



Investigate the quality parameters of fish crockets manufactured using different proportions of Jerusalem artichoke fibre

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ABSTRACT

This study determined the physico-chemical, microbiological and sensory properties of rainbow trout (*Oncorhynchus mykiss*) croquettes prepared with different proportions of Jerusalem artichoke fibre. For this purpose, three different concentrations of Jerusalem artichoke fibre (2%, 4% and 6%) were used, and a total of 4 groups of fish croquettes were prepared, including the control group without fibre. The prepared fish croquettes were packaged in styrofoam plates, covered with stretch film, and stored in the refrigerator ($4 \pm 1^\circ\text{C}$) for 25 days. In terms of physicochemical properties between groups, water and fat contents were found to be significant ($p < 0.05$), but protein, ash, carbohydrate and pH values were found to be insignificant ($p > 0.05$). TVB-N and TBARS values were very significant ($p < 0.01$). According to the microbiological analysis results, the bacterial counts of trout croquettes prepared with Jerusalem artichoke fibre were lower than the control group, and an increase was detected in all groups in parallel with storage. The most liked sensory group was the group B croquettes. In light of all these results, it was concluded that it is possible to use Jerusalem artichoke fibre in rainbow trout croquettes.

Keywords: Crocket, Fibre, Jerusalem artichoke, Quality

Introduction

Recently, consumers have started to show interest in ready meals, and demands have increased for foods that are easy to prepare and consumed quickly. In addition, showing awareness of healthy nutrition has caused consumers to prefer healthy and low-calorie foods (Kılınççeker & Karahan, 2019).

With rapid urbanisation and the increase in working women, fast food's popularity is increasing daily, and consumer preferences are shifting significantly towards such products. In addition, young people are now more interested in fast food style products. Fish croquettes, among the new generation fast food products, are especially popular among the young generation due to their delicious taste, unique texture and colour, and high nutritional quality. The fact that it is easy to prepare increases its popularity among employees (Emir Çoban, 2020; Emir Çoban, 2021).

Seafood is important for consumption because it contains significant amounts of protein, essential amino acids, and unsaturated fatty acids. In this respect, seafood and products prepared with seafood are important in fast and ready-meal consumption. Fish croquettes are a nutritious and delicious ready food and appear as a ready-to-use alternative for consumers. By using fish in the form of croquettes, the consumption rate can be increased, and fish with a short shelf life can be kept longer. In addition, the added additives contribute positively to the taste. Croquettes, marketed as cooked and ready for consumption, provide consumers convenience and offer delicious and nutritious foods (Bilgin & Metin, 2022).

Seafood processing in different forms is among the preferred products, especially in luxury hotels and restaurants. Using fish with low economic value, such as fish balls, croquettes, cakes, and sausages, will support large-scale factories (Lin et al., 2019). Croquettes are also consumed for breakfast, as a hors d'oeuvre, as a second course or as a side dish with fried meats. The main ingredients remain unchanged: chicken, fish, game, mushrooms, potatoes, artichokes, ham, shrimp, etc. Croquettes can be made with many food items (Patır et al., 2009).

Although fish products have many functional properties, such as high-quality and easily digestible proteins, health-beneficial polyunsaturated fatty acids, and vitamins and minerals necessary for human nutrition, they do not contain fibre. In this context, the use of dietary fibres in aquatic products is important in terms of not only improving functionality but also creating functional foods that are beneficial to health. In addition to increasing the nutritional value of products, dietary fibres also bring many advantages,

such as reducing the total amount of fat, water binding, volumising, improving emulsion capacity and gelling properties, increasing product yield by reducing cooking loss and cost, increasing storage stability and improving textural properties (Jayasinghe et al., 2013; Kerimoğlu, 2020).

Nowadays, diseases such as celiac, diabetes, heart and digestive disorders are quite common, and the food industry has tended to offer alternatives to people with these diseases by producing different products in this context (Keskin & Kaplan Evlice, 2015). The meat industry is focused on producing healthier meat and meat products by reducing commonly perceived “negative” ingredients and/or using health-promoting ingredients (Fernández-López, 2021). One of these functional substances is “dietary fibres” (Jayasinghe et al., 2013).

Root vegetables are essential components of human food. Jerusalem artichoke (*Helianthus tuberosus* L.) is a plant that grows naturally in the central regions of North America. It was introduced to Europe by the French in the 17th century and has been used as human food and animal feed since then. Another name is the Jerusalem artichoke plant. It is known that yams have spread to many regions in Turkey, especially the Central Anatolia and Aegean regions, but are grown in very small areas for fresh consumption (Atlıhan, 2011; Tian & Liu, 2019; Yılmaz Acar, 2021).

Many studies have shown that Jerusalem artichoke has anticancer, antioxidant, antirheumatic and antidiabetic activities. Jerusalem artichoke is an important source of inulin. Inulin is used as a functional food source. It is also a good source of dietary fibre due to the presence of inulin. It is reported that Jerusalem artichoke roots contain inulin between approximately 7% and 30% of fresh weight (Atlıhan, 2011; Çetin Babaoğlu et al., 2021). When its chemical composition is examined, it is 80% water, 1%-2% protein and high amounts of mineral substances iron (0.4-3.7 mg), calcium (14-37 mg), potassium (420-657 mg) and sodium (1,8-mg-4.0 mg) content. They are rich in lysine and methionine. It contains all the necessary amino acids in appropriate proportions. Tubers are a good source of vitamins, especially vitamin B complex (thiamine, riboflavin, niacin, B6, pantothenic acid, biotin and cobalamin), vitamin C (ascorbic acid) and β -carotene, relatively high in folate or folic acid (13-22 $\mu\text{g} \cdot 100 \text{g}^{-1}$) are available. Jerusalem artichoke tubers are low-calorie products. (Takeuchi & Nagashima, 2011; Baltacıoğlu, 2012; Harmankaya et al., 2012).

A literature review revealed a limited number of studies investigating the effect of dietary fibre addition on fish

fingers. Additionally, no study has found that Jerusalem artichoke, a rich source of inulin, was used in fish fingers. Our work is also important in developing a new product; in this context, it will contribute to the literature. At the same time, it has developed a functional product that is healthy for the consumer and producer and is thought to be important in increasing product diversity. This study investigated the usage possibilities of different ratios of Jerusalem artichoke fibre in rainbow trout (*O. mykiss*) croquettes.

Materials and Methods

Rainbow trout fillets, with an average weight of approximately 10 kg, were supplied from Atatürk University Faculty of Fisheries, and the products required for croquettes and Jerusalem artichoke were procured from a local market.

Jerusalem artichokes (*Helianthus tuberosus*) were washed with tap water and cut into slices with a knife. It was then dried in an oven at 60°C for 2 days, crushed into powder using a kitchen robot, and passed through the screen. The minced fish meat for making croquettes was added with various additives (10% wheat flour, 10% breadcrumbs, 2% salt, 5% granulated onion, 0.5% black pepper, 0.5% red pepper, 1% granulated garlic) and kneaded until a homogeneous mixture was obtained and shaped into croquettes. After shaping the dough, the coating stage was started. For this purpose, the croquettes were first breaded with a mixture containing 70% egg white, 12% baking soda and 2% salt, then with a mixture containing 50% wheat flour and 50% breadcrumbs (Çankırılıgil & Berik, 2017) and divided into 4 groups. It was prepared as a control (without Jerusalem artichoke fibre), and application groups were enriched with Jerusalem artichoke fibre in different amounts (2%, 4% and 6%). The prepared croquettes were fried, packed in styrofoam plates with stretch film and stored at +4°C for 25 days.

Physico-Chemical Analyses

Moisture and dry matter

After drying in the oven at 100°C for 2 hours, 10 g of the sample will be weighed and placed in aluminium drying containers, which will be placed in a desiccator, cooled and tared on a precision scale. The containers were taken to the desiccator, cooled, and weighed, and the %moisture value was calculated. The dry matter value was calculated by subtracting the moisture content from 100. (Gökalp et al., 2001).

Crude protein content

The protein content of the samples was determined using a Kjeldahl system. First, the nitrogen content of the samples was determined, and then the crude protein content ($N \times 6.25$) was calculated (AOAC, 2000).

Fat content

The lipid extraction process of samples was made according to Folch et al. (1957).

Carbohydrate

Total carbohydrates were calculated using the numerical formula (Duman, 2022).

$$\text{Carbohydrate} = 100 - (\text{moisture} + \text{protein} + \text{fat} + \text{ash})$$

pH

Approximately 10 g of sample was taken, 100 mL of pure water was added, it will be homogenised with the help of ultra-turrax and measured using a pH meter (Gökalp et al., 2001).

Thiobarbituric acid reactive substance (TBARS)

TBARS content was determined according to Lemon (1975) and Kilic and Richards (2003). Approximately 2 g of the croquette sample was taken, and 12 mL of trichloroacetic acid was added to it, homogenised and then filtered with Whatman 1 filter paper. 3 mL of the resulting filtrate was taken, and 3 mL of 0.02 M thiobarbituric acid was added. Then, it was left to cool by keeping it in a water bath at 100°C for 40 minutes and centrifuged at 2000 g and a spectrophotometric (530 nm) reading was taken. The TBARS content was expressed as $\mu\text{mol MA (MDA) kg}^{-1}$ fish muscle.

Total volatile basic nitrogen (TVB-N)

TVB-N content was determined, as reported by Malle and Tao (1987). The TVB-N contents were expressed as $\text{mg } 100 \text{ g}^{-1}$ fish muscle. 40 g of the croquette sample was taken, and 80 mL of 7.5% trichloroacetic acid was added, homogenised and centrifuged. Filtering was done with the Whatman 3 filter paper. 5 mL NaOH was added to the resulting filtrate, placed in the distillation device, and the distillate was titrated with 0.1 N H_2SO_4 until a pink colour was obtained.

$$\text{TVB-N} = n \times 16.8 \text{ mg nitrogen}$$

Microbiological Analysis

For microbiological analysis, 10 grams of samples were taken from the croquette, transferred to sterile stomacher bags, and homogenised using a stomacher device by adding 90 mL of sterile saline. The surface spreading method was used, and each microorganism was incubated at the appropriate temperature and time (Table 1).

Sensory Analysis

Ten panellists analysed the croquettes' sensory properties, including appearance, odour, texture, colour, flavour, and overall acceptability. They scored the samples during storage from 1 to 9 (Choi et al., 2014).

Statistical Analysis

Statistical analyses of the results obtained were made in the SPSS program, and the obtained results were compared with Duncan's multiple comparison tests ($p < 0.05$).

Results and Discussion

Physicochemical Analysis Results of Samples

The nutritional composition of seafood varies from species to species or among the same species, depending on gender, fishing region, season and age (Karşlı & Çağlak, 2021). The proximate composition results of rainbow trout croquettes are given in Table 2. The lowest moisture value was determined in sample C at 49.22%, followed by samples B at 49.70%, A at 51.11% and K at 51.90%. The difference between the groups was statistically significant ($p < 0.05$). Similarly, Fuchs et al. (2013) reported that the moisture value was higher in raw control croquette compared with other groups (fried

control croquette, raw and fried enriched with flaxseed flour croquette).

The ash values of the samples varied between 3.85 and 4.10%. Ash content increased in croquettes enriched with Jerusalem artichoke, and Çankırılıgil & Berik (2017a) reported that the ash content in fried sardine croquettes increased compared to meat and croquettes. The increased crude ash content is due to the added ingredients and water loss depending on the frying process. The researchers' results are similar to the findings of this study.

The protein values of the samples were determined between 15.52% and 16.57%. Depending on the Jerusalem artichoke fibre addition rate, the protein contents of the samples tended to increase. Alkuraief et al. (2020) found that after six months of storage, the protein content of Indian mackerel fish balls compared to fresh products decreased, while the protein content of Indian mackerel fish fingers increased. Altan et al. (2023), in their study with Atlantic salmon meatballs, determined that the crude protein and moisture content of the MTGase-added group was higher than the control group.

It was observed that the highest lipid content was in group C samples and the lowest in group control. Jerusalem artichoke tubers contain a small amount (0.02 g) of fat (Ünver Alçay, 2020). The difference between the groups in terms of lipid content was statistically significant ($p < 0.05$). Çankırılıgil & Berik (2017b) emphasised that there was a statistical increase in the crude oil amount of rainbow trout croquettes ($p < 0.05$).

Carbohydrate values were found between 15.98-16.79%. The lowest carbohydrate value of the croquette samples was detected in sample A and the highest in sample B. Berik et al. (2011) emphasised that the carbohydrate value was higher in fried rainbow trout fingers compared to the control group.

Table 1. Incubation conditions for groups of microorganisms

Microorganisms	Medium	Incubation Conditions	References
Total Aerobic Mesophilic Bacteria	Plate Count Agar	30°C for 2 days	Baumgart et al., 1986
Psychrophilic Bacteria	Plate Count Agar	10°C for 7 days	Anonymous 1992
Yeast and Mold	Rose Bengal Chloramphenicol Agar	25°C for 5 days	Halkman 2005
Lactic Acid Bacteria	de Man, Rogosa Sharpe Agar	30°C for 2 days	Halkman 2005
Enterobacteriaceae	Violet Red Glucose Agar	30°C for 2 days	Gökcalp et al., 2001

Table 2. Proximate composition results of samples

Analysis (%)	Samples			
	K	A	B	C
Moisture	51.90 ±1.11 ^a	51.11 ±0.55 ^{ab}	49.70 ±0.20 ^{bc}	49.22 ±0.38 ^c
Ash	3.85 ±0.09 ^b	3.99 ±0.03 ^{ab}	4.00 ±0.07 ^{ab}	4.10 ±0.02 ^a
Lipid	12.03 ±0.16 ^a	12.40 ±0.10 ^a	13.00 ±0.06 ^b	14.13 ±0.21 ^c
Carbohydrate	16.70 ±0.37 ^{ab}	16.48 ±0.36 ^{ab}	16.79 ±0.13 ^a	15.98 ±0.12 ^b
Protein	15.52 ±0.47 ^b	16.02 ±0.04 ^{ab}	16.50 ±0.20 ^a	16.57 ±0.45 ^a

Values shown with different letters are statistically different from each other ($p \leq 0.05$).

