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RESEARCH ARTICLE

Determination of shelf life of rainbow trout (*Oncorhynchus mykiss*) fillets cooked at different combinations of temperatures using the sous vide technique

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ABSTRACT

This study aimed to determine the shelf life of rainbow trout (*Oncorhynchus mykiss*) fillets, which were applied sous vide technique at different temperatures (55, 65 and 70°C) and stored at 4±1°C for 18 days. The fillets were subjected to chemical (total volatile basic nitrogen, thiobarbituric acid reacting substances and pH), microbiological (total aerobic mesophilic, psychrophilic bacteria and yeast-mold) and sensory analyzes (appearance, texture, odor and color). The results showed that the total number of mesophilic aerobic and psychrophilic bacteria did not exceed the limit values during the storage period in the groups treated with sous vide. In addition, temperature and storage time had a statistically significant ($p<0.01$) effect on all bacterial groups. The control group samples had higher TVB-N, TBARS and pH values during the storage period compared to the samples with the sous vide technique. When the sensory analysis results were examined, it was found that the most liked group among all groups, except for the odor parameter, was the group that was cooked at 55°C during storage time. As a result of the analysis, it was determined that the sous vide technique applied to the fish had a positive effect on the shelf life, and the most suitable cooking temperature and time were 15 minutes at 70°C.

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Introduction

Seafood is a foodstuff that contains very high nutritional value and contains both fat and water-soluble vitamins and essential amino acids, which are rich in omega-3 fatty acids (EPA and DHA), and have an important role in human health (Valenzuela & Valenzuela, 2013; Ceylan & Ünal Şengör, 2017; Korkmaz et al., 2020).

Despite its high nutritional value, seafood is one of the foodstuffs that tend to deteriorate quickly due to the loose connective tissue and the polyunsaturated fatty acids they contain. Therefore, if it is not to be consumed immediately, seafood should be preserved using appropriate processing techniques following harvesting (Korkmaz et al., 2020). Many preservation methods have been applied throughout history in order to maintain the freshness of seafood, increase product variety to extend the consumption period. The main purpose here is to extend the shelf life of the fish, as well as to supply the fish for consumption outside the hunting and consumption season. For this purpose, many methods such as drying, salting, smoking, cooling, freezing, surimi, canning, and marinating technology are used to preserve fish. In addition to these, alternative methods have also been found to be applicable in the processing of fish (Anonymous, 2021).

The sous vide technique was firstly developed in France and it means "under vacuum". It is the process of cooking a product by vacuum packaging it in heat-resistant bags and pasteurizing it in a water bath under controlled temperature and time. Sous vide technology emerges as a preservation technique used to increase the shelf life of the product and to obtain products that have not lost their nutritional components (Aksoy & Mete, 2017; Yıldız & Yılmaz, 2020; İlyasoğlu, 2021).

In this technique, aerobic microorganism growth and oxidation is able to be controlled by vacuum packaging of the product by absorbing the oxygen in the package. It is aimed to obtain a product with a long shelf life by applying vacuum packaging and heat treatment in tandem to the product. In this aspect, it is also preferred commonly by schools, hospitals, factories, hotels, etc. that provide mass catering (Mol & Özturan, 2009; Baltalı & Akoğlan Kozak, 2021). This technique has advantages in terms of applying to products such as meat, chicken and fish that are prone to spoilage, being made ready for consumption easily, being suitable for flavoring along with other products, maintaining microbiological development under control with vacuum packaging, and resulting in products with a long shelf life. In addition, it is reported that it preserves products' original taste for a long time, improves their sensory properties positively, and provides healthy and nutritious cooking, which is more beneficial than traditional cooking (Creed & Reeve, 1998; Baldwin, 2012; Ceylan & Ünal Şengör, 2017; Yıldız & Yılmaz, 2020).

The application of the sous-vide technique to seafood is a cooking method that is not widely known in Turkey, but has become increasingly important in the world in recent years. This study investigated increasing the shelf life by preserving the quality of the product. It is a different option for the developing food industry in our country, and in this context, a contribution will be made to the food industry. In addition, the effect of this technique on the nutritional quality of rainbow trout fillets will be determined and the sensory properties will be improved compared to other classical methods. This study aimed to determine the changes in the quality and shelf life of rainbow trout (*Oncorhynchus mykiss*) fillets, which were kept cold and applied sous vide technique at different combinations of temperatures.

