http://agriprojournal.com

JOURNAL OF AGRICULTURAL PRODUCTION

ISSN: 2757-6620

https://prensip.gen.tr

RESEARCH ARTICLE

Investigation of Quality Parameters of Trout Fishballs Cooked with Sous-Vide Method

Nesim Maskan • Pınar Oğuzhan Yıldız✉

Atatürk University, Faculty of Fisheries, Erzurum/Türkiye

ARTICLE INFO

Article History
Received: 26.03.2024
Accepted: 31.05.2024
First Published: 22.06.2024

Keywords
Cooking
Quality
Shelf life
Sous vide
Troutball

ABSTRACT

This study was conducted to determine the changes in the quality of rainbow trout (*Oncorhynchus mykiss*) meatballs cooked with the sous-vide technique. Vacuum-packaged fishball were cooked using the sous-vide method under two different temperature (60 °C and 80ºC) and two different times (15 and 20 minute) and stored at 4±1ºC for 25 days. The results showed that sous vide cooking technique at 80 °C for 20 min. effectively limited bacterial growth. It was determined that sous vide cooking technology significantly reduced the levels of total volatile base nitrogen (TVB-N) and thiobarbituric acid reactive substances (TBARS) at the end of storage. As the cooking temperature increased, the pH values of the meatball samples also increased. According to the sensory evaluation results, the meatballs cooked with the sous vide technique received higher scores than the control group, and the most preferred cooking temperature and time was determined to be 60ºC for 20 minutes.

Please cite this paper as follows:

Maskan, N., & Oğuzhan Yıldız, P. (2024). Investigation of quality parameters of trout fishballs cooked with sous-vide method. *Journal of Agricultural Production*, *5*(2), 121-130. https://doi.org/10.56430/japro.1459198

1. Introduction

Nowadays, the increase in the number of working women and the population and the difficult working conditions have increased the demand for nutritious and delicious foods that can be prepared in a short time. In this context, the ready-made food sector has gained importance (Oğuzhan & Yangılar, 2014).

Sous vide (vacuum cooking) is a cooking method that finds application in homes and in the ready-made food industry. Cooking methods are important in terms of both nutrition and health. Sous vide has recently become widely used as a popular cooking method around the world. Sous vide cooking is a healthier technique because less nutritional value of meat is lost compared to traditional cooking (Kaya, 2021).

It is also a method that provides quality food for the ready-made food industry. It is also advantageous both in terms of sensory aspects and in terms of significantly inhibiting microorganism activities (Creed & Reeve, 1998; Seyyar, 2015).

Sous vide is the process of cooking food at controlled temperatures and in vacuum packages. With this technique, foods are cooked alone or together with products such as sauce and spices in vacuum packaging (Haskaraca & Kolsarıcı, 2013).

Sous vide cooking is the process of cooking vacuum-packaged foods by immersing them in a temperature-controlled

✉ Correspondence
E-mail address: pinaroguzhan@atauni.edu.tr

water bath for the desired time. In French, sous vide means "under vacuum". The cooking process is generally carried out at low temperatures below 100°C and requires longer cooking time than traditional cooking methods (Bozova, 2020; Yıldız & Yılmaz, 2020; Ceylan, 2021; Öztürk et al., 2021).

Seafood is very important in human nutrition due to its unique composition. It is considered a quality food for human consumption due to its high protein content, essential amino acid profile and other nutritional benefits such as omega-3/omega-6 fatty acids. It is also known to be rich in unsaturated fatty acids, minerals and vitamins (A, B1, B2, D and K) (Erol, 2013; Abdel-Wahab et al., 2020). It contains many functional properties such as high quality and easily digestible proteins, polyunsaturated fatty acids beneficial to health, and vitamins and minerals necessary for human nutrition (Jayasinghe et al., 2013).

Seafood is a food with extremely high nutritional value and beneficial for health and has an important place in consumption. Therefore, products prepared with seafood are of great importance in ready meal consumption. In this context, fish meatball cooked with the sous vide technique are a delicious and nutritious alternative product for the ready-made food industry (Bilgin & Metin, 2022). The sous-vide technique improves the sensory properties of foods and preserves their nutritional values. In addition, this method preserves various vitamins and fatty acids found in foods (Yıldız & Yılmaz, 2020).

Especially for young people and school-age children, products prepared with fish (meatball, croquette, nugget, finger, sausage, cake) are healthy and delicious alternative products for children with fast food habits. Today, in addition to traditional cooking methods, there is a need to apply innovative techniques that have many advantages (fast and safe, longer shelf life, preserves nutritional value, and is heated for consumption). In the literature review, no study was found on cooking rainbow trout meatballs with the sou vide technique. With this study, the possibilities of cooking fish meatball using the sous vide technique at appropriate temperatures and times was be investigated and the quality parameters of rainbow trout balls cooked with the sous vide technique at different temperatures and times was be examined.

2. Materials and Methods

2.1. Material

Rainbow trout fillets (approximately 10 kg) an average of 250±25 g weight and 28±0.8 cm lengths were supplied from Atatürk University Faculty of Fisheries, and meatball ingredients were be supplied from a local market in Erzurum.

2.2. Method

The filleted fish meat was passed through a meat grinder (Empero EM.08). The formulation of meatball dough is shown in Table 1.

Table 1. Meatball formulation.

