Original Article

Effects of Salting and Refrigerator Storage on Rainbow Trout (*Oncorhynchus mykiss*) Roe Quality: Chemical and Microbial Changes

***Hojat Mirsadeghi[1], Alireza Alishahi[1], Bahareh Shabanpour[1], Reza Safari[2], Maryam Daneshvar[1]**

1. Department of Seafood Processing, Faculty of Fisheries and Environmental Sciences, Gorgan University of Agricaltural Sciences and Natural Resources, Gorgan, Iran.
2. Caspian Sea Ecology Research Institute, Sari, Iran.

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ABSTRACT

Background: In recent years, rainbow trout roe has become a valuable and popular product among consumers. In this study, the quality and health status of this product were studied during the salting and refrigeration process.

Objectives: This study aimed to compare the effects of salting rainbow trout roe on its shelf life, volatile nitrogen, and changes in fatty acid profile during refrigerated storage.

Methods: After the first wash, we grouped the fish roe into the raw roe (control group) and the salted roe (1.5% pure salt). The groups were kept in the refrigerator for 0, 15, and 30 days and analyzed for chemical, microbial, organoleptic, and fatty acids.

Results: The results showed that salt content affected the fatty acid profile during the salting of the fish roe, but no significant differences were observed between the two treatments. Total bacterial counts increased during refrigerated storage, but the salted fish roe had lower total bacterial counts than the raw roe. Total volatile basic nitrogen in raw roe increased from 5.97 to 30.00 mg/kg and in salted roes from 6.05 to 23.18 mg/kg.

Conclusion: Salting (1.5%) fish roe is a good way to increase its shelf life while preserving its high quality. After salting, the amount of fatty acid decreased, but no change was observed during storage.

Keywords: Fatty acid profile, Microbial changes, Quality changes, Rainbow trout roe, Volatile nitrogen

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*** Corresponding Author:**
Alireza Alishahi
Address: *Department of Seafood Processing, Faculty of Fisheries and Environmental Sciences, Gorgan University of Agricaltural Sciences and Natural Resources, Gorgan, Iran.*
Phone: *+98 (17) 14427040*
E-mail: *seafood1144@yahoo.com*

1. Introduction

Over the last six decades, there has been a significant increase in demand for fish and fish products. Among these products, fish roe has been one of the most sought-after culinary items traded globally, and its value is based on cultural factors and familiarity with fish roe products. Fish roe refers to the mature and immature ovaries of fish, as well as a range of aquatic animals such as shrimp, squid, sea urchins, and scallops. Although the shelf life of raw fish roe is quite limited, a range of processing methods, such as salting, drying, smoking, fermentation, and canning, are mostly applied to maintain the quality of the roe product, extend shelf life, and enhance its flavor (Rahman et al., 2022). Fish roe is used worldwide, and the most famous of them is caviar. Fish roe has a complex of vital ingredients, such as polyunsaturated fatty acids, protein, essential amino acids, minerals, and vitamins (Vilgis, 2020). Various types of fish roe products are manufactured and consumed in Japan. Common products are salted or spicy seasoned walleye pollock roe, salted salmon roe, salted herring roe, salted-dried mullet roe, and flying fish roe (Saeki et al., 2022). The main stage during caviar processing is salting, playing a key role in the quality of the product. Besides salting, other preservation methods are employed within caviar production, such as freezing, smoking, canning, and sausage production technologies (Donatella Restuccia et al., 2015).

Fish roe contains a large amount of functional compounds, namely, eicosapentaenoic acid (C20:5n3), docosahexaenoic acid (C22:6n3), and a high amount of phosphatidylcholine that play a pivotal role in restraining and improving cardiovascular diseases, reinforcing educational ability, and declining plasma harmful lipids (Shirai et al., 2006). Regarding the high price and hard access to sturgeon caviar, consuming fish roe from other species, such as lumpfish, cod, mackerel, carp, grey mullet, and especially salmon, seems a good alternative. These kinds of fish roe represent the trade names used before the name 'caviar,' e.g., 'trout caviar,' 'tuna caviar,' or 'cod caviar' (Bronzi and Rosenthal, 2014). Today, rainbow trout is one of the most important reared commercial fish (Schafberg et al., 2019). Hence, the processing of its roe to produce fish caviar is of high importance. People use fish roe-based products because of their desirable flavor and taste and their nutritional value. Value-added products from fish roe are cherished and of high-consumed products worldwide. There are different ways to produce fish roe depending on the fish's species that considerably affect its quality and marketing. To the best of our knowledge, fish roe does not receive any further processing during production with novel or peculiar techniques, and in the end, it is prone to chemical and microbial deterioration. Furthermore, excessive salt upsets the product's taste and causes digestive difficulty. Therefore, the salt level should be determined precisely. Absorption and distribution of salt depend on many factors, such as the physiology of roe (size, thickness), chemical composition, method of salt grinding, salt concentration, temperature, and duration of salting (Shirai et al., 2006; Inanli et al., 2010). Hence, the present study aimed to investigate the fatty acid composition and qualitative changes in raw roe (control) and salted roe of rainbow trout during refrigerated storage.

2. Materials and Methods

Fish roe preparation

The fish roe of rainbow trout was prepared as a gift by Ghezelala Parvar Company in Mazandaran Province, Iran. The number of 12 brood fish (2.5kg) with rip roe were selected and washed with clean water, and dried. Afterward, they were transported to the laboratory for further analysis. The fish roe was collected by pressing the ventral part of the fish, and the roe was collected in a clean and completely dried container. The roe was soaked in boiled water at 3°C-5°C with salt (1.5%). Then, the fish roe was washed by sieve for 10 to 20 minutes to eliminate waste particles, connective tissue, and broken membrane. Afterward, the dry salt (1.5%) was added to the container and blended for 20 minutes. Finally, the processed roe was filled in a polyethylene can by 40g (Inanli et al., 2010) and kept in a refrigerator to assess its chemical, microbial, organoleptic, and fatty acid parameters during 0, 15, and 30 days.

Chemical analysis

The initial analysis of rainbow trout roe was assessed according to the Association of Official Analytical Chemists (AOAC) (2005). The pH was evaluated using a homogeneous complex of the roe with deionized water (1:10, w:v) via a digital pH meter according to some method (Yang et al., 2019). Total volatile basic nitrogen (TVB-N) was quantified by Pearson's method (Li et al., 2019). Thiobarbituric acid reactive substances (TBA; mg malondialdehyde [MDA] kg-1 sample) were assessed according to some methods (Allou, 2018).

Microbial assay

The total bacterial count (TBC) was performed according to AOAC (2005). Briefly, a ratio of 1 to 9 portions of roe sample and 0.1% peptone water (Difco, 0118-17-0, Difco, Detroit, MI, USA) were mixed via a Stomacher lab blender (Seward type 400, London, UK) for 1 min. From the stock dilution, other serial decimal dilutions were prepared. In the present research, TBC was quantified using plate count agar (PCA), following AOAC (2005), and afterward assessing the colony forming units (log10 CFU g-1) after incubating the plates at 30°C for 48 h. The yeast and mold counts were evaluated according to some methods (Xu et al., 2020).

Fatty acid profile analysis

The lipid was saponified with 0.5 M NaOH in methanol for 15 min at 100°C. The fatty acids were methylated with 14% BF3 (Boron trifluoride) in methanol for 20s at 100°C and then assessed using a gas chromatograph (Shimadzu GