdehyde/kg fish meat [32]. It is evident from the data that none of the investigated samples exceeded the limits indicated above. An increase in the WHC values was recorded for the control, T1 and T2 samples with pass of storage time. An increase for the control, T1 and T2 was 31.6%, 20.0% and 17.4%, respectively. In general, the microbial load of fish leads to its more rapid spoilage compared to other muscle foods like meat and chicken, and this spoilage is largely bacterial in nature. Therefore, effective preservation methods should prevent the microbiological decomposition of fish without diminishing its quality or nutritional value. To test the microbiological safety of the products, the total bacterial count and psychrophilic count of the control, T1 and T2 samples were examined microbiologically each month during frozen storage at –18 °C.

Table 4 shows the total plate count (TPC) and psychrophilic bacterial (PSY) count of the control, T1 and T2 samples as affected by storage time at –18 °C. The initial TPC and PSY loads were 2.32 and 2.02 log cfu/g for control; 2.24 and 1.72 log cfu/g for T1; 2.30 and 1.47 log cfu/g for T2, respectively. During frozen storage, the levels of TPC in the control, T1, and T2 samples changed. The TPC and PSY values in the control, T1 and T2 samples showed the downward trend to the values of 2.25 and 1.81; 1.82 and 1.23; 1.89 and 1.28 log cfu/g, respectively, at the end of 3-month storage. A decrease in TPC and Psy may be attributable to bacterial cell damage brought on by the ice crystal growth [33]. Freezing causes a reduction in bacterial count, which continues to fall in the majority of cases throughout frozen storage [34]. The permissible recommended limit of TPC by EOS in chilled fish is 10^6 cfu/g= 6 log cfu/g [35]. Our results after storage time of 3 months at –18 °C did not exceed the recommended limits.

Conclusion

In summary, for innovative utilization of Nile perch fish, we have successfully prepared Nile perch fish nuggets by replacing a part of fish flesh with sesame hulls or sunroot and stored for 3 months at –18 °C. Nile perch flesh had the highest protein content (20.21%), while sesame hulls were rich in fat (13.54%), crude fiber (17.24%) and ash (16.11%). The results show that the sensory score of fish nuggets with sunroot was acceptable up to the 10% replacement ratio (T1). When this ratio was exceeded, a big change in texture and taste, as well as the overall acceptability of fish nuggets, was observed. On the other hand, regarding the sensory evaluation of fish nuggets with sesame hulls, the replacement ratio reached 7.5% (T2). In conclusion, this study suggests that it is possible to develop an alternative ready-to-eat product from fish by replacing a part of fish flesh with sesame hulls or sunroot with an appropriate amount of ingredients in the formulation.

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