Meatball composition	Amount (%)
Minced fish	75
Breadcrumbs	7.5
Salt	1.5
Ground red pepper	0.25
Ground black pepper	0.25
Cumin	0.25
Allspice	0.25
Garlic powder	15

This mixture was kneaded well to obtain meatball dough and the meatballs were shaped into 20 grams. Then the trout meatballs were packaged using a vacuum packaging machine (Multivac A 300/16 Sepp Haggenmuller D 87787 Wolfertschwenden, Germany), the packaged samples were cooked using sous vide cooking equipment (Lacia SVC107). They were divided into 5 groups: K: control, A: 60ºC for 15 min, B: 60ºC for 20 min, C: 80ºC for 15 min, D: 80ºC for 20 min. Fish meatball in the control group were grilled at 175°C for 3 minutes on each side. The cooked meatballs were cooled quickly (30 minutes) in ice water. All meatball samples were stored in the refrigerator at 4±1 °C for 25 days and sensory, microbiological and chemical sensory analyses of the samples were performed on days 0, 5, 10, 15, 20 and 25 of storage. The study was carried out in three replications and two parallels, and the results are given as average.

2.3. pH, TBARS and TVB-N

A 10 g sample was taken from the meatball sample, 100 ml of pure water was added, homogenized and pH value measured (Gökalp et al., 2001).

For TBARS analysis, 2 g of each meatball sample was taken and 12 ml of Trichloroacetic acid solution was added to it. It was homogenized in ultra-turrax and filtered through filter paper. 3 ml of the filtrate was taken and 3 ml of Thiobarbituric acid (0.02 M) was added to it, the mixed and cooled test tubes were centrifuged (2000 g). Readings were made at the absorbance value in the spectrophotometer (530 nm) (Lemon, 1975).

TBARS (µmol malonaldehyde/g): [(absorbance/ k(0.06) x 2/1000) x 6.8] x 1000/ sample weight

TVB-N value was determined as reported by Kızılkaya (2020). An amount of 10 g of the meatball sample was taken, 90 ml of 0.6 N perchloric acid solution was added to it, homogenized with ultra-turrax, filtered, 50 ml of the mixture was taken and phenol phthalein was dropped on it. Then, 6.5 ml of 20% NaOH solution was added, 100 ml of boric acid solution and 3-5 drops of methyl red + methylene blue indicator were

added to the distillate flask and the process was continued until 100 ml of distillate was collected. The resulting distillate was titrated with 0.1 N HCl solution until it turned gray, and the total amount of volatile base-nitrogen was calculated by taking into account the HCl solution spent in the titration.

TVB-N (mg/100g) = n x 16.8 mg nitrogen

2.4. Microbiological Analysis

For microbiological analyses, 10 grams of the meatball sample was taken and placed in a stomacher bag under aseptic conditions, and 90 ml of sterile saline (0.85% NaCl) was added to it and homogenized in the stomacher device. Then, appropriate dilutions were prepared from the homogenate and inoculated into the medium using the surface spreading method. The results are given as log cfu/g. Plate Count Agar was used for total aerobic mesophilic and psychrotrophic bacteria analyses, and the media were stored at 30 °C for 2 days and 10 °C for 7 days, respectively (Baumgart et al., 1986; Vanderzant & Splittstoesser, 1992). De Man Rogosa Sharpe Agar was used for lactic acid bacteria count, and Violet Red Glucose Agar was used for Enterobacteriaceae count, and the media were incubated for 2 days at 30 °C under anaerobic conditions (Baumgart et al., 1986; Gökalp et al., 2001). For yeast-mold counting, Rose Bengal Chloramphenicol medium was used and incubated at 25ºC for 5 days (Halkman, 2005). For Pseudomonas counting, Pseudomonas Agar Base+CFC Selective Agar+Supplement Agar was used and the media were incubated under aerobic conditions at 25ºC for 2 days (Gökalp et al., 2001).

2.5. Sensory Evaluation

The meatballs were subjected to sensory analysis by a group of 10 panelists in terms of appearance, texture, odor, taste, color and general acceptability. Meatball samples were given scores between 1-9 (1: unconsumable; 2: very bad; 3: bad; 4: somewhat bad; 5: neither good nor bad; 6: somewhat good, 7: good, 8: very good, 9: quite good) (Choi et al., 2014). The samples were presented to the panelists after being removed from the vacuum packages without any further processing at room temperature.

2.6. Statistical Analysis

The data obtained from the research were evaluated by applying the analysis of variance technique according to the random trial plan with the SPSS program. All measurements were performed twice. Duncan's multiple comparison tests ($p<0.05$) was used to compare the means of significant sources of variation.

3. Results and Discussion

3.1. Microbiological Analysis

The microbiological analysis results of samples are given in Table 2. According to the results of analysis of variance, the difference between the groups was found to be statistically significant ($p<0.05$)

Although the limit value for the total number of bacteria in order to see spoilage in fish is 7-8 log CFU/g, most regulations accept 6-7 log CFU/g as the limit to ensure more reliability for human health (Mol Tokay, 2009). The initial total mesophilic aerobic number of fresh rainbow trout was determined as 3.32 log CFU/g, and a significant decrease in bacterial load was detected after the sous vide process. In our study, the number of mesophilic bacteria in the groups that underwent sous vide treatment varied between 2.00 and 5.95 log CFU/g. While the number of bacteria reached the upper limit value in the control group on the 15th day of storage, it was determined that this value was not reached in the sous vide treated groups. As the cooking process and time increased, bacterial growth slowed down due to exposure to heat treatment. It was observed that the applied cooking treatment had a positive effect on slowing down the growth of total mesophilic aerobic bacteria. After sous vide cooking, significant decreases were determined in the TMAB counts of all samples compared to the control group. Erdem et al. (2022) observed that the decrease in bacterial count may be due to the breakdown of the, denaturation of proteins, plasma membrane and change in the permeability of the cell wall of microorganisms. Additionally, the advantage of the sous vide cooking technique is to prevent aerobic bacterial growth. (Haskaraca & Kolsarıcı, 2013; Erdem & Gökmen, 2022). Gürel İnanlı and Yaz (2020) reported that the numbers of aerobic mesophilic bacteria were higher in the control group (raw pike fish) compared to the sous vide applied groups, which is in agreement with our study. Pongestkul and Benjakul (2022) noted that the total bacterial counts of dried sour-salted fish treated with the sous vide technique at different levels increased in parallel with storage.

