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Effect of Encapsulated Fish Oil and Herbal Extracts on the Quality and Shelf Life Fish Burger (*Hypophtalmichtys molitrix*) at -18°C

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Abstract: This study was to investigate the effect of encapsulated fish oil and herbal extracts on the quality and shelf-life of fish burger (*Hypophtalmichtys molitrix*) functional at -18°C. Low consumption of omega-3 unsaturated fatty acids (EPA and DHA) in the community due to many factors such as the high cost of fish, the reluctance of many consumers to seafood (fishy odor, the presence of large intramuscular bones and difficult to clean by Consumer), the presence of methyl mercury, low access to offshore provinces and its sensitivity to fat oxidation. Therefore, delaying fat oxidation in order to increase the shelf life of a food during storage and preservation of a product in terms of sensory properties (tasty) has positive effects on consumer health. In this study, omega-3 fish oil is added to the fish burger by adding alginate, xanthan and maltodextrin in the form of emulsion by coagulation method (the simplest and cheapest method); along with cinnamon and rosemary plant extracts (natural antioxidants). Therefore the results showed, the highest and lowest baking yields were related to control treatments containing vegetable oil (87.65%) and rosemary extracts emulsion treatment (83.24%). The oxidation of fish burgers in microencapsulation and rosemary treatments was 5.98, and the burger treatments containing rosemary emulsion with 5.62 showed the lowest pH ($P < 0.05$). The index of TBA was in the treatment of rosemary microencapsulated burgers, 6.40 mg, which showed the least amount in comparison with the two treatments. The highest and lowest amounts of active Thiol group index were recorded in emulsification and rosemary treatments in Burger (4.17) and cinnamon emulsion (3.10) µmole respectively. According to the results of Sensory scores this study, the use of emulsion of rosemary and cinnamon is recommended to enrich the fish burger. Fish burgers enriched with omega-3 emulsion containing rosemary and cinnamon extract prevent fat oxidation, microbial spoilage and preserve the nutritional value of the product during storage at -18°C in the freezer for up to 4 months.

Keywords: Emulsion, Omega-3, Enrichment, Fish Burger, Microencapsulation

1. Introduction

Considering the lack of protein in most human societies, as well as the benefits of using protein found in seafood and the existence of abundant sources of seafood in the world, it is considered a suitable motivation to introduce seafood to people's diet. Compared to the tissues of mammals and birds, fish tissue deteriorates quickly mainly due to the presence of significant amounts of long chain fatty acids with multiple double bonds (PUFAs) [34]. Oxidation of lipids in meat products is a key problem for increasing the shelf life of meat products. Oxidation of lipids causes harmful changes in the flavor of products [43, 44]. Considering the benefits of fish oil [1], one of the ways to enrich food products is adding fish oil to them [12]. In recent years, the production of food products enriched with oils containing high amounts of unsaturated fatty acids from various sources, such as canola seeds [42], Olivine [11], fish oil [37]. Fish oil is often thought of as a source of omega-3 fatty acids in the diet. The effects of these fatty acids on human health, the prevention of cardiovascular disease, cancer, and the proper functioning of the brain and neural tissues have been well documented [37, 47]. One of the ways to increase the consumption of fish oil is to enrich various foods with it. Fish oil does not usually have good taste and odor and is very sensitive to oxidation [32]. The microcapsulated of unsaturated oils to enrich various foods is one of the strategies to reduce the oxidation reaction and thus improve the taste of the oil [11]. In microcapsulation technology, some carbohydrates and proteins can be used to form a microcapsulation wall [26]. Carbohydrates such as xanthan and alginate, due to their variety and low cost, plus the properties of optimum solubility, have good potential for use in microcapsulated systems [7]. In the previous study, the determination of optimal amounts of xanthan and alginate for the preparation of fish oil microcapsulation revealed that the microcapsulation fish oil with xanthan was 0.75% + alginate 0.25% had the smallest amount of microcapsulation, moisture content and surface oil content [6]. Another system of protection against oxidation of fish oil is the use of emulsion systems. In these systems, fish oil emulsion can be used to enrich the meat products [8]. Oxidation of fats in meat products is one of the main problems in increasing the shelf life of frozen meat [14]. The oxidation of fats is responsible for the degradation of the flavor of several unsaturated oils [38]. To prevent the occurrence and control of the oxidation phenomenon, plant extracts can be used during the processing and maintenance of marine products [46]. In the study Hasan [18], Nano-Encapsulation of Lemon Essential Oil Approach to Reducing the Oxidation Process in Fish Burger during Refrigerated Storage showed that nano-encapsulated Lemon essential oils (LEOs) in Chitosan as a bioactive compound with antioxidativepotential 0.5 and 1% (w/w) are used as safe additives in foods during storage [19]. Cinnamon extract has antimicrobial properties and is rich in phenolic compounds and strong antioxidants that reduce fat oxidation and improve the sensory properties of the product [38]. Rosemary extract is widely used in food industry due to its antioxidant and antimicrobial properties, and this is due to the presence of compounds that break the free radical production chain by giving a hydrogen atom and subsequently delaying the oxidation of fat. Rosemary is also accepted as a spice [46]. In order to produce fish oil-rich foods, the effects of omega-3 oil fish in emulsion forms and microencapsulated powder and herbal extracts were kept on the chemical changes and sensory properties of silver carp (*Hypophthalmichthy molitrix*) at a negative temperature of 18°C.