Material and Methods

Material

Rainbow trout fillets (168 pieces) an average of 250±25 g weight, were obtained from Atatürk University Fisheries Faculty and brought to our faculty's processing laboratory in accordance with the cold supply chain conditions. Trouts were thoroughly washed with water, then the head, viscera, and skin were removed and the skinless fillets were obtained and vacuum packaging was performed.

Method

Sous-Vide

For the sous vide process, the trout fillets were heat-treated at different temperatures (55, 65 and 70°C) for 15 minutes. The cooking process was applied in a water bath (double boiler) until cooking was observed in both parts of the fillets. The time and temperature of the application have been determined by preliminary studies. The control group that did not any heat treatment. After the cooking process was completed, the bags were immersed in a bucket containing 1/3 water and 2/3 ice and kept for 30 minutes and cooled rapidly. Then, they were stored at 4±1°C for 18 days, and the samples were subjected to chemical, sensory and microbiological analyzes on certain days (0, 3, 6, 9, 12, 15 and 18 days) of storage.

Microbiological Analysis

For microbiological analysis, 25 g of fish samples were taken into a sterile stomacher bag and 225 ml of sterile saline solution was added and homogenized in a stomacher device (Lab Stomacher Blender 400-BA 7021 Seward Medical, England). Plate Count Agar was used for the analysis of total aerobic mesophilic and psychrophilic bacteria and the media were incubated for 2 days at 30°C and 10 days at 4°C, respectively. The Potato Dextrose Agar medium was used for yeast-mold enumeration and incubated at 25°C for 5 days (Gökalp et al., 2001).

Chemical Analysis

100 ml of distilled water was added to 10 g of the sample and the pH value was determined after homogenizing for 1 minute (Gökalp et al., 2001).

The TBARS value was made according to the method used by Lemon (1975) and Kılıç & Richards (2003). 7.5% trichloroacetic acid (TCA) was added to the 2 g sample and filtered through filter paper after homogenization. TBA reagent was added to the filtrate and kept in a water bath at 100°C for approximately 40 minutes. Then, it was taken from the water bath and allowed to cool, and a reading was made in the spectrophotometer (530 nm). TBARS value was calculated according to the following equation (1):

$$TBARS = \left(\left({}^{Abs}/_{k(0.006)} \right) \times {}^{2}/_{1000 \times 6.8} \right) \times \frac{1000}{sample\ weight} \qquad (1)$$

The method proposed by Malle & Tao (1987) was used to determine the TVB-N value. 7.5% (v/v) trichloroacetic acid (TCA) was added to 40 grams of sample, homogenized, centrifuged and filtered through filter paper. 10% NaOH (w/v) was added to the obtained filtrate and placed in the distillation device until the final volume was approximately 50 ml. The obtained distillate was titrated with 0.1 N H_2SO_4 solution and the TVB-N value was calculated using equation (2):

$$TVB - N \left(\frac{mg}{100g} \right) = n \times 16.8\ mg\ nitrogen \qquad (2)$$

Sensory Analysis

The sensory analysis of fish samples was carried out by a panelist group of 10 using a hedonic type scale consisting of appearance, texture, odor and color parameters. The panelists evaluated the samples over 5 points and scored as 1: very bad, 2: bad, 3: normal, 4: good, and 5: very good (Huss, 1995).

Statistical Analysis

This study was carried out according to an entirely random trial plan consisting of control groups of 3 different temperatures (55, 65, and 70°C) and 3 replications. The results obtained were subjected to statistical analysis and the Duncan multiple comparison test was applied to averages that were found to be significant.

Results and Discussion

Microbiological Results

The microbiological analysis results of rainbow trout fillets applied sous vide technique at different temperatures (55, 65, and 70°C) during cold storage (4±1°C) are given in Table 1.