Psychrotrophic bacterial (TPAB) growth was slower in the sous vide technique applied groups compared to the control group. The lowest number of bacteria was observed in group D meatball samples. It has been determined that as the temperature and period increases, the growth of psychrotrophic bacteria slows down accordingly. Mol et al. (2012) emphasized that the numbers of psychrotrophic bacteria were lower in whiting fish cooked with the sous vide technique. Çağlak et al. (2017) while the total number of psychrophilic bacteria was 3.72 log CFU/g in fresh zander samples, it was detected below the value of 1.47 log CFU/g in the first 7 days in the sous vide treated groups.

The initial yeast-mold counts of all meatball samples were found to be 2.00 log CFU/g and increased as the storage period progressed. It is thought that this situation is caused by both heat treatment and vacuum packaging. Bozova and İzci (2021), no yeast or mold was detected in meagre fillets applied sous vide during the 42-day storage period. Russo et al. (2023) noted that mussel samples cooked sous vide at temperatures higher

than 80ºC inhibited the growth of yeast and mold.

Differences between groups and storage days were found to be statistically significant ($p<0.05$) on lactic acid bacteria (LAB) count. LAB counts were determined as 2.00 log CFU/g in all groups at the beginning of storage, and an increase was observed during the storage period. Bongiorno et al. (2018) reported that LAB was not detected in mussel samples after the sous vide process.

Enterobacteriaceae counts were initially detected as 2.00 log CFU/g in all meatball groups. Depending on the heat treatment applied, lower Enterobacteriaceae numbers were obtained in the sous vide method groups compared to the control group during the storage period. Similarly, while the number of Enterebacteriaceae was determined as 2.87 log CFU/g in raw pikeperch fillets, it was determined as 2.00 log CFU/g, <100 log CFU/g and <100 log CFU/g in fillets applied sous vide at different temperatures and times (65ºC 45 min, 75ºC 20 min. and 90ºC 10 min.), respectively (Modzelewska-Kapituła et al., 2022).

Table 2. Microbiological analysis results of count of raw and sous vide-cooked trout meatballs.

Samples	Storage period (days)	Microbiological Analysis (log CFU/g)				
		TMAB	**TPAB**	**TYM**	**LAB**	**ENTERO**
K	0	3.32±0.23^{f}	3.21±0.29^{f}	<2.00^{e}	<2.00^{e}	<2.00^{f}
	5	4.99±0.04^{e}	4.93±0.10^{e}	2.10±0.06^{e}	2.41±0.19^{d}	2.34±0.12^{e}
	10	6.37±0.16^{d}	6.36±0.07^{d}	3.10±0.24^{d}	2.38±0.08^{d}	2.70±0.20^{d}
	15	7.14±0.13^{c}	7.13±0.17^{c}	4.73±0.16^{c}	2.32±0.04^{c}	3.08±0.09^{c}
	20	9.41±0.24^{b}	7.33±0.16^{b}	5.56±0.25^{b}	4.13±0.18^{b}	3.95±0.08^{b}
	25	11.51±0.09^{a}	11.05±0.08^{a}	6.35±0.13^{a}	4.97±0.11^{a}	4.65±0.13^{a}
A	0	<2.00^{e}	<2.00^{e}	<2.00^{c}	<2.00^{d}	<2.00^{d}
	5	2.03±0.04^{e}	2.11±0.15^{e}	<2.00^{c}	<2.00^{d}	<2.00^{d}
	10	2.92±0.04^{d}	2.90±0.18^{d}	2.14±0.12^{c}	2.15±0.01^{d}	2.01±0.02^{d}
	15	4.04±0.05^{c}	3.90±0.04^{c}	2.63±0.23^{b}	2.68±0.13^{c}	2.16±0.01^{c}
	20	5.00±0.07^{b}	4.95±0.07^{b}	3.00±0.00^{b}	3.00±0.01^{b}	2.83±0.08^{b}
	25	5.95±0.05^{a}	5.63±0.21^{a}	3.51±0.32^{a}	3.42±0.19^{a}	3.00±0.00^{a}
B	0	<2.00^{e}	<2.00^{d}	<2.00^{d}	<2.00^{d}	<2.00^{c}
	5	2.02±0.03^{e}	2.05±0.07^{d}	<2.00^{d}	<2.00^{d}	<2.00^{c}
	10	2.57±0.19^{d}	2.30±0.21^{d}	2.10±0.14^{d}	2.04±0.05^{d}	<2.00^{c}
	15	3.72±0.24^{c}	3.40±0.24^{c}	2.50±0.11^{c}	2.35±0.16^{c}	2.07±0.09^{c}
	20	4.58±0.21^{b}	4.72±0.22^{b}	2.95±0.07^{b}	2.93±0.04^{b}	2.45±0.09^{b}
	25	5.78±0.16^{a}	5.50±0.41^{a}	3.25±0.15^{a}	3.15±0.09^{a}	2.83±0.04^{a}
C	0	<2.00^{d}	<2.00^{e}	<2.00^{c}	<2.00^{c}	<2.00^{c}
	5	<2.00^{d}	<2.00^{e}	<2.00^{c}	<2.00^{c}	<2.00^{c}
	10	2.36±0.25^{d}	2.35±0.09^{d}	<2.00^{c}	<2.00^{c}	<2.00^{c}
	15	3.10±0.19^{c}	2.95±0.07^{c}	2.11±0.04^{c}	2.11±0.15^{c}	<2.00^{c}
	20	4.07±0.25^{b}	3.90±0.14^{b}	2.90±0.01^{b}	2.67±0.14^{b}	2.26±0.12^{b}
	25	5.35±0.12^{a}	5.07±0.10^{a}	3.14±0.19^{a}	2.99±0.02^{a}	2.54±0.06^{a}
D	0	<2.00^{d}	<2.00^{d}	<2.00^{c}	<2.00^{b}	<2.00^{b}
	5	<2.00^{d}	<2.00^{d}	<2.00^{c}	<2.00^{b}	<2.00^{b}
	10	<2.00^{d}	<2.00^{d}	<2.00^{c}	<2.00^{b}	<2.00^{b}
	15	2.59±0.13^{c}	2.45±0.16^{c}	<2.00^{c}	<2.00^{b}	<2.00^{b}
	20	3.22±0.04^{b}	3.13±0.18^{b}	2.28±0.12^{b}	2.14±0.12^{b}	2.07±0.09^{b}
	25	4.88±0.14^{a}	4.61±0.12^{a}	2.85±0.02^{a}	2.82±0.10^{a}	2.53±0.04^{a}