Chemical Analysis Results

Chemical analysis results of rainbow trout croquettes prepared with different proportions of Jerusalem artichoke fibre during cold storage ($4 \pm 1^\circ\text{C}$) are given in Table 3. TVB-N is an important criterion in determining the product's quality, and the fish's spoilage quality can be seen from the value of nitrogen bases (Febriani et al., 2023). At the beginning of storage, the lowest TVB-N value was 10.21 mg/100g in the C sample and the highest value was 12.20 mg/100g in the K sample. TVB-N values of all croquet groups increased significantly ($p < 0.05$) according to storage time. According to Varlık et al. (1993), the limit value for TVB-N for aquatic products was determined as 35 mg/100g. Values above this may make the product unconsumable. This limit values were not exceeded in all groups during the storage period. Similarly, Balıkçı et al. (2022), in their study investigating the addition of rosemary, thyme and basil herbal extracts to mackerel meatballs, reported that TVB-N values in all groups remained below the acceptability limits during storage. Çorapçı et al. (2023) emphasised that although no statistical difference was observed between the groups on the 0th day in rainbow trout balls prepared by adding different concentrations of MTGase (0.5% and 0.8%), the TVB-N values of Group B (0.8% MTGase added trout ball) were different from the other groups at the end of storage ($p < 0.05$). Nguyen et al. (2023) emphasised that the TVB-N values of fishballs obtained from knifefish and striped catfish increased gradually from the beginning to the end of storage.

TBARS value is the analysis method used to determine oxidation in aquatic products, and this value below 3 mg/kg indicates that the product is of very good quality (Özturan, 2022; Çorapçı et al., 2023). In our study, the highest TBARS value was observed at 8.36 $\mu\text{mol MA/kg}$ in the K sample, and

the lowest value was found to be 6.45 $\mu\text{mol MA/kg}$ in C samples at the end of storage. Compared to the control group, a lower TBARS value was determined in croquettes prepared with Jerusalem artichoke. Chen et al. (2014) found the Jerusalem artichoke plant to have antioxidant activities. The results of our study also support this. Statistical differences were observed between groups ($p < 0.05$). Similarly, Sa'nchez-Alonso et al. (2007) found that the TBA values of grape antioxidant dietary fibre added to minced fish muscle were lower. Özpolat (2022) reported that the TBA values of fish balls prepared from Capoeta trutta with different concentrations of liquid smoke increased with the storage time but did not exceed the consumable limit value in any group. Vidyarthi et al. (2022) emphasised that fruit powder slowed the lipid peroxidation of fish nuggets. Abdel-Wahab et al. (2020), in their study investigating the antioxidant potential of clove, sage and kiwi peel extracts and mixtures on fish fingers, stated that the lipid oxidation rate was delayed and remained below the standard level.

The pH value for fresh fish meat is between 6.0-6.5 and rises slowly depending on storage time. The consumability limit value for fish meat is between 6.8 and 7.0. However, pH value is not an absolute criterion and should always be supported by sensory and chemical tests (Güngör, 2011). It was determined that there were fluctuations in the pH values of the storage samples. The highest pH value was determined in group K, while the lowest was in group C croquettes. Statistically significant differences between the samples in pH values ($p < 0.05$) were detected. Dalbosco et al. (2010) found that the pH values of goldfish crockets increased significantly after cooking. Ajik-Cerbas et al. (2022) observed that while the pH value of the crab balls obtained from blue swimming crab was 9.04, it gradually decreased to almost neutral on the 35th day.

Table 3. Chemical analysis results of fish croquettes produced using different proportions of Jerusalem artichoke fibre

Analysis	Storage time (days)	Samples			
		K	A	B	C
TVB-N (mg/100 g)	0	12.20 ±0.12 ^h	11.17 ±0.12 ^h	10.94 ±0.08 ^h	10.21 ±0.12 ^h
	4	13.74 ±0.05 ^g	12.14 ±0.15 ^g	11.90 ±0.01 ^g	11.14 ±0.12 ^g
	7	15.34 ±0.15 ^f	13.79 ±0.06 ^f	13.05 ±0.11 ^f	12.67 ±0.16 ^f
	11	17.08 ±0.08 ^e	15.74 ±0.10 ^e	15.12 ±0.19 ^e	14.35 ±0.28 ^e
	14	18.88 ±0.05 ^d	16.73 ±0.20 ^d	16.00 ±0.08 ^d	15.20 ±0.07 ^d
	18	20.65 ±0.18 ^c	18.63 ±0.06 ^c	18.07 ±0.15 ^c	17.11 ±0.16 ^c
	21	21.52 ±0.19 ^b	19.79 ±0.07 ^b	18.82 ±0.04 ^b	18.04 ±0.10 ^b
	25	23.10 ±0.07 ^a	20.52 ±0.09 ^a	20.00 ±0.02 ^a	19.77 ±0.14 ^a
TBARS (µmol MA/kg)	0	1.24 ±0.05 ^h	1.20 ±0.02 ^g	1.14 ±0.02 ^g	1.07 ±0.01 ^g
	4	1.92 ±0.05 ^g	1.65 ±0.13 ^{fg}	1.64 ±0.23 ^{fg}	1.42 ±0.13 ^{fg}
	7	2.43 ±0.06 ^f	2.13 ±0.11 ^f	1.99 ±0.07 ^f	1.92 ±0.03 ^{ef}
	11	3.10 ±0.26 ^e	2.89 ±0.16 ^e	2.77 ±0.16 ^e	2.39 ±0.23 ^e
	14	3.93 ±0.21 ^d	3.60 ±0.26 ^d	3.46 ±0.28 ^d	3.04 ±0.14 ^d
	18	5.69 ±0.19 ^c	5.00 ±0.11 ^c	4.66 ±0.30 ^c	4.13 ±0.28 ^c
	21	6.32 ±0.19 ^b	5.94 ±0.09 ^b	5.77 ±0.30 ^b	5.40 ±0.35 ^b
	25	8.36 ±0.10 ^a	7.38 ±0.55 ^a	6.79 ±0.32 ^a	6.45 ±0.51 ^a
pH	0	6.80 ±0.01 ^a	6.50 ±0.01 ^a	6.43 ±0.04 ^{ab}	6.45 ±0.33 ^b
	4	6.86 ±0.02 ^b	6.62 ±0.20 ^a	6.34 ±0.09 ^{bc}	6.33 ±0.19 ^b
	7	6.70 ±0.06 ^{ab}	6.53 ±0.35 ^a	6.53 ±0.07 ^a	6.83 ±0.04 ^a
	11	6.38 ±0.02 ^c	6.23 ±0.01 ^{ab}	6.24 ±0.07 ^c	6.21 ±0.05 ^{bc}
	14	6.48 ±0.01 ^{bc}	6.43 ±0.07 ^a	6.38 ±0.08 ^{abc}	6.37 ±0.05 ^b
	18	6.40 ±0.16 ^c	6.23 ±0.15 ^{ab}	6.06 ±0.06 ^d	6.12 ±0.09 ^{bc}
	21	6.01 ±0.19 ^d	6.26 ±0.09 ^{ab}	5.99 ±0.00 ^{dc}	5.87 ±0.03 ^{cd}
	25	6.00 ±0.02 ^d	5.91 ±0.02 ^b	5.85 ±0.01 ^e	5.74 ±0.02 ^d

Means shown with different letters are statistically different (p<0.05). A: control; B: 2% Jerusalem artichoke fiber; C: 4% Jerusalem artichoke fiber; D: 6% Jerusalem artichoke fiber

Microbiological Analysis Results

Microbiological analysis results of rainbow trout croquettes prepared with different proportions of Jerusalem artichoke fibre during cold storage (4±1°C) are given in Table 4. Total aerobic mesophilic bacteria is an important parameter for determining microbial quality in foods and is widely used (Anonymous, 2024). According to ICMSF (1986), the limit value for the total seafood is recommended as 6-7 log cfu/g.

These limits were exceeded in the control group (K) on the 14th day of storage. The total number of mesophilic aerobic microorganisms in the control group samples, which was 3.36 log cfu/g on day 0, increased to 8.20 log cfu/g at the end of storage of the croquet samples. An increase in the total number of mesophilic aerobic microorganisms was observed with storage in all groups. Similarly, Cadun et al. (2015)

reported that the total number of aerobic bacteria increased during storage in whiting fish balls prepared by adding different fibre types (wheat and apple fibre). Bacterial counts of trout croquettes prepared with Jerusalem artichoke fibre were lower than the control group. It is thought to be due to the antimicrobial effect of *Jerusalem artichoke*. Studies have reported that the crude extract of Jerusalem artichoke leaves has antifungal or antimicrobial activities (Chen et al., 2013). The use of high concentrations of fibre further increased its positive effect. Çağlak & Karslı (2023) reported that the number of total aerobic mesophilic in rainbow trout croquettes enriched with dill extracts was lower than in the control group.

The number of psychrotrophic bacteria in the control group was 3.27 log cfu/g at the beginning of storage, and an increase

was detected in all groups in parallel with storage. The lowest number of bacteria was determined in group C samples. The differences between groups and storage days were statistically significant ($p < 0.01$). Similarly, Gürel İnanlı & Amin (2022) observed increases in the number of psychrophilic bacteria in all groups depending on the time during storage in fish fingers coated with the addition of goji berry. İzci & Ümüt (2023) found that the total number of psychrophilic aerobic bacteria in bogue meatball samples was determined as 4.67 ± 0.01 log cfu/g, and it was emphasised that the increase in the number of microorganisms was significant ($p < 0.05$) during storage.