The acceptable limit for total aerobic mesophilic bacteria in fresh fish was reported as 6 log cfu/g by Anonymous (2022). The total number of mesophilic aerobic was found to be lower in the samples with the sous vide technique compared to the control group samples. Total aerobic mesophilic bacteria count of rainbow trout fillets ranged from 2.00-10.53 log cfu/g. The effect of the storage time on the bacterial counts was significant and as the time increased, a significant increase was detected in the bacterial counts in all groups ($p<0.01$). The highest total number of aerobic mesophilic bacteria was observed in the control group with a value of 7.15±2.43 log cfu/g, while the lowest was found in rainbow trout fillets cooked with the sous vide technique at 70°C with a value of 2.33±0.48 log cfu/g. It was observed that the applied heat treatment and vacuum packaging had a positive effect on slowing the bacterial growth of the samples. In particular, it was observed that bacterial growth slowed down significantly as the temperature increased. In the study conducted by Şişmanlar Altıkaya (2016), it was reported that the number of mesophilic aerobic bacteria in total in zander fish (*Sander lucioperca* Linnaeus, 1758) was 6.49, 5.24, and 1.60 log cfu/g on the 42nd day of storage in the samples which had sous vide method applied at 60°C, 70°C, and 80°C, respectively. Nyati (2000) reported that the total number of mesophilic bacteria reached the level of 5 log cfu/g during 5 weeks of storage at 3°C in fish fillets that were treated with sous vide technique for 2 minutes at 70°C. Mol et al. (2012) reported that the total number of aerobic mesophilic bacteria decreased with the sous vide cooking method in a study conducted with whiting (*Merlangius merlangus euxınusi* Nordman, 1840) prepared with the sous vide method. According to Coşansu et al. (2011), the number of mesophilic aerobic bacteria in bonito fish (*Sarda sarda*, Bloch, 1793) with lemon juice and kept at

4±1°C by applying the sous vide technique for 10 minutes at 70°C remained at the acceptable limit values (6 log cfu/g) until the 35th day. Diaz et al. (2011) reported yeast-mold growth in their study with salmon (*Salmo salar*) fillets. Jeya Shakila et al. (2012) reported that the total number of mesophilic bacteria reached the level of 3 log cfu/g after 6 weeks of storage in cobia fish cakes in which 20 minutes of sous vide was applied at 95°C. These results were consistent with the findings of our study.

Psychrotrophic bacteria count of rainbow trout fillets ranged from 2.00-10.83 log cfu/g. Psychrotrophic bacteria was found to be lower in the samples with the sous vide technique compared to the control group samples. The highest number of psychrotrophic bacteria was observed in the control group with a value of 7.46±2.51 log cfu/g, while the lowest was found in samples cooked with the sous vide technique at 70°C with a value of 2.42±0.58 log cfu/g. As the degree of heat treatment applied increased, the number of psychrotrophic bacteria decreased. González-Fandos et al. (2005) found that the groups treated with sous vide at 90°C for 5 minutes (2°C storage) and at 65°C for 10 minutes (2-10°C storage) gave better results. The psychrophilic aerobic bacterial load of raw bonito and whiting was 2.72±0.03 log cfu/g, and 2.61±0.06 log cfu/g, respectively, while it was >1.00±0 log cfu/g in both sous vide-treated fish samples (Özturan, 2009). Garcia-Linares et al. (2004) found that psychrophilic bacteria levels in both fish species were 4-5 log cfu/g in their study with trout and salmon. Kato et al. (2017) emphasized that the numbers of psychrophilic bacteria remained within the limits recommended by the Brazilian legislation during storage, in a study conducted with tambaqui (*Colossoma macropomum*) in which sous vide treatment was applied at 65°C for 12.5 minutes. Bozova & İzci (2021) determined significant increases in total psychrophilic aerobic bacteria counts during storage in meagre (*Argyrosomus regius*) treated with rosemary and thyme extracts and subjected to sous vide treatment. The data obtained in this study are in agreement with the study data reported by the researchers.

Table 1. Microbiological analysis results of rainbow trout fillets applied sous vide technique at different temperatures (log cfu/g)