Different letters in the same column indicate statistical difference ($p<0.05$). K: Control, A: 60ºC for 15 min, B: 60ºC for 20 min, C: 80ºC for 15 min, D: 80ºC for 20 min.

3.2. pH, TBARS and TVB-N

pH, TBARS and TVB-N analysis results of samples are given in Table 3. While it was determined that the group and storage days had a significant effect on the pH value ($p<0.05$), the interaction of group and storage days did not have a significant effect on the pH value ($p>0.05$). While the pH value of raw trout meatballs were 6.34 at the beginning of storage, it increased to 6.35, 6.39, 6.42 and 6.45 in groups A, B, C and D after sous vide cooking, respectively. As can be seen in Table 2, the pH value was affected by the cooking process. As the cooking temperature increased, the pH values of the meatball samples also increased because of heat treatment. del Pulgar et al. (2012) reported that this increase in pH was attributed to the formation of disulfide bonds during the cooking process. Becker et al. (2016) stated that increasing temperature causes an increase in pH, mainly due to protein denaturation and change in protein load. Our study is consistent with previous studies showing that the pH value of fish meat increases with increasing temperature (Mohan et al., 2017; Cui et al., 2019; Cropotovaa et al., 2019; Erdem et al., 2022; Pongsetkul et al., 2022).

The difference between the groups was found to be statistically significant ($p<0.05$) on TBARS value. As can be seen in Table 2, increases were detected depending on the progression of storage time and the highest TBARS value was determined in the control group samples at the end of storage. Varlık et al. (1993), the consumable limit value for fresh fish is between 7-8 mg MDA/1000 g, and it was observed that only the control group samples (8.00±0.20 µmol MA/kg) exceeded this limit value on the 20th day of storage. There are studies showing that the TBARS value decreases as the cooking temperature increases in the sous vide cooking technique for the same period of time. It is thought that decreasing the cooking time due to increasing temperature reduces lipid oxidation. It is also stated that the compounds detected by TBARS analysis are very reactive and the TBARS value may be determined lower since the compounds they form by interacting with different compounds such as amino acids and proteins in meat are not determined as a result of the analysis (Özyürek, 2021). Yuan et al. (2023) found that the TBARS values of Russian sturgeon meat cooked with the sous vide technique increased depending on storage. Karki et al. (2023) stated that the TBARS values of tilapia fish cooked with the sous vide technique were within acceptable consumption limits until the end of storage. Yang et al. (2023) reported that the TBA value of tilapia fillets processed using the sous-vide method (0.47 ± 0.06 mg MDA/kg) was significantly lower compared to the control group (0.69 ± 0.03 mg MDA/kg) ($p<0.05$). They observed that the sous-vide cooking method has the capacity to effectively inhibit the lipid oxidation process in meat.

While the initial TVB-N value in raw trout meatballs was determined as 8.16 mg/100 g, it were found to be 6.99, 6.56, 5.95 and 5.20 mg/100 g in group A, B, C and D meatball samples after sous vide cooking, respectively. As the storage period increased, TVB-N values increased accordingly. At the end of storage, TVB-N values of all groups were determined below the acceptable limit (≤35 mg/100 g) (Varlık et al., 1993). Similarly, Zhan et al. (2022) found that the TVB-N contents of three groups of scallop samples cooked at different temperatures (70ºC and 75ºC) with control and sous vide techniques increased with increasing storage time. Kurt Kaya (2022) emphasized that when the quality of marinated crayfish was examined in brine, vacuum packaging and sous-vide cooking, increases were detected depending on time in all groups during storage ($p < 0.05$). Gokoglu et al. (2024) noted that they determined lower TVB-N values in fish and shrimp cooked with sous-vide compared to control samples. It has been reported that this condition is associated with bacterial growth and microbial proliferation.

Table 3. pH, TVB-N and TBARS values of raw and sous vide-cooked trout meatballs.