Yeast-mold numbers were determined as 2,00 log cfu/g in all groups at the beginning of storage, and an increase was observed in all groups during the storage period. The differences between groups and storage days were statistically significant ($p < 0.01$). Lower yeast and mould counts were observed in fish croquettes with Jerusalem artichoke addition. Chen (2013) demonstrated that leaf extracts could exhibit antifungal capacities based on the structural properties of Jerusalem artichoke phenolics. The results of our study also support this. Altan (2020) determined the total yeast and mould numbers of trout balls on the first day of storage as 3.22 log cfu/g in the control group, 3.05 log cfu/g in the 0.5% MTGase group and 3.15 log cfu/g in the 1% MTGase group.

Lactic acid bacteria (LAB) are characterised as non-aerobic, Gram-positive cocci and rods (Nath et al., 2013). LAB is naturally dominating the microflora of many foods (Ghanbari et al., 2013). It is also part of the natural microbiota of fish fillets. LAB counts were determined as 2,00 log cfu/g in all groups at the beginning of storage (day 0). The highest LAB count was determined as 4.11 log cfu/g in the control group at the end of storage (25th day). Storage time and sample x storage time interactions on the number of lactic acid bacteria were significant ($p < 0.01$). In their study, Uçak & Afreen (2022) found that the number of lactic acid bacteria was higher in the control and chitosan coating applied fish meatballs than in the group treated with peppermint essential oil emulsion containing chitosan.

Enterobacteriaceae is an indicator microorganism that is part of the microflora of seafood products and is considered an indicator of hygiene in fish and fish products (Uçak & Afreen, 2022). Yi et al. (2011) reported that the number of Enterobacteriaceae was highest in the control group in their study with fish balls prepared with different concentrations (0, 0.10, 0.15, 0.20, 0.25, and 0.30 g kg⁻¹) of tea polyphenols.

Sensory Analysis Results

Sensory analysis results of rainbow trout croquettes prepared with different proportions of Jerusalem artichoke fibre during cold storage ($4 \pm 1^\circ\text{C}$) are given in Figure 1. Sensory properties are crucial in consumer food choices (Li et al., 2024). According to the sensory analysis results, a decrease was observed in all sample groups in parallel with storage. The panellists especially liked sample B regarding colour, texture, smell, taste, and appearance. As seen in Figure 1, the croquette samples with Jerusalem artichoke fibre were liked by most panellists regarding sensory properties. For acceptability, panellists gave the highest value to sample A and the lowest value to the control sample. According to their taste parameter scores, the ranking was B>C>A>K. Colour and smell are important parameters in sensory evaluation, and the panellists gave higher scores to the croquette samples prepared with Jerusalem artichoke compared to the control group. Çankırılıgil & Berik (2018) emphasised that shrimp croquettes were the group's favourite regarding the sensory properties of the fish fingers they produced from different seafood such as deep-water rose shrimp, sardines and rainbow trout. Budaraga et al. (2021) reported that according to the sensory analysis results of red tuna and white oyster mushroom meatballs, the best storage time of 0 hours was using wrap packaging. İnanlı & Amin (2022) reported that fish burgers prepared using gojibery received better sensory scores than the control group. The study results are similar to those of our study. Gonal (2023) observed that adding broccoli flour to carp fish cake processing significantly affected consistency, taste and texture but did not affect aroma.

Table 4. Microbiological analysis results (log cfu/g) of fish croquettes produced using different proportions of Jerusalem artichoke fibre.