2. Materials and Methods

2.1. Preparation of Experimental Treatments

For this research, in the first step, the fish oil (Polaris, France) with the amount of omega-3 fatty acids (39%), and the extract of cinnamon and rosemary (Crop Industry and Pharmaceutical Plant of Essential Oil of Dr. Soleimani) from prestigious companies It was purchased. Alginate gum and xanthan gum were used in the amounts (0.25% alginate + 0.75% xanthan) as wall material. To prepare the gum, the gum was homogenized with water plus maltodextrin for 1 minute. Then, by adding fish oil to the wall solution, the mixture was homogenized over a period of more than 2 minutes over a range of 10000 rpm [6]. Also, for the production of powder for microcapsuled powder treatments, the emulsions were dried in a freezer dryer for 48 hours. In the second step for the preparation of burgers, *Hypophtalmichtys molitrix* (fish with an average weight of 200 ± 1000 gr), which was used in this research, was prepared from Urmia city and transferred to the Aquatic Processing Laboratory of Artemia and Aquaculture Research Institute immediately. It turned out in the laboratory, weeding, evacuating, weeding and filleting. After washing, the fillets were bone-skeletal and placed in a refrigerator at 4°C. After the spices were added, the emulsions and microcapsuled dried powder were mixed together with the filler and binding agent. At this stage, extracts were added to treatments containing plant extracts (microcapsuled powder or emulsion). Vegetable extracts of rosemary and cinnamon were added to fish burgers in 0.5%. After burgers were molded by a hand-held burger, they were put into a zip lock -belted nylon and frozen (Figure 1). Treatments containing omega-3 emulsion and microcapsulated dried powder were compared with simple (without extract), fish oil and vegetable oil burgers. The procedure for adding oil to the fish burger was in three ways: a) adding and extract (cinnamon or rosemary) separately; b) adding the extract to the emulsion and then drying it (microcapsule powder); and c) adding the extract to the emulsion and then Burger enrichment of fish (concentration of extracts in the final burger product was 1% by weight), based on oilseed treatments and moisture content of the treatments were considered the same. Fish-enriched burgers were tested for physicochemical and sensory experiments in zero, one, two, three and four months.

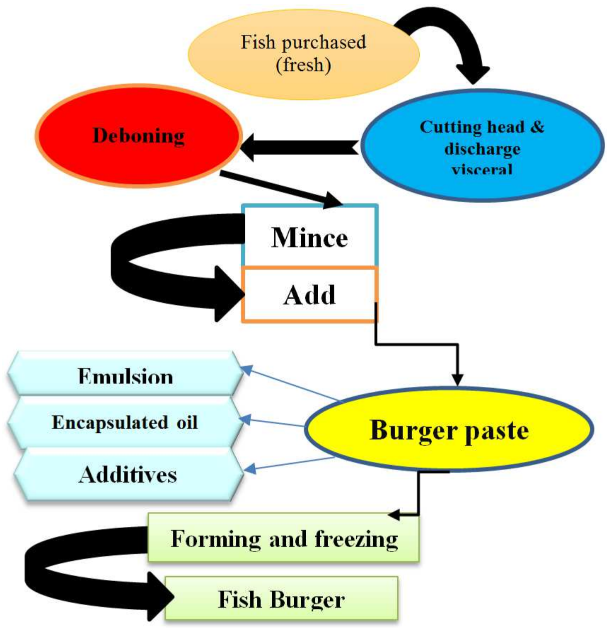

Figure 1. *Diagram of fish burger production.*

2.2. Methods

2.2.1. Baking Yield

The percentage of baking yield examines the burger weight loss after blush and is calculated from the following equation [3].

$$\text{Baking yield (\%)} = \frac{\text{Fried Burger weight}}{\textit{Weight raw burger}} \times 100$$

2.2.2. Determination of PH

5 g of sample in 45 ml of distilled water and then stirred and uniformly using a smooth sterile gauze and help pH meter, pH was measured at room temperature [35].

2.2.3. Lipid Oxidation (Thiobarbituric Acid Reactive Substances (TBARS))

The amount of thiobarbituric acid is monitored according to the Buege and Aust method. In the first step, 0.1 g of burger fish is mixed with 5 ml of thiobarbituric acid solution (containing 0.375 ppm of reagent of thiobarbituric acid, 15% trichloroacetic acid and chloride acid 0.25% normal). The tubes are placed in boiling water for 10 minutes to get pink and then cool with the tap. The tubes are centrifuged at 7000 g for 10 minutes and the absorbance of the solution is read by a spectrophotometer at 532 nm. The amount of thiobarbituric acid is determined by drawing a standard curve determined with 1, 1, 3, and 3-tetraethanol propane and expressed as milligrams of malonaldehyde per kg of sample [10].