Samples	Storage period (days)	Analysis		
		TVB-N (mg/100 g)	TBARS (µmol MA/kg)	pH
K	0	8.16±0.14^{f}	1.25±0.07^{f}	6.34±0.07^{d}
	5	13.61±0.52^{e}	2.84±0.09^{e}	6.38±0.03^{cd}
	10	17.06±0.15^{d}	4.30±0.07^{d}	6.50±0.02^{abc}
	15	20.38±0.24^{c}	6.27±0.17^{c}	6.48±0.08^{bc}
	20	24.40±0.23^{b}	8.00±0.20^{b}	6.57±0.02^{ab}
	25	28.46±0.45^{a}	9.65±0.19^{a}	6.62±0.02^{a}
A	0	6.99±0.07^{f}	1.05±0.07^{f}	6.35±0.08^{d}
	5	10.40±0.16^{e}	1.72±0.11^{e}	6.45±0.04^{cd}
	10	14.73±0.23^{d}	2.97±0.15^{d}	6.56±0.06^{bc}
	15	17.66±0.31^{c}	4.37±0.26^{c}	6.48±0.03^{cd}
	20	21.30±0.17^{b}	5.46±0.11^{b}	6.64±0.03^{ab}
	25	24.70±0.02^{a}	6.24±0.13^{a}	6.70±0.02^{a}

Table 3. (continued)

Samples	Storage period (days)	Analysis		
		TVB-N (mg/100 g)	**TBARS (µmol MA/kg)**	**pH**
B	0	6.56±0.14^{f}	1.12±0.09^{f}	6.39±0.07^{c}
	5	9.70±0.25^{e}	1.79±0.09^{e}	6.49±0.02^{bc}
	10	13.90±0.04^{d}	3.19±0.06^{d}	6.61±0.02^{ab}
	15	16.98±0.27^{c}	4.70±0.05^{c}	6.55±0.07^{b}
	20	20.73±0.20^{b}	6.00±0.04^{b}	6.68±0.03^{a}
	25	23.99±0.02^{a}	6.72±0.08^{a}	6.70±0.11^{a}
C	0	5.95±0.08^{f}	1.17±0.04^{f}	6.42±0.08^{c}
	5	9.01±0.17^{e}	1.88±0.15^{e}	6.55±0.00^{bc}
	10	13.17±0.25^{d}	2.57±0.28^{d}	6.60±0.0^{ab}
	15	16.27±0.38^{c}	4.36±0.43^{c}	6.65±0.07^{ab}
	20	20.30±0.22^{b}	6.33±0.07^{b}	6.75±0.07^{a}
	25	23.22±0.05^{a}	6.98±0.03^{a}	6.75±0.04^{a}
D	0	5.20±0.17^{f}	1.19±0.01^{f}	6.45±0.08^{c}
	5	8.72±0.10^{e}	2.00±0.07^{e}	6.57±0.04^{bc}
	10	12.65±0.32^{d}	2.99±0.19^{d}	6.62±0.02^{ab}
	15	15.65±0.28^{c}	4.98±0.28^{c}	6.73±0.03^{a}
	20	19.54±0.28^{b}	6.74±0.06^{b}	6.74±0.02^{a}
	25	22.72±0.09^{a}	7.20±0.12^{a}	6.75±0.07^{a}

Different letters in the same column indicate statistical difference ($p<0.05$). K: Control, A: 60ºC for 15 min, B: 60ºC for 20 min, C: 80ºC for 15 min, D: 80ºC for 20 min.

3.3. Sensory Evaluation Results

Sensory features are one of the important factors that consumers consider (Cai et al., 2021). Sensory evaluation results of samples are given in Figure 1 (a-d). According to the sensory analysis results, it was determined that group and storage days had a significant effect ($p<0.05$), while the interaction of group and storage days did not have a significant effect ($p>0.05$). It was found that the meatballs cooked with the sous vide technique during storage had higher scores than the control. It is thought that this is due to the fact that the aroma components in the product remain in the package by processing the products in vacuum packaging in the sous-vide technique, increasing their sensory preferability. A decrease was observed in all sample groups in parallel with storage. It was determined that group B meatballs were the most preferred group, receiving the highest score in terms of sensory parameters. Similarly, Ceylan and Gokoglu (2022), emphasized that the sensory scores of squid cooked sous vide at 60 °C were higher than those cooked at 80 °C. Karki et al. (2023) reported that the sensory evaluation scores of tilapia samples cooked with sous vide were lower in the herb supplemented group than in the control group at the beginning of storage. It appeared to significantly improve the texture and overall acceptability of sous vide-treated fish burgers, but had no effect on color or odor (Zhou et al., 2021).