Samples	Storage time (days)	TMAB	TPAB	TYM	LAB	ENTERO
K	0	3.36 ±0.11 ^g	3.27 ±0.08 ^h	2.00 ±0.00 ^f	2.00 ±0.00 ^e	2.00 ±0.00 ^d
	4	4.13 ±0.14 ^f	4.19 ±0.09 ^g	2.00 ±0.00 ^f	2.00 ±0.00 ^e	2.00 ±0.00 ^d
	7	4.68 ±0.01 ^e	4.50 ±0.07 ^f	2.17 ±0.14 ^f	2.15 ±0.09 ^e	2.00 ±0.00 ^d
	11	5.39 ±0.18 ^d	5.31 ±0.02 ^e	2.90 ±0.02 ^e	2.00 ±0.00 ^e	2.10 ±0.06 ^d
	14	6.16 ±0.14 ^c	5.90 ±0.12 ^d	3.23 ±0.14 ^d	2.60 ±0.08 ^d	2.00 ±0.00 ^{cd}
	18	6.97 ±0.16 ^b	6.63 ±0.12 ^c	3.94 ±0.08 ^c	3.03 ±0.12 ^c	2.23 ±0.14 ^c
	21	7.92 ±0.04 ^a	7.19 ±0.26 ^b	4.77 ±0.16 ^b	3.72 ±0.21 ^b	3.00 ±0.07 ^b
	25	8.20 ±0.12 ^a	8.04 ±0.07 ^a	5.80 ±0.15 ^a	4.11 ±0.09 ^a	3.70 ±0.05 ^a
A	0	3.00 ±0.11 ^h	3.14 ±0.19 ^g	2.00 ±0.00 ^e	2.00 ±0.00 ^d	2.00 ±0.00 ^d
	4	3.57 ±0.16 ^g	3.46 ±0.17 ^g	2.00 ±0.00 ^e	2.00 ±0.00 ^d	2.00 ±0.00 ^d
	7	4.26 ±0.02 ^f	4.19 ±0.09 ^f	2.11 ±0.09 ^e	2.00 ±0.00 ^d	2.00 ±0.00 ^d
	11	5.00 ±0.03 ^e	5.22 ±0.09 ^e	2.85 ±0.10 ^d	2.09 ±0.12 ^d	2.13 ±0.18 ^d
	14	5.90 ±0.03 ^d	5.87 ±0.11 ^d	3.02 ±0.03 ^d	2.07 ±0.09 ^d	2.00 ±0.00 ^d
	18	6.50 ±0.07 ^c	6.46 ±0.28 ^c	3.63 ±0.11 ^c	2.74 ±0.06 ^c	2.40 ±0.10 ^c
	21	7.23 ±0.14 ^b	7.37 ±0.12 ^b	4.05 ±0.09 ^b	3.18 ±0.14 ^b	2.86 ±0.12 ^b
	25	7.93 ±0.05 ^a	7.94 ±0.09 ^a	5.12 ±0.19 ^a	3.93 ±0.04 ^a	3.34 ±0.14 ^a
B	0	2.67 ±0.14 ^h	2.90 ±0.06 ^g	2.00 ±0.00 ^d	2.00 ±0.00 ^d	2.00 ±0.00 ^d
	4	3.09 ±0.05 ^g	3.14 ±0.19 ^g	2.00 ±0.00 ^d	2.00 ±0.00 ^d	2.00 ±0.00 ^d
	7	3.94 ±0.07 ^f	4.06 ±0.07 ^f	2.07 ±0.09 ^d	2.00 ±0.00 ^d	2.00 ±0.00 ^d
	11	4.48 ±0.12 ^e	4.60 ±0.22 ^e	2.12 ±0.16 ^d	2.04 ±0.06 ^d	2.00 ±0.00 ^d
	14	5.37 ±0.16 ^d	5.29 ±0.23 ^d	2.50 ±0.08 ^c	2.00 ±0.00 ^d	2.02 ±0.03 ^d
	18	6.03 ±0.06 ^c	6.17 ±0.12 ^c	3.01 ±0.04 ^b	2.39 ±0.07 ^c	2.31 ±0.11 ^c
	21	7.01 ±0.04 ^b	7.07 ±0.09 ^b	3.07 ±0.09 ^b	3.00 ±0.10 ^b	2.75 ±0.09 ^b
	25	7.84 ±0.09 ^a	7.54 ±0.16 ^a	3.66 ±0.15 ^a	3.64 ±0.10 ^a	3.13 ±0.12 ^a
C	0	2.20 ±0.17 ^h	2.24 ±0.16 ^h	2.00 ±0.00 ^e	2.00 ±0.00 ^c	2.00 ±0.00 ^d
	4	2.79 ±0.14 ^g	3.29 ±0.20 ^g	2.00 ±0.00 ^e	2.00 ±0.00 ^c	2.00 ±0.00 ^d
	7	3.33 ±0.16 ^f	3.93 ±0.21 ^f	2.00 ±0.00 ^e	2.00 ±0.00 ^c	2.00 ±0.00 ^d
	11	4.10 ±0.02 ^e	4.40 ±0.09 ^e	2.14 ±0.06 ^{de}	2.00 ±0.00 ^c	2.00 ±0.00 ^d
	14	5.01 ±0.04 ^d	5.06 ±0.08 ^d	2.18 ±0.07 ^d	2.08 ±0.04 ^c	2.00 ±0.00 ^d
	18	5.88 ±0.13 ^c	6.02 ±0.04 ^c	2.70 ±0.09 ^c	2.20 ±0.28 ^c	2.17 ±0.10 ^c
	21	6.39 ±0.08 ^b	6.60 ±0.24 ^b	2.99 ±0.01 ^b	2.99 ±0.02 ^b	2.40 ±0.01 ^b
	25	7.28 ±0.19 ^a	7.76 ±0.12 ^a	3.51 ±0.11 ^a	3.44 ±0.15 ^a	3.00 ±0.02 ^a

Means shown with different letters are statistically different (p<0.05). A: control; B: 2% Jerusalem artichoke fiber; C: 4% Jerusalem artichoke fiber; D: 6% Jerusalem artichoke fiber