TBA (mg/malonaldehyde per kg) = (Number of absorbed numbers read × 9.48) / Weight sample

2.2.4. Determination of Thiol Group

Active Thiol group is performed according to the Beveridge [9] method. For this purpose, start with 0.5 grams of burger fish with 20 milliliters of solvent buffer (solvent buffer containing 10.4 grams of tries, 6.9 grams of glycine, 1.2 grams of ethylenediamine tetraacetic acid (EDTA) In a 800 ml volumetric balloon, then the pH was adjusted to pH 8. Using a sulfuric acid, in another, dissolved 10 g of laboratory salt in 150 ml of distilled water, after which the two solutions were in a balloon The tube was fed into a volume of 1000 ml) into a falcon tube and homogenized using a homogenizer for 30 seconds. It should be noted that in each treatment, the apparatus was first washed with distilled water. After that, the falcon tubes were centrifuged with 10,000 rpm for 7 minutes, then 3 ml of supernatant was removed by pipette and 0.3 ml of DTNB reagent entered the tube and placed in a 40°C incubator for 25 minutes. The spectrophotometer was then adjusted to 412 nm and the solvent adsorption was read. The control sample consisted of 3 ml of distilled water plus 0.3 ml of DTNB reagent.

Concentration of sulfidryl (µmole per gram of protein) = (73/53 × absorbed numbers) / Protein%

2.2.5. Sensory Evaluation

The prepared burgers were fried in the same way and provided to the evaluator group. Sensory evaluation was performed using a panel of 22 trained panel members. These people presented their views after evaluating the taste, appearance and acceptance indicators with a 9-point standard (9 high and 1 extremely bad [3]. The critical point of acceptance of each of the features was considered 5, and the score below 5 (average quality) meant a rejection of the desired sensory characteristics.

2.3. Statistical Analyses

The sampling method for the entire period of investigation was random. Kolmogorov-Smirnov test was used to check the normality of the data. The results of ANOVA or two-way ANOVA using SPSS software to analyze and compare the mean data using Duncan's multiple range test (for quantitative data) and Tukey test (to check data sensory evaluation) was conducted at the level of 5.0 percent.

3. Results and Discussion

3.1. Baking Yield

The results of the baking yield process of omega-3-enriched fish burgers are shown in Table 1. The results showed that bilateral analysis of variance showed no significant effect on the type of plant extracts on the yield index of the first month ($P < 0.05$). In other months, the effect of plant extracts on baking yield was significant ($P < 0.05$). Oil state index except the second month ($P < 0.05$) had a significant effect on the amount of baking yield index ($P < 0.05$). The effect of interaction between the type of plant extracts and the oil state added to the fish burger, except in the third month, was significant ($p < 0.05$) in other months ($P < 0.05$). The difference in baking yield index varied over time. In the time zero, the production of Burger fish was different between different treatments ($P < 0.05$). In the third month, the control of the fish burgers in the control group showed the highest amount of vegetable oil with the highest amount of 87.65 and the burger treatment of the rosemary extract with a sample of 83.25 grams showed the least amount of baking yield ($P < 0.05$). In the study of López-Vargas, the quality of burger pigs obtained with yellow-flowered flavors fiber (flaviakarpa), frying yield was 69/70 percent, while in this study the baking yield was from 84 percent to 91 percent Percentage. Different cooking yields in this study compared to the research by López-Vargas [24] can be related to the amount of moisture and type of meat consumed.

3.2. pH

Two-way analysis of variance indicated that the effect of the type of extract on the pH of the first month was not significant ($P < 0.05$) (Table 1), whereas in the other months, the effect of the extracts on pH was significant (P < 0.05). PH changes are used as an indicator of the microbial degradation of marine products. Oil level index, with the exception of month 1 (P < 0.05), had a significant effect on pH value (p < 0.05) in the rest of the measured periods. The interaction of plant extracts and oil added to fish burger, except for the first and second months of sampling, which was not significant (P < 0.05), had a significant effect on other months (0.05 > P). In the months of inspection, the fish burgers in microcapsulated and rosemary treatments were 5.98 and the lowest and the burger treatments contained a rosemary emulsion with the lowest pH of 5.62 (P < 0.05). In the two treatments, the pH value first decreased and then increased. On day zero, burger production showed that treatments containing cinnamon extract had higher pH than cinnamon-free treatments (P < 0.05). The pH index ranges from 7 to 8/6 to an acceptable level and above that corruption occurs [31]. In the studied treatments, the pH first decreased and then increased over time. Several authors have reported different results in reducing or increasing pH in different species of fish [29]. Research the Angiolillo [4] in 2015, was in line with Hassanpour [18] research in 2015. In the results, the researchers found that in all the experimental factors, adding extracts on the burgers would have a positive effect on increasing the shelf life of the product. In a study by Ozogul [30] and other researchers, similar results were observed in pH changes for Burger fish [25, 41]. Other authors also reported an increase in pH in burger meat with different types of dietary fiber [17, 36].

Table 1. *Baking Efficiency and pH values (%) of omega-3 oil enriched fish burgers during storage at -18°C.*

Treatment	Time (month)	0	1	2	3	4
Baking yield	Emulsion and cinnamon	^{abcA}0.54±88.50	^{aB}0.56±81.96	^{aAB}0.85±86.52	^{aAB}0.52±87.22	^{cB}0.76±82.00
	Microencapsulation powder + cinnamon	^{abA}0.30±88.66	^{aA}0.68±82.76	^{aA}0.17±87.73	^{cdA}0.91±84.8	^{bA}0.63±86.11
	Cinnamon Emulsion	^{abcA}0.62±87.45	^{aA}0.45±82.89	^{aA}0.06±88.96	^{bA}0.30±85.90	^{bA}0.72±85.97
	Emulsion and rosemary in burger	^{abA}0.83±89.67	^{aB}0.89±82.39	^{bB}0.45±81.50	^{bcAB}0.25±85.10	^{bAB}0.76±85.90
	Microencapsulation Powder + Rosemary	^{aA}0.68±91.22	^{aAB}0.10±87.55	^{aA}0.86±89.68	^{dB}0.63±83.58	^{eA}0.53 ±88.88
	Rosemary Emulsion	^{cAB}0.75±84.54	^{aAB}0.18±84.08	^{aA}0.85±89.79	^{dB}0.69±83.25	^{aAB}0.52±88.61
	Microencapsulation powder	^{bcB}0.57±85.30	^{aB}0.71±85.36	^{aA}0.13±87.32	^{cdB}0.71±84.49	^{cC}0.37±83.20
	Check with fish oil	^{abA}0.45±89.97	^{aA}0.87±88.25	^{aA}0.72±86.89	^{aA}0.217±87.65	^{aA}0.34±88.13
	Check with vegetable oil	^{abA}0.52±89.99	^{aAB}0.84±87.56	^{aA}0.19±90.22	^{baB}0.12±85.41	^{aAB}0.42±87.68
pH	Emulsion and cinnamon	^{aA}0.20±7.12	^{aB}0.10±6.78	^{abD}0.11±5.64	^{deD}0.60±5.68	^{dC}0.52±5.91
	Microencapsulation powder + cinnamon	^{bA}0.13±6.96	^{aB}0.10±6.62	^{cD}0.78±5.84	^{deD}0.80±5.68	^{cC}0.11±6.02
	Cinnamon Emulsion	^{aA}0.20±7.10	^{aB}0.80±6.62	^{cE}0.05±5.61	^{bD}0.23±5.83	^{bC}0.17±6.13
	Emulsion and rosemary in burger	^{aA}0.32±7.09	^{aB}0.11±6.71	^{aD}0.01±5.57	^{bcD}0.10±5.78	^{cC}0.28±6.03
	Microencapsulation Powder + Rosemary	^{abA}0.45±7.08	^{aA}0.20±6.83	^{cC}0.11±5.88	^{aD}0.10±5.98	^{aC}0.40 ±6.25
	Rosemary Emulsion	^{cA}0.35±6.73	^{aA}0.20±6.69	^{cD}0.77±5.58	^{eC}0.47±5.62	^{cB}0.15±6.03
	Microencapsulation powder	^{cA}0.49±6.64	^{aA}0.26±6.68	^{cD}0.55±5.65	^{cdC}0.20±5.75	^{dB}0.50±5.93
	Check with fish oil	^{cA}0.10±6.75	^{aA}0.12±6.81	^{cD}0.20±5.63	^{bCc}0.25±5.78	^{aB}0.20±6.23
	Check with vegetable oil	^{cA}0.10±6.75	^{aA}0.51±5.70	^{bcC}0.11±5.70	^{cdC}0.25±5.75	^{aB}0.26±6.22

The numbers represent mean ± SD.'(A-B) Various capital letters in each row indicate a significant difference between various test times in a treatment. (a-b) Various small letters in each column indicate a significant difference between various treatments at a specific sampling time.

3.3. Thiobarbituric Acid (TBA)

Thiobarbituric acid is expressed as a secondary oxidation index of lipid degradation [23]. Secondary combinations of lipid oxidation from brown oxidation of omega-3 and fortified plant extracts were measured by measuring the index of TBA. The results of oxidative degeneration of the burger specimens in Table 2 showed that the sample values on day zero (production Burger), no significant differences were observed (P < 0.05). In 1996, Karakam and Boran reported higher levels of malondialdehyde greater than 3-4 mg per kilogram of fish meat [21, 28]. The changes in the index of TBA during the storage at -18°C in the two treatments had an increasing trend. Due to the fact that in the two treatments, the oils in liquid form were added to the burger formulation without the microcapsulation technique, so this increase indicates the development of lipid oxidation corruption, the lack of protection of unsaturated fatty acids [22]. Rosemary micropcapsulated burgers had a decreasing trend over the course of 4 months with 6.40 mg malondialdehyde per kg of sample compared to two treatments, while burger treatments containing freeze-dried microcapsulated powder, emulsion and powder containing cinnamon extract had higher fat oxidation (05/0> P). Ucak Ozogul reported in 2011 that the mackerel burgers survived without a rosemary extract for 10 days, while burgers containing 0.4% rosemary extract could increase shelf-life by up to 15 days [41]. The use of various antioxidants decreases the amount of TBA in fish products [30]. Also, the low levels of TBA in 1.6 g malondialdehyde in 100 g of samples were observed in 0.4% and 0.8% rosemary extract [41]. The results of other studies by the researchers confirm the increasing trend and then the decrease in the amount of TBA during storage of products in freezing conditions, including the results of Chuapoehuk [13], on snap fingers produced from Lizard fish, Threadfin, Barracuda, and Calvo [11]. On *Tinca tinca* and Yanar, [45], on the capillaries of *Tilapia Tilapia* and *Cyprinus carpio*, as well as Gelman & Benjamin, [16], on silver carp of *Hypophthalmichthys molitrix* and Tokur [39], on the *Tinca tinca* fish burgers. In the present study, the treatment had a microcapsul powder and the rosemary extract had the least amount of thiobarbituric acid during the storage period of the burgers in the freezer.