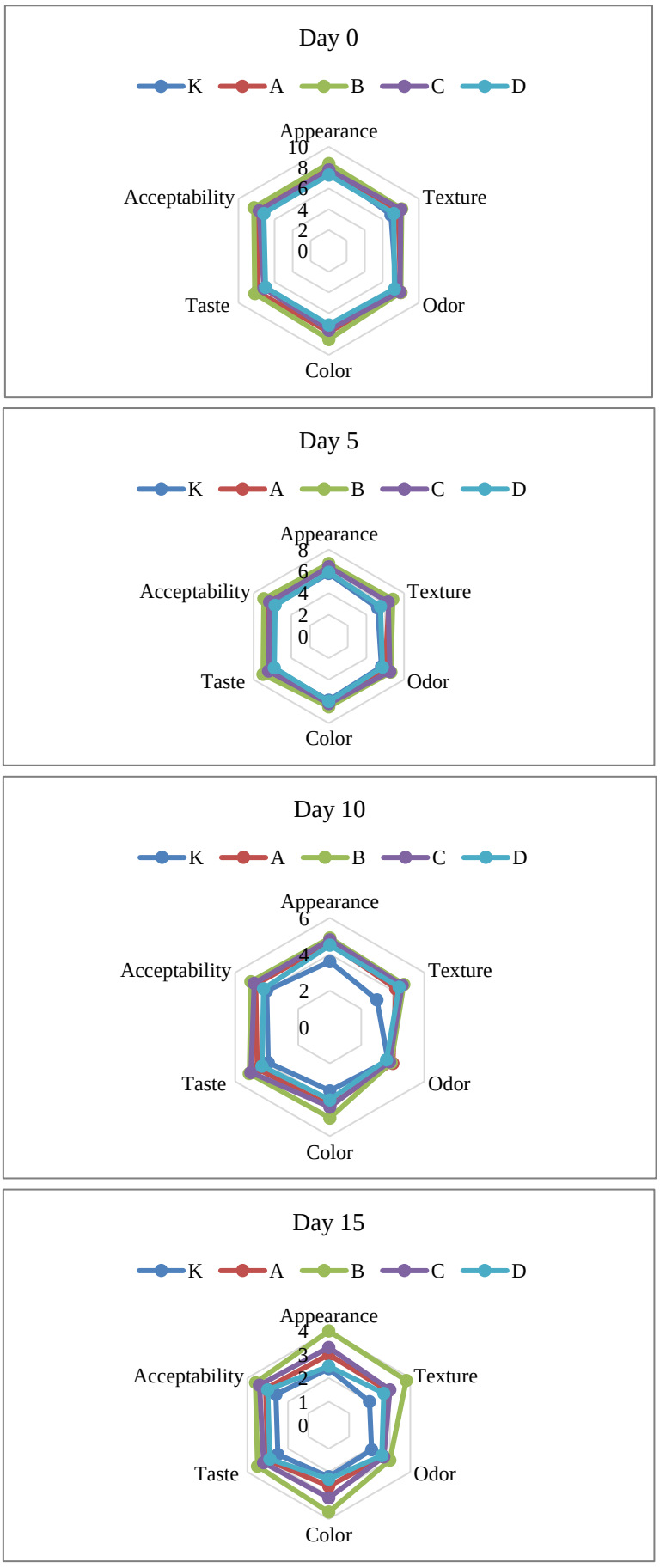

Figure 1. Sensory evaluation results of raw and sous vide-cooked trout meatballs.

4. Conclusion

Today, in addition to traditional cooking methods, there is a need to apply innovative techniques that have many advantages (fast and safe, longer shelf life, preserves nutritional value, and is heated for consumption). Sous vide is a modern culinary and processing method with these advantages. Sous vide cooking significantly affected the chemical, sensory and microbiological properties of rainbow trout meatballs. As a result, it was clearly observed that higher cooking temperature or longer processing time led to lower microorganisms. In addition, it was determined that the TBARS and TVB-N values of the samples applied with this technique remained well below the levels considered inconsumable throughout the storage period. Sensory analysis results showed that sous-vide cooking method increases the flavor of fish and is a good alternative method for cooking it. It was found that the sous vide technique is an effective cooking method on the quality parameters of trout meatballs. While there were a limited number of studies on the application of sous vide technique to fish and fish products in the literature review, no studies were found in which this technique was applied to rainbow trout meatballs. In this context, the results of the research will shed light on future studies.

Acknowledgment

This work was supported by the Ataturk University, Unit of Research Projects under Grant number (FYL-2023-12555). This work was produced from the master thesis prepared by the first author under the supervision of the second author.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

Abdel-Wahab, M., El-Sohaimy, S. A., Ibrahim, H. A., & El-Makarem, H. S. A. (2020). Evaluation the efficacy of clove, sage and kiwifruit peels extracts as natural preservatives for fish fingers. *Annals of Agricultural Sciences*, *65*(1), 98-106. https://doi.org/10.1016/j.aoas.2020.06.002

Baumgart. J., Firnhaber, J., & Spicher, G. (1986). *Mikrobiologische untersuchung von lebensmitteln*. Behr's Verlag.

Becker, A., Boulaaba, A., Pingen, S., Krischek, C., & Klein, G. (2016). Low temperature cooking of pork meat-physicochemical sensory aspects. *Meat Science*, *118*, 82-88. https://doi.org/10.1016/j.meatsci.2016.03.026

Bilgin, Ş., & Metin, S. (2022). Bazı doğal antioksidanların sudak (*Sander lucioperca*) köftelerinin kalitesine etkisi. *Journal of Limnology and Freshwater Fisheries Research*, *8*(2), 140-149. https://doi.org/10.17216/limnofish.900731 (In Turkish)

Bongiorno, T., Tulli, F., Comi, G., Sensidoni, A., Andyanto, D., & Iacumin, L. (2018). Sous vide cook-chill mussel (*Mytilus galloprovincialis*): evaluation of chemical, microbiological and sensory quality during chilled storage (3ºC). *LWT*, *91*, 117-124. https://doi.org/10.1016/j.lwt.2017.12.005

Bozova, B. (2020). *Bitki özütlerinin sous vide uygulanmasında sarıağız balığı (Argyrosomus regius) filetolarının kalite özelliklerine etkisi* (Doctoral dissertation, Isparta Uygulamalı Bilimler University). (In Turkish)

Bozova, B., & İzci, L. (2021). Effects of plant extracts on the quality of sous vide meagre (*Argyrosomus regius*) fillets. *Acta Aquatica Turcica*, *17*(2), 255-266. https://doi.org/10.22392/actaquatr.798584

Çağlak, E., Karslı, B., & Şişmanlar Altıkaya, E. (2017). Investigation of quality change of zander (*Sander lucioperca* Linnaeus, 1758) stored at +2±1ºC'de appling sous-vide technique in different temperature combinations. *Yunus Araştırma Bülteni*, *17*(1), 71-81. https://doi.org/10.17693/yunusae.v17i26557.274312

Cai, W. Q., Chen, Y. W., Dong, X. P., Shi, Y. G., Wei, J. L., & Liu, F. J. (2021). Protein oxidation analysis based on comparative proteomic of Russian sturgeon (*Acipenser gueldenstaedti*) after sous-vide cooking. *Food Control*, *121*, 107594. https://doi.org/10.1016/j.foodcont.2020.107594

Ceylan, A. (2021). *Sous-vide pişirme tekniğinin kalamar (Loligo vulgaris) kasının tekstür ve fizikokimyasal özelliklerine etkisinin araştırılması* (Master's thesis, Akdeniz University). (In Turkish)