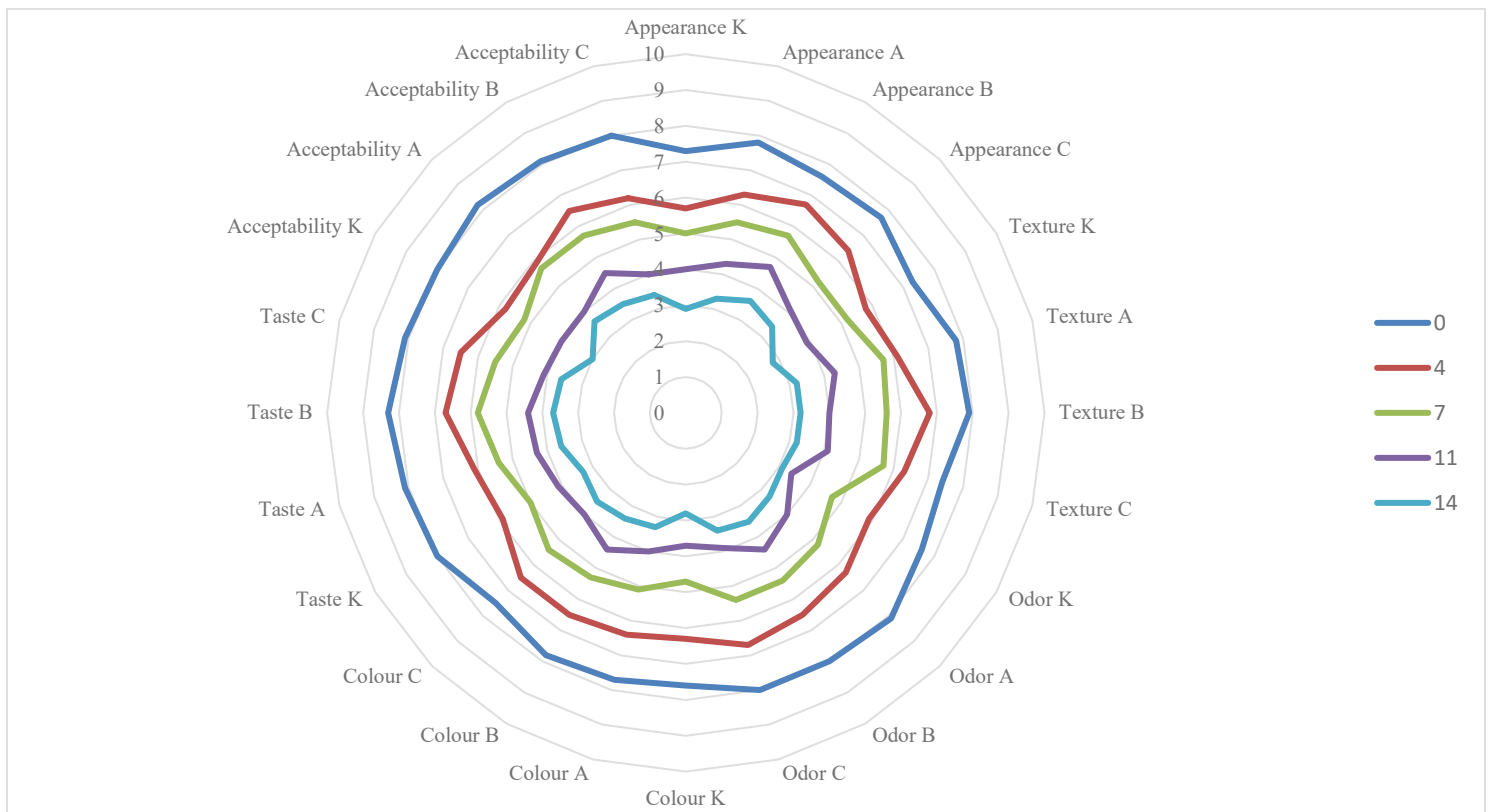


Figure 1. Sensory analysis results of fish croquettes produced using different proportions of Jerusalem artichoke fibre

Conclusion

With the spread of diseases, consumers have started to turn to healthy foods. Dietary fibres and fibre-rich products have therapeutic and curative properties for common diseases such as heart disease, cancer, and obesity. In addition, since plant-based flours contain high protein, starch and fibre, the shelf life of fish and fish products can be extended. Jerusalem artichoke is a low-calorie product. In addition to being rich in inulin, it is a good source of dietary fibre. Many studies have shown that Jerusalem artichoke has anticancer, antioxidant, antirheumatic and antidiabetic activities. In light of all the analyses, it was determined that the croquettes prepared with yam fibre gave positive results regarding physical, chemical and microbiological properties. It was determined that it gave better results than the control group croquettes in terms of sensory evaluation. It is thought that this study can be further developed by shedding light on further studies.

Compliance with Ethical Standards

Conflict of interest: The authors declare no actual, potential, or perceived conflict of interest for this article.

Ethics committee approval: Ethics committee approval is not required for this study.

Data availability: Data will be made available on request.

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