Table 2. *Thiobarbituric Acid values of omega-3 oil enriched fish burgers during storage at -18°C.*

Treatment	Time (month)	0	1	2	3	4
Thiobarbituric Acid	Emulsion and cinnamon	^{aC}1.25±3.51	^{cBC}0.13±6.53	^{bAB}1.12±10.09	^{abA}4.18±12.95	^{abA}2.20±13.99
	Microencapsulation powder + cinnamon	^{aB}1.10±3.98	^{fB}0.66±4.78	^{aA}0.96±14.29	^{aA}1.57±16.32	^{aA}2.25±16.20
	Cinnamon emulsion	^{aC}0.96±3.24	^{gC}0.86±4.43	^{bB}0.55±9.56	^{aB}2.71±8.90	^{abA}1.77±12.79
	Emulsion and rosemary in burger	^{aC}1.20±3.19	^{hB}0.29±7.98	^{cB}0.57±7.25	^{cdB}0.51±8.70	^{bA}1.21±12.11
	Microencapsulation Powder + Rosemary	^{aA}0.56±3.78	^{fB}0.95±4.87	^{dB}0.29±5.01	^{eB}0.47±4.85	^{cA}0.20 ±6.40
	Rosemary emulsion	^{aB}0.93±3.45	^{eB}0.13±5.51	^{aAA}1.31±13.06	^{bcA}1.25±11.95	^{abA}1.87±12.96
	Microencapsulation powder	^{aB}1.12±3.36	^{bB}0.66±7.13	^{aA}0.68±14.43	^{abA}1.19±13.55	^{abA}2.85±15.09
	Check with fish oil	^{aB}0.77±3.69	^{aB}0.22±9.18	^{aA}2.44±14.45	^{abA}1.56±13.07	^{abA}2.61±13.13
	Check with vegetable oil	^{aB}2.55±3.67	^{dB}0.76±6.09	^{aA}0.69±14.91	^{deB}0.62±14.81	^{aB}0.65±14.93

The numbers represent mean ± SD.'(A-B) various capital letters in each row indicate a significant difference between various test times in a treatment. (a-b) Various small letters in each column indicate a significant difference between various treatments at a specific sampling time.

Table 3. *Thiol group values of omega-3 oil enriched fish burgers during storage at -18°C.*

Treatment	Time (month)	0	1	2	3	4
Thiol group	Emulsion and cinnamon	^{deC}0.01±3.21	^{cC}0.06±3.29	^{aB}0.28±3.73	^{aA}0.06±4.12	^{dD}0.10±2.45
	Microencapsulation powder + cinnamon	^{cA}0.02±3.59	^{dC}0.03±3.12	^{aB}0.07±3.35	^{abcA}0.10±3.69	^{aB}0.08±3.35
	Cinnamon Emulsion	^{fB}0.08±3.10	^{cB}0.03±3.26	^{aA}0.41±3.76	^{abcA}0.40±3.79	^{eC}0.10±2.05
	Emulsion and rosemary in burger	^{aA}0.09±4.17	^{cC}0.04±3.22	^{aB}0.10±3.67	^{abcB}0.33±3.55	^{bD}0.17±2.89
	Microencapsulation Powder + Rosemary	^{dAB}0.08±3.32	^{cAB}0.02±3.32	^{aA}0.02±3.65	^{bcAB}0.34±3.57	^{aB}0.12 ±3.30
	Rosemary Emulsion	^{dB} 0.08±3.31	^{eC}0.09±2.99	^{bD}0.20±2.53	^{abA}0.21±3.92	^{bcCD}0.13±2.80
	Microencapsulation powder	^{bA}0.08±3.82	^{dC}0.00±3.09	^{bE}0.16±2.25	^{cB}0.01±3.43	^{bcD}0.08±2.77
	Check with fish oil	^{efA}0.09±3.14	^{aB}0.09±4.07	^{bD}0.40±2.25	^{bcB}0.27±3.50	^{cC}0.01±2.67
	Check with vegetable oil	^{deB}0.12±3.28	^{bA}0.02±3.81	^{bC}0.30±2.43	^{abcA}0.06±3.70	^{aB}0.06±3.20

The numbers represent mean ± SD.'(A-B) Various capital letters in each row indicate a significant difference between various test times in a treatment. (a-b) Various small letters in each column indicate a significant difference between various treatments at a specific sampling time.