Ceylan, A., & Gokoglu, N. (2022). Improving the physicochemical and textural properties of squid (*Loligo vulgaris*) muscle by sous-vide cooking in different time-temperature combinations. *Journal of Aquatic Food Product Technology*, *31*(8), 872-881. https://doi.org/10.1080/10498850.2022.2108360

Choi, Y. M., Jung, K. C., Jo, H. M., Nam, K. W., Choe, J. H., Rhee, M. S., & Kim, B. C. (2014). Combined effects of potassium lactate and calcium ascorbate as sodium chloride substitutes on the physicochemical and sensory characteristics of low-sodium frankfurter sausage. *Meat Science*, *96*(1), 21-25. https://doi.org/10.1016/j.meatsci.2013.06.022

Creed, P. G., & Reeve, W. (1998). Principles and applicatios of sous vide processed foods. In S. Ghazala (Ed.), *Sous vide and cook-chill processing for the food industry* (pp. 25-56). Aspen Publishers.

Cropotovaa, J., Mozuraityte, R., Standal, I. B., & Rustad, T. (2019). The influence of cooking parameters and Ccilled storage time on quality of sous-vide atlantic mackerel (*Scomber scombrus*). *Journal of Aquatic Food Product and Technology*, *28*(5), 505-518. https://doi.org/10.1080/10498850.2019.1604595

Cui, Z. K., Dubova, H., & Mo, H. Z. (2019). Effects of sous vide cooking on physicochemical properties of squid. *Journal of Hygienic Engineering and Design*, *29*, 35-40.

del Pulgar, J. S., Gázquez, A., & Ruiz-Carrascal, J. (2012). Physico-chemical, textural and structural characteristics of sous-vide cooked pork cheeks as affected by vacuum, cooking temperature, and cooking time. *Meat Science*, *90*(3), 828-835. https://doi.org/10.1016/j.meatsci.2011.11.024

Erdem, N., & Gökmen, S. (2022). *Sous vide teknolojisinin genel özellikleri ve gıdalardaki uygulamaları: Et endüstrisi örneği*. 1st International Conference on Engineering and Applied Natural Sciences. Konya. (In Turkish)

Erdem, N., Karakaya, M., Babaoğlu, A. S., & Unal, K. (2022). Effects of sous vide cooking on physicochemical, structural, and microbiological characteristics of cuttlefish, octopus, and squid. *Journal of Aquatic Food Product Technology*, *31*(7), 636-648. https://doi.org/10.1080/10498850.2022.2092433

Erol, P. (2013). *Sodyum laktat ve thymol'ün aynalı sazan balığı (Cyprinus carpio L.)'ndan yapılan köftelerin bazı mikrobiyolojik, kimyasal ve duyusal nitelikleri üzerine etkisi* (Master's thesis, Fırat University). (In Turkish)

Gökalp, H. Y., Kaya, M., Zorba, O., & Tulek, Y. (2001). *Et ve ürünlerinde kalite kontrolü ve laboratuvar uygulama kılavuzu*. Atatürk Üniversitesi Ziraat Fakültesi Yayını. (In Turkish)

Gokoglu, N., Yatmaz, H. A., Ceylan, A., Gumuş, B., Toktas, B., & Korun, J. (2024). Effects of different sous-vide cooking conditions on the chemical, physical, microbiological, and sensory quality of fish and shrimp during storage at 3 °C. *International Journal of Food Engineering*, *20*(2), 1-10. https://doi.org/10.1515/ijfe-2023-0245

Gürel İnanlı, A., & Yaz, Y. (2020). Assessment of chemical, microbiological and sensory quality of sous vide cooked *Luciobarbus esocinus* (Heckel, 1843) during chilled storage. *Progress in Nutrition*, *22*(2), 617-625. https://doi.org/10.23751/pn.v22i2.9316

Halkman, A. K. (2005). *Merck gıda mikrobiyolojisi uygulamaları*. Başak Matbaacılık Ltd. Şti. (In Turkish)

Haskaraca, G., & Kolsarıcı, N. (2013). Sous vide cooking and its potential applications in meat industry. *Akademik Gıda*, *11*(2), 94-101.

Jayasinghe, C. V. L., Silva, S. S. G., & Jayasinghe, J. M. J. K. (2013). Quality improvement of tilapia fish nuggets by addition of legume flour as extenders. *Journal of Food and Agriculture*, *6*(1-2), 32-44. https://doi.org/10.4038/jfa.v6i1-2.5186

Karki, S., Chowdhury, S., Dora, K. C., Murmu, P., & Nath, S. (2023). Influence of a traditional herb (*Bergenia ciliata*) from darjeeling himalayas on lipid oxidation and sensorial quality of sous-vide cooked tilapia (*Oreochromis niloticus*). *Journal of Aquatic Food Product Technology*, *32*(3), 256-268. https://doi.org/10.1080/10498850.2023.2199734

Kaya, E. (2021). *İstanbul ilinde belirlenen pilot cafe-restoranlarda "sous vide (vakumla pişirme)'' tekniği ile hazırlanan sığır eti ve tavuk eti tercihinde tüketici profillerinin belirlenmesi* (Master's thesis, Istanbul Gedik University). (In Turkish)

Kızılkaya, P. (2020). *Nanokompozit kaplama materyallerinin alabalık filetolarında kullanım imkânları* (Doctoral dissertation, Atatürk University). (In Turkish)

Kurt Kaya, G. (2022). The effects of different packaging methods and sous vide cooking on chemical, sensory, and microbiological changes of marinated crayfish (*Astacus leptodactylus* Esch., 1823). *Journal of Food Processing and Preservation*, *46*(10), e16919. https://doi.org/10.1111/jfpp.16919

Lemon, D. W. (1975). *An improved TBA test for rancidity*. Fisheries and Marine Service.