Microbiological Analysis	Storage time (days)	Groups			
		Control	55°C	65°C	70°C
Total aerobic mesophilic bacteria	0	3.06±0.06^{a}	2.00±0.00^{a}	2.00±0.00^{a}	2.00±0.00^{a}
	3	5.16±0.23^{a}	2.00±0.00^{a}	2.00±0.00^{a}	2.00±0.00^{a}
	6	6.42±0.30^{a}	2.27±0.10^{b}	2.08±0.11^{b}	2.00±0.00^{a}
	9	7.30±0.16^{a}	3.04±0.09^{c}	2.58±0.12^{c}	2.00±0.00^{a}
	12	8.03±0.11^{a}	3.69±0.25^{d}	3.07±0.08^{d}	2.20±0.14^{b}
	15	9.54±0.29^{a}	4.07±0.10^{e}	3.26±0.07^{e}	2.92±0.13^{c}
	18	10.53±0.21^{a}	4.93±0.10^{f}	3.54±0.12^{e}	3.16±0.10^{a}
Psychrophilic bacteria	0	3.20±0.05^{a}	2.00±0.00^{a}	2.00±0.00^{a}	2.00±0.00^{a}
	3	5.38±0.21^{b}	2.00±0.00^{a}	2.00±0.00^{a}	2.00±0.00^{a}
	6	6.69±0.27^{c}	2.61±0.14^{b}	2.25±0.06^{a}	2.00±0.00^{a}
	9	7.66±0.09^{d}	3.41±0.24^{c}	2.60±0.16^{a}	2.00±0.00^{a}
	12	8.37±0.13^{e}	3.94±0.09^{d}	3.23±0.22^{a}	2.37±0.19^{b}
	15	10.07±0.14^{f}	4.19±0.17^{e}	4.04±0.07^{a}	3.26±0.07^{c}
	18	10.83±0.15^{g}	5.29±0.11^{f}	3.91±0.14^{a}	3.32±0.11^{c}
Yeast-mold	0	2.00±0.00^{a}	2.00±0.00^{a}	2.00±0.00^{a}	2.00±0.00^{a}
	3	2.29±0.14^{b}	2.00±0.00^{a}	2.00±0.00^{a}	2.00±0.00^{a}
	6	3.11±0.11^{c}	2.00±0.00^{a}	2.00±0.00^{a}	2.00±0.00^{a}
	9	4.27±0.16^{d}	2.13±0.08^{a}	2.00±0.00^{a}	2.00±0.00^{a}
	12	5.35±0.28^{e}	2.54±0.09^{b}	2.34±0.20^{a}	2.00±0.00^{a}
	15	7.02±0.09^{f}	2.93±0.13^{c}	2.74±0.31^{b}	2.30±0.14^{b}
	18	6.61±0.18^{g}	3.82±0.13^{d}	2.69±0.34^{b}	2.52±0.27^{c}

Note: Means shown with different letters are statistically different from each other ($p<0.05$).

Table 2. Chemical analysis results of rainbow trout fillets applied sous vide technique at different temperatures

Chemical analysis	Storage time (days)	Groups			
		Control	55°C	65°C	70°C
TVB-N	0	14.95±0.07^{a}	12.61±0.33^{a}	11.65±0.20^{a}	10.88±0,19^{a}
	3	15.24±0.21^{a}	13.25±0.12^{b}	12.12±0.18^{b}	11.37±0,16^{b}
	6	16.29±0.12^{b}	14.21±0.26^{c}	12.81±0.24^{c}	11.04±0.06^{ab}
	9	17.57±0.12^{c}	15.48±0.37^{d}	14.47±0.31^{d}	13.71±0.52^{c}
	12	18.62±0.28^{d}	16.95±0.06^{e}	15.63±0.14^{e}	15.11±0.12^{d}
	15	21.92±0.14^{e}	20.21±0.33^{f}	17.13±0.10^{f}	17.04±0.04^{e}
	18	24.27±0.29^{f}	21.17±0.17^{g}	20.07±0.11^{g}	19.48±0.24^{f}
TBARS	0	2.55±0.13^{a}	1.72±0.14^{a}	1.13±0.09^{a}	0.87±0,12^{a}
	3	3.48±0.15^{b}	2.26±0.14^{b}	0.96±0.09^{a}	0.54±0.12^{b}
	6	4.66±0.23^{c}	2.84±0.08^{c}	1.81±0.14^{b}	1.13±0.14^{c}
	9	5.54±0.23^{d}	3.24±0.09^{d}	2.25±0.15^{c}	1.61±0.17^{d}
	12	6.83±0.12^{e}	4.23±0.22^{e}	2.92±0.14^{d}	2.60±0.16^{e}
	15	7.25±0.18^{f}	5.05±0.15^{f}	3.36±0.26^{e}	3.12±0.10^{f}
	18	7.57±0.17^{g}	5.57±0.14^{g}	4.47±0.09^{f}	4.05±0.14^{g}
pH	0	6.35±0.19^{ab}	6,53±0,00^{b}	6,46±0,02^{c}	6.45±0.00^{c}
	3	6.10±0.06^{b}	6,76±0,09^{a}	6,73±0,03^{ab}	6.44±0.00^{c}
	6	6.15±0.06^{ab}	6,38±0,05^{a}	6,22±0,10^{b}	6.69±0.00^{c}
	9	6.28±0.09^{abc}	6.15±0.06^{c}	6.15±0.06^{a}	6.38±0.08^{bc}
	12	6.49±0.14^{c}	6.15±0.06^{b}	6.15±0.06^{a}	6.15±0.08^{a}
	15	6.30±0.09^{abc}	6.15±0.06^{b}	6.15±0.06^{c}	6.29±0.06^{b}
	18	6.20±0.04^{ab}	6.15±0.06^{b}	6.15±0.06^{ab}	6.46±0.04^{d}