3.4. Thiol Group

To investigate the structural changes of proteins by oxidation, sulfidryl is investigated. The results of active sulfidryl variations in omega-3 oil-rich burger and various herbal extracts in the 4-month period at -18°C are shown in Table 3. The results of this study are presented in Table 3. Based on these findings, Burger samples showed that bilateral analysis of variance showed no significant effect on the type of plant extracts in active sulfidrile ($P < 0.05$) during the 3rd month. In other months, the effect of plant extracts on this index was significant ($P < 0.05$). Oil state index except for months 1 and 4 ($P < 0.05$), which was significant, did not affect the amount of active sulfidilic acid in the rest of the measured periods ($P < 0.05$). The interaction of plant extracts and oil additive to Burger fish, except for the 3rd month, was not significant ($p < 0.05$), in other months was significant ($P < 0.05$). The difference in active sulfidryl index was different at different times. At zero time, there was no difference between different treatments ($P < 0.05$). In the month of zero (day of production), the Burger fish emulsion and rosemary in a burger with a value of 4.17 (the increase in their amount as a protein breakdown and fragmentation) and cinnamon emulsion treatment with a sample of 3.10 g, the lowest indicating the interaction Proteins exhibited active sulfidilic index ($P < 0.05$). Rahmani Farah [33], with the study of total sulfidryl, active sulfidryl and disulfide bonds of Kilka fish protein powder, said active sulfidryl assay is a reliable indicator for evaluating the quality of fish protein and its oxidation. Investigating these researchers, the amount of active sulfidryl was reduced by oxidation of the protein, and the amount of sulfide bonds increased. In addition, a decrease in the total sulfidryl content can be associated with the reduction of cysteine along with the formation of insoluble compounds [20]. During the storage period, the denaturation of proteins led to the oxidation of the thiol group, and at the same time, sulfidryl myosin groups were exposed to oxidation and participated in sulfide-sulfide exchange reactions and eventually denatured and formed heavy communities Molecules help [5]. In total, during the storage period of fish in the refrigerator, changes in the shape of proteins have occurred and this process leads to the continuation of the emergence and burial of sulfidryl groups. Investigating active sulfidryl measurements revealed that its reduction in cinnamon emulsion treatment was lower than that of other treatments, which had a significant difference with control treatments ($P < 0.05$). According to the results of this section, control treatment with vegetable oil and treatments containing plant extracts had a higher sulfidryl content at the end of the experiment period. Also, the results showed that the microstructured oil had no effect on the amount of protein oxidation.

3.5. Sensory Evaluation

3.5.1. Taste

The results of the burger flavor test are presented in Table 4. The results showed that the quality of flavors of all treatments decreased significantly after 4 months of storage at -18°C ($P < 0.05$). However, this reduction was significant for control treatments with vegetable oil and emulsification treatments and rosemary in Burger not acceptable (05/0> P). According to chemical experiments, the burger's taste loss can be due to the oxidation of fat and protein, as well as the hydrolysis of lipids [39]. Adding plant extracts and microcapsulated oil to fish burgers during the whole experiment did not significantly change the smell of samples ($P < 0.05$). In other fish storage, the differences between treatments were significant ($P < 0.05$). Changes in the odor scores over time were not significant ($P < 0.05$).

3.5.2. Appearance

The appearance index of omega-3-enriched fish burgers and plant extracts during the storage period at -18°C is presented in Table 4. Two-way analysis of variance indicated that none of the studied factors had any significant effect on the appearance index of the tested burgers ($P < 0.05$). The difference between experimental treatments and the differences in experimental treatments over time was not significant ($P < 0.05$). Therefore, it can be concluded that although the quality of flavor and odor of emulsified oil burgers was better than microcapsulated oil burgers, but generally the oil was added or the type of extract did not affect the appearance of the fish burger, and in this regard all the burgers had a seemingly Acceptance throughout the trial period. The results of studies by Tokur on *Cyprinus carpio* fish fingers show that the fingers were kept at a temperature of -18°C for four months at a temperature of -5°C for stable qualitative properties, and no significant difference was observed in changes Their senses have not been seen [40].