Modzelewska-Kapituła, M., Pietrzak-Fiećko, R., Zakrzewski, A., & Więk, A. (2022). The influence of sous vide parameters on nutritional characteristics and safety of pikeperch fillets. *Foods*, *11*(11), 1605. https://doi.org/10.3390/foods11111605

Mohan, C. O., Ravishankar, C. N., & Srinivasa Gopal, T. K. (2017). Effect of vacuum packaging and sous vide processing on the quality of Indian white shrimp (*Fenneropenaeus indicus*) during chilled storage. *Journal of Aquatic Food Product Technology*, *26*(10), 1280-1292. https://doi.org/10.1080/10498850.2016.1236869

Mol Tokay, S. (2009). *Vakum ambalajda pişirilmiş (sous vide) balikta kalite ve raf ömrünün belirlenmesi* (Master's thesis, Istanbul University). (In Turkish)

Mol, S., Ozturan, S., & Cosansu, S. (2012). Determination of the quality and shelf life of sous vide packaged whiting (*Merlangius merlangus* euxinus, Nordman, 1840) stored at cold (4ºC) and temperature abuse (12ºC). *Journal of Food Processing and Preservation*, *36*(6), 497-503. https://doi.org/10.1111/j.1745-4549.2011.00616.x

Oğuzhan, P., & Yangılar, F. (2014). Su ürünlerinin hazır yemek teknolojisindeki yeri ve önemi. *Erzincan University Journal of Science and Technology*, *7*(1), 65-76. https://doi.org/10.18185/eufbed.91310 (In Turkish)

Öztürk, F., Gündüz, H., & Sürengil, G. (2021). The effects of essential oils on inactivation of *Listeria monocytogenes* in rainbow trout cooked with sous-vide. *Journal of Food Processing and Preservation*, *45*(10), e15878. https://doi.org/10.1111/jfpp.15878

Özyürek, F. B. (2021). *Sous vide yönteminin konjuge linoleik asit içeriği zenginleştirilmiş köftenin kalite parametreleri ve depolama stabilitesi üzerine etkisi* (Master's thesis, Nevşehir Hacı Bektaş Veli University). (In Turkish)

Pongsetkul, J., & Benjakul, S. (2022). Impact of sous vide cooking on quality and shelf-life of dried sour-salted fish. *Journal of Food Processing and Preservation*,

46(1), e16142. https://doi.org/10.1111/jfpp.16142

Pongsetkul, J., Benjakul, S., Boonanuntanasarn, S., & Yongsawatdigul, J. (2022). Sensory characteristics and microbiological quality changes of Nile tilapia fillet processed by various sous-vide conditions during chilled storage. *Turkish Journal of Fisheries and Aquatic Sciences*, *22*(9), TRJFAS21079. https://doi.org/10.4194/TRJFAS21079

Russo, G. L., Langellotti, A. L., Buonocunto, G., Puleo, S., Di Monaco, R., Anastasio, A., Vuoso, V., Smaldone, G., Baselice, M., Capuano, F., Garofalo, F., & Masi, P. (2023). The sous vide cooking of Mediterranean mussel (*Mytilus galloprovincialis*): Safety and quality assessment. *Foods*, *12*(15), 2900. https://doi.org/10.3390/foods12152900

Seyyar, E. (2015). *Sous-vide yöntemi ile pişirilen alabalık filetolarında heterosiklik aromatik amin oluşumu ve bisfenol-a migrasyon düzeyinin belirlenmesi* (Master's thesis, Atatürk University). (In Turkish)

Vanderzant, C., & Splittstoesser, D. F. (1992). *Compendium of methods for the microbiological examination foods, 3rd edition*. American Public Health Assocation.

Varlık, C., Uğur, M., Gökoğlu, N., & Gün, H. (1993). *Su ürünlerinde kalite kontrol ilke ve yöntemleri*. Gıda Teknolojisi Derneği Yayınları. (In Turkish)

Yang, L., Li, Z., Xie, T., Feng, J., Xu, X., Zhao, Y., & Gao, X. (2023). Effects of sous-vide on quality, structure and flavor characteristics of Tilapia fillets. *Molecules*, *28*(24), 8075. https://doi.org/10.3390/molecules28248075

Yıldız, M., & Yılmaz, M. (2020). Sous vide technique in Turkish literature. *Journal of Tourism and Gastronomy Studies*, *8*(3), 2318-2336. https://doi.org/10.21325/jotags.2020.662

Yuan, Y. W., Cai, W. Q., Wang, M. Z., Liu, Y. T., Fu, J. J., & Chen, Y. W. (2023). Effects of sous vide cooking combined with ultrasound pretreatment on physicochemical properties and microbial communities of Russian sturgeon meat (*Acipenser gueldenstaedti)*. *Journal of the Science of Food and Agriculture*, *103*(4), 2166-2174. https://doi.org/10.1002/jsfa.12369

Zhan, Y., Tu, C., Jiang, H., Benjakul, S., Ni, J., Dong, K., & Zhang, B. (2022). Effects of sous vide cooking on the physicochemical and volatile flavor properties of half-shell scallop (*Chlamys farreri*) during chilled storage. *Foods*, *11*(23), 3928. https://doi.org/10.3390/foods11233928

Zhou, P., Feng, Q., Yang, X., Gao, R., Li, Y., Bai, F., Wang, J., Zhou, X., Wang, H., Xiao, F., Yang, X., Gao, X., & Zhao, Y. (2021). Sous vide pretreatment in cooking sturgeon fish burger: Effects on physicochemical properties and sensory characteristics. *International Journal of Food Science & Technology*, *56*(6), 2973-2982. https://doi.org/10.1111/ijfs.14938