Note: Means shown with different letters are statistically different from each other ($p<0.05$)

While the number of yeast-mold was determined as 2.00 log cfu/g in all groups, it increased until the end of storage. The highest yeast-mold count was found in the control group with a value of 4.38±1.92 log cfu/g, while the lowest was observed in the samples cooked at 70°C, with a value of 2.11±0.22 log cfu/g. Gürel İnanlı & Yaz (2020), determined the number of yeast-mold in *Luciobarbus esocinus* (Heckel, 1843) as 3.93±0.29 log cfu/g in the control group, 4.09±0.08 log cfu/g in the group cooked at 43°C for 20 minutes and 81±0.47 log cfu/g in the group cooked at 56°C for 10 minutes. Diaz et al. (2011) reported yeast-mold growth in their study with salmon (*Salmo salar*) fillets. In the study conducted by Pongsetkul & Benjakul (2021) with dried sour-salt fermented torpedo scad fish, yeast-mold was not detected in any of the samples. It has been determined that storage time and application processes have a significant effect on yeast and mold numbers.

Chemical Results

The chemical analysis results of rainbow trout fillets applied sous vide technique at different temperatures (55, 65 and 70°C) during cold storage (4±1°C) are given in Table 2.

The TBARS value, which was 2.55 µ mol MA/kg at the beginning of storage (day 0) in the control group samples, was determined as 1.73, 1.13 and 0.88 µ mol MA/kg in the samples applied with the sous vide technique at different temperatures (55, 65 and 70°C), respectively. It was determined that the increase in cooking temperatures of the samples decreased the TBARS value. In our study, it was observed that the TBARS value determined in the heat-treated samples was in parallel

with the data in the literature. It increased in parallel with the storage period and at the end of the storage period as well, with a value of 7.57 µ mol MA/kg being obtained from the control group, 5.57 µ mol MA/kg from the 55°C group, 4.47 µ mol MA/kg from the 65°C group and 4.05 µ mol MA/kg from the 70°C group. According to the TBARS value results obtained during storage, it was observed that the fillets in the control group were close to the consumption limit value from the 15th day, but did not exceed the consumption limit value of 8 µmol MA/kg. It was determined that the results, which did not exceed

Table 3. Sensory analysis results of rainbow trout fillets applied sous vide technique at different temperatures