Table 4. *Sensory index of omega-3 oil-rich burgers and herbal extracts during storage at -18°C.*

Treatment	Time (month)	0	1	2	3	4
	Emulsion and cinnamon	^{aAB}2.05±7.20	^{aAB}1.12±7.21	^{aA}0.95±7.71	^{abB}1.61±5.57	^{aB}1.00±6.00
	Microencapsulation powder + cinnamon	^{aA}1.48±7.20	^{abA}1.60±6.43	^{bB}2.43±4.29	^{abAB}1.60±5.70	^{aB}0.89±5.60
	Cinnamon Emulsion	^{aA}2.36±6.90	^{abA}0.76±6.50	^{abA}1.21±6.40	^{abAB}1.59±5.77	^{aB}0.89±4.40
	Emulsion and rosemary in burger	^{aA}1.58±7.00	^{abA}1.18±7.00	^{abA}1.62±6.43	^{aA}1.59±6.60	^{aA}1.52±5.60
Taste	Microencapsulation Powder + Rosemary	^{aA}1.95±5.60	^{bA}1.34±5.64	^{bAB}1.80±4.71	^{bAB}1.88±4.67	^{aB}0.84±3.20
	Rosemary Emulsion	^{aA}1.14±7.40	^{abA}1.35±6.86	^{abAB}0.79±6.43	^{abAB}1.41±6.17	^{aB}1.92±5.20
	Microencapsulation powder	^{aA}1.48±7.20	^{abA}1.27±6.93	^{abAB}0.76±6.29	^{abAB}1.67±5.63	^{aB}1.73±5.00
	Check with fish oil	^{aA}1.58±7.00	^{abA}1.27±7.07	^{abAB}1.60±5.71	^{aA}1.32±6.57	^{aB}2.59±4.80
	Check with vegetable oil	^{aA}0.89±7.60	^{abA}1.49±7.07	^{aA}1.27±6.43	^{aA}1.50±6.67	^{aA}1.92±6.20
	Emulsion and cinnamon	^{aA}1.67±7.60	^{aA}0.38±8.14	^{aA}1.10±7.14	^{aA}1.00±7.00	^{aA}1.51±6.00
	Microencapsulation powder + cinnamon	^{aA}1.41±7.50	^{aA}1.90±6.57	^{aA}1.38±7.07	^{aA}1.00±7.00	^{aA}1.15±6.20
	Cinnamon Emulsion	^{aA}2.07±7.10	^{aA}1.21±7.14	^{aA}1.10±7.14	^{aA}1.10±6.80	^{aA}1.72±5.67
	Emulsion and rosemary in burger	^{aA}1.30±7.80	^{aA}0.95±7.71	^{aA}1.14±7.07	^{aA}1.10±6.60	^{aA}1.45±6.40
Appearance	Microencapsulation Powder + Rosemary	^{aA}1.40±7.30	^{aA}1.25±7.29	^{aA}1.07±7.29	^{aA}1.00±7.00	^{aA}1.15±6.20
	Rosemary Emulsion	^{aA}1.00±8.00	^{aA}1.13±7.43	^{aA}0.97±7.21	^{aA}0.55±7.40	^{aA}1.51±6.47
	Microencapsulation powder	^{aA}1.20±7.70	^{aA}0.76±7.71	^{aA}1.05±7.21	^{aA}1.00±7.00	^{aA}1.28±6.73
	Check with fish oil	^{aA}1.00±8.00	^{aA}0.76±7.71	^{aA}0.94±7.43	^{aA}0.89±7.40	^{aA}1.16±6.93
	Check with vegetable oil	^{aA}1.58±7.50	^{aA}0.76±7.29	^{aA}0.99±7.71	^{aA}0.89±7.40	^{aA}0.88±7.17

The numbers represent mean ± SD.'(A-B) Various capital letters in each row indicate a significant difference between various test times in a treatment. (a-b) Various small letters in each column indicate a significant difference between various treatments at a specific sampling time.

3.5.3. General Acceptance

The results of the general acceptance of omega-3 oil-rich burgers and herbal extracts during storage at -18°C are presented in Table 5. Statistical analysis showed significant differences between experimental treatments in the 3rd month ($P > 0.05$). There was no significant difference between treatments in other months ($P < 0.05$). With a general look at the samples of Burgers kept at -18°C, we can state that the overall acceptance and duration of burger samples seem logical for sensory evaluations of up to 4 months, and the samples are sensory, The market will not miss its consumption and acceptance, but there were significant differences between different burgers. In a study by Al-bulushi [2], on the *Argyrosomus heinii* fish burgers product, it was observed that maintaining the burgers for 3 months at -20°C would not cause loss of qualitative properties and their usability. And burger snails will be of good quality during this and subsequent period [15]. Also, the results of Ersoy et al.'S research in 2005 on *Barbus luteus* fish flasks during the 6 months of freezing showed that sensory parameters such as appearance, smell, taste, texture, and total acceptance of wing wings during Six months of maintenance have been modest and no significant differences were observed during this period in sensory factors [15]. In this study, the addition of herbal and oil extracts to simple, emulsion and microcapsul forms did not negatively affect the acceptance and acceptability of fish burgers. Therefore, Burger can be enriched with omega-3 oil with selected treatment for other qualitative indicators.

3.5.4. Color

The results of the color index of omega-3 oil-rich burgers and herbal extracts during storage at -18°C are presented in

Table 5. There was no significant difference between treatment and time with the results of Burger's sensory examination (P < 0.05). However, the color score decreased with time, but this decrease was not statistically significant (P < 0.05). Two-way analysis of variance showed no significant effect on the type of extract and oil state (P < 0.05). Statistical analysis showed significant differences between experimental treatments in the 3rd month (P > 0.05). There was no significant difference between treatments in other months (P < 0.05). Monjurul In 2013, Reviewed the quality of the carnivorous grass carp (*Ctenopharyngodon idella*). In the sensory evaluation of the production burgers, it was found that samples that had a bright brown color were better for the consumer. These researchers reported a drop in brown color due to excessive heat during frying in oil or the presence of a small amount of black muscle in minced meat [27]. The study of taste, appearance, general acceptance and fish burgers color shows that over a period of 4 months burgers at -18°C, There is no restriction products were of acceptable quality for consumers.

Table 5. *Sensory index of omega-3 oil-rich bergers and herbal extracts during storage at -18°C.*

Treatment	**Time (month)**	**0**	**1**	**2**	**3**	**4**
General acceptance	Emulsion and cinnamon	^{aA}1.20±7.70	^{aA}1.23±7.20	^{aA}1.21±6.35	^{aA}0.58±8.00	^{aA}0.50±5.87
	Microencapsulation powder + cinnamon	^{aA}1.30±6.80	^{aA}1.34±6.41	^{aA}1.15±6.23	^{aA}2.45±5.00	^{aA}0.63±5.67
	Cinnamon Emulsion	^{aA}1.60±6.10	^{aA}0.92±6.34	^{aA}1.45±5.88	^{aA}1.21±6.14	^{aA}0.72±5.06
	Emulsion and rosemary in burger	^{aA}1.40±7.30	^{aA}1.15±6.74	^{aA}1.25±6.99	^{aA}0.70±6.71	^{aA}1.62±5.87
	Microencapsulation Powder + Rosemary	^{aA}1.30±6.20	^{aA}1.42±6.09	^{aA}1.32±5.80	^{aA}1.57±6.14	^{aA}2.00±4.66
	Rosemary Emulsion	^{aA}0.97±7.30	^{aA}1.12±6.91	^{aA}1.10±6.58	^{aA}0.79±6.43	^{aA}1.54±5.66
	Microencapsulation powder	^{aA}1.20±6.70	^{aA}0.95±6.97	^{aA}1.10±6.49	^{aA}0.79±6.43	^{aA}2.02±5.66
	Check with fish oil	^{aA}0.84±6.80	^{aA}1.21±6.96	^{aA}1.01±6.94	^{aA}1.77±5.14	^{aA}2.22±5.25
	Check with vegetable oil	^{aA}0.89±7.40	^{aA}1.32±7.21	^{aA}1.15±6.95	^{aA}1.40±6.57	^{aA}1.83±6.27
Color	Emulsion and cinnamon	^{aA}1.79±7.80	^{aA}0.93±7.64	^{aA}0.58±8.00	^{aA}0.84±6.80	^{aA}1.65±6.00
	Microencapsulation powder + cinnamon	^{aA}1.52±7.40	^{aA}1.16±7.43	^{aA}1.90±6.43	^{aA}0.84±6.80	^{aA}1.45±6.33
	Cinnamon Emulsion	^{aA}1.67±7.60	^{aA}0.94±7.43	^{aA}1.15±7.00	^{aA}0.84±6.80	^{aA}1.65±6.00
	Emulsion and rosemary in burger	^{aA}1.34±7.60	^{aA}0.73±7.29	^{aA}0.53±7.57	^{aA}0.85±6.80	^{aA}1.51±6.47
	Microencapsulation Powder + Rosemary	^{aA}1.30±7.80	^{aA}1.05±7.21	^{aA}1.40±6.57	^{aA}0.86±6.80	^{aA}1.30 ±6.13
	Rosemary Emulsion	^{aA}1.10±8.20	^{aA}1.15±7.36	^{aA}0.69±7.14	^{aA}0.55±7.40	^{aA}1.19±6.87
	Microencapsulation powder	^{aA}0.84±7.80	^{aA}0.89±7.21	^{aA}0.76±7.29	^{aA}0.84±7.20	^{aA}1.20±6.97
	Check with fish oil	^{aA}1.00±8.00	^{aA}0.84±7.36	^{aA}1.11±7.29	^{aA}1.00±7.00	^{aA}1.14±7.10
	Check with vegetable oil	^{aA}0.84±8.20	^{aA}0.95±7.86	^{aA}1.07±6.86	^{aA}0.84±7.20	^{aA}1.08±7.20

The numbers represent mean ± SD.'(A-B) various capital letters in each row indicate a significant difference between various test times in a treatment. (a-b) Various small letters in each column indicate a significant difference between various treatments at a specific sampling time.

4. Conclusion

Based on the results of chemical and physical tests, in this study, fish oil treatments in the form of emulsions or oils in the form of microcapsuled powder with cinnamon and rosemary extracts showed better quality than adding fish oil without preparation to fish burgers. In the sensory evaluation section, the effect of chemical reactions resulting from fat and protein degradation was not significant enough to change the taste and appearance and overall acceptance of burgers. Based on this study, emulsion and herbal extracts have been used better than other methods. Also, Rosemary extract was more effective in reducing the process of corrosivity of the product than the cinnamon extract.

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