Microbiological Analysis	Storage time (days)	Groups			
		Control	55°C	65°C	70°C
Appearance	0	4.67±0.57^{c}	5.00±0.00^{e}	3.67±0.57^{cd}	4.00±0.00^{cd}
	3	3.33±0.57^{b}	4.33±0.57^{cd}	4.33±0.57^{e}	4.33±0.57^{d}
	6	2.66±0.57^{b}	4.00±1.00^{cd}	3.67±0.57^{cd}	3.66±0.57^{abc}
	9	2.66±0.57^{b}	3.33±0.57b^{c}	3.33±0.57^{abc}	3.00±0.00^{ab}
	12	1.66±0.57^{a}	2.66±0.57^{ab}	3.00±0.00^{ab}	2.66±0.57^{a}
	15	1.33±0.57^{a}	2.66±0.57^{ab}	2.66±0.57^{ab}	3.00±1.00^{ab}
	18	1.00±0.00^{a}	1.66±0.57^{a}	2.33±0.57^{a}	2.66±0.57^{a}
Texture	0	4.66±0.57^{e}	5.00±0.00^{e}	3.66±0.57^{bc}	3.66±0.57^{ab}
	3	3.33±0.57^{d}	4.33±0.57^{cd}	4.33±0.57^{bc}	4.33±0.57^{b}
	6	2.33±0.57^{bc}	4.00±1.00^{cd}	3.66±0.57^{e}	3.66±0.57^{ab}
	9	2.66±0.57^{cd}	3.33±0.57^{bc}	3.33±0.57^{abc}	3.00±0.00^{a}
	12	1.66±0.57^{ab}	2.66±0.57^{ab}	3.00±0.00^{ab}	2.66±0.57^{a}
	15	1.00±0.00^{a}	2.66±0.57^{ab}	2.66±0.57^{ab}	3.00±1.00^{a}
	18	1.00±0.00^{a}	1.66±0.57^{a}	2.33±0.57^{a}	2.66±0.57^{a}
Odor	0	4.67±0.57^{e}	4.67±0.57^{e}	3.66±0.57^{d}	4.00±0.00^{cd}
	3	3.33±0.57^{d}	4.33±0.57^{cd}	4.33±0.57^{d}	4.33±0.57^{d}
	6	2.00±0.00^{c}	3.66±0,57^{bcd}	3.00±0.00^{abc}	3.66±0.57^{abc}
	9	2.00±0.00^{c}	3.33±0.57^{bc}	3.33±0.57b^{c}	3.00±0.00^{ab}
	12	1.66±0.57^{ab}	2.66±0.57^{ab}	3.00±0.00^{abc}	2.66±0.57^{a}
	15	1.33±0.57^{ab}	2.66±0.57^{ab}	2.66±0.57^{ab}	3.00±1.00^{ab}
	18	1.00±0.00^{a}	1.66±0.57^{a}	2.33±0.57^{a}	2.66±0.57^{a}
Color	0	4.67±0.57^{e}	4.67±0.57^{e}	3.33±0.57^{b}	3.33±.1.15^{ab}
	3	3.33±0.57^{d}	4.33±0.57^{cd}	4.33±0.57^{c}	4.33±0.57^{c}
	6	6,42±0,02^{c}	3.66±0.57^{bcd}	3.00±0.00^{ab}	3.66±0.57^{ab}
	9	2.00±0.00^{c}	3.33±0.57^{bc}	3.33±0.57^{b}	3.00±0.00^{ab}
	12	2.00±0.00^{ab}	2.66±0.57^{ab}	3.00±0.00^{ab}	2.66±0.57^{a}
	15	1.66±0.57^{ab}	2.66±0.57^{ab}	2.66±0.57^{ab}	3.00±1.00^{ab}
	18	1.33±0.57^{a}	1.66±0.57^{a}	2.33±0.57^{a}	2.66±0.57^{a}

Note: Means shown with different letters are statistically different from each other ($p<0.05$)

the limit value during storage in the heat-treated groups, remained within consumable values. The highest mean (5.42±1.84 mol MA/kg) was observed in the control group, while the lowest average (1.99±1.24 mol MA/kg) was found in rainbow trout fillets that were sous-vide cooked at 70°C. However, no significant difference was observed between the fillets cooked at all three temperatures (55, 65 and 70 °C) and the values were different from each other. Jeya Shakila et al. (2012) observed that the TBARS values were well below the limit values after 12 weeks of storage in cobia fish cakes in which sous vide was applied for 20 minutes at 95°C. According to Diaz et al. (2011), TBARS value was observed as 1.10±0.39 mg MDA/kg at week 0, 2.06 mg MDA/kg at week 5, and 2.30 mg MDA/kg at week 10 in salmon fillets (*Salmo salar*) treated with sous vide technology. TBARS value showed differences in the studies according to the application temperature and storage time.

It increased in parallel with the storage period and at the end of the storage period as well, with a value of 14.95 mg/100 g being obtained from the control group, 12.61 mg/100 g from the 55°C group, 11.65 mg/100 g from the 65°C group and 10.89 mg/100 from the 70°C group. According to the TVB-N value results obtained during storage, none of the sous vide applied groups, including the control group, exceeded the TVB-N limit value. The highest TVB-N value results were observed in the control group (18.41±3.33 mg/100 g), while the lowest was found in trout fillets that were cooked sous vide (14.09±3.15 mg/100 g) at 70°C. No significant difference was observed between the fillets cooked at all three temperatures and the values were different from each other. Ramos et al. (2016) determined that the TVB-N value in tambaqui (*Colossoma macropomum*) fish treated with spices and cooked in sous vide was lower than in plain fish fillets treated with sous vide, with the TVB-N value being 11.17 mg/100 g in the control group samples and 8.38 mg/100g in the spice group. It was found that the highest TVB-N value was observed as 30.80 mg N/100 g in sea bass (*Dicentrarchus labrax*) treated with sous vide technology by adding laurel at the end of the storage period (Bolat et al., 2019). In another study conducted by Ceylan & Ünal Şengör (2019) on sea bass fillets (*Dicentrarchus labrax*, Linnaeus, 1758), the TVB-N value in the first week of storage was 21.2 mg/100 g in the control group, 20.79 mg/100 g in the group with dried basil, and garlic added, and 20.52 mg/100g in the group with dried basil, garlic, and dill added. In another study conducted with rainbow trout, the TVB-N value was 15.80±0.69 mg/100g on the 40th day of storage in the sous vide group, and it was 15.13±0.00 mg/100g in the sous vide group treated with ground sage. (Çetinkaya, 2020).

At the beginning of storage, the lowest pH value was found in the control group (6.35), and the highest was found in the samples of the sous vide technique with the highest temperature (70°C) (7.00). On the 18th day of storage, the lowest pH value was found in the control group (6.21) samples, and the highest pH value was found in the samples which were cooked at 70°C using the sous vide method (6.47). Wan et al. (2019) reported that largemouth bass (*Micropterus salmoides*) cooked with the sous vide group showed an increased pH tendency when compared to the control group without any cooking process. The results of the study were consistent with the findings we obtained. del Pulgar et al. (2012) emphasized that the pH increase of fish during cooking was attributed to the formation of disulfide bonds during the cooking process. Seyyar (2015) reported that the pH value of untreated trout was 6.56 in rainbow trout fillets cooked with the sous vide cooking method, while the samples cooked with the sous vide method at different temperatures and cooking levels varied between 6.63-7.00. Ramos et al. (2016) reported that the pH value of tambaqui fish cooked with the sous vide method, which was 5.52±0.51, was significantly lower (6.34±0.04) compared to raw fish.

Sensory Results

The sensory analysis results of rainbow trout fillets applied sous vide technique at different temperatures (55, 65, and 70°C) during cold storage (4±1°C) are given in Table 3.

According to the results of the sensory analysis, a decrease was observed in all sample groups in parallel with the storage and the difference between the groups was found to be statistically significant ($p<0.05$). In terms of sensory parameters, the most liked group, excluding smell, was the group in which the sous vide technique was applied at 55°C. In general, it was determined that the groups in which sous vide cooking was applied were preferred more in terms of all parameters. It has been emphasized that the applied heat treatment time, temperature and storage conditions are determinative in improving the shelf life of the product sensorially (Gonzalez-Fandos et al., 2004). Prevention of aroma loss in sous vide technique a better sensory quality can be achieved with components that give flavor and smell to the fish. It has been reported that sous vide samples treated with rosemary and thyme extracts were more appreciated by the panelists in terms of all sensory parameters than the samples applied without any (Bozova, 2020). Şişmanlar Altıkaya (2016) reported that the group in which the sous vide technique was

applied at 80°C got the highest score in terms of sensory parameters for pike perch fillets. Bolat et al. (2019) determined that there was a decrease in parallel with storage in all sample groups of sea bass fish (*Dicentrarchus labrax*) that they applied sous vide cooking by adding ground laurel (LS) and ginger (CS). It was determined that the sensory analysis results reported by the researchers were consistent with the data obtained in our study. Pongsetkul & Benjakul (2022) reported that the group in which 30 minutes of sous vide cooking at 40°C got the highest approval in terms of sensory parameters. The difference in applied temperature and time causes differences between studies.

Conclusion

It was concluded that the sous vide technique slowed the growth of microorganisms in rainbow trout fillets, TVB-N and TBARS values were lower in the sous vide applied groups compared to the control group, and the pH value was highest in the sous vide cooking method at 70°C, and in the fillet group at 3 different temperatures. It has been determined that the sous vide cooking technique extends the storage time. In terms of sensory parameters, it was determined that the groups that applied sous vide cooking were more appreciated. In the light of all these analyses, it was determined that high-temperature application was effective on chemical and microbiological properties. It has been concluded that the vacuum packaged cooking method can be applied to rainbow trout, and we believe that it is also important to evaluate fish meat in this way, both to extend the shelf life and to provide an economic contribution by presenting it to the consumer as an alternative to the consumption of ready-made food.

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Compliance With Ethical Standards

Authors' Contributions

This work was produced from the master thesis prepared by the first author under the supervision of the second author. POY designed the study. Both authors read and approved the final version of the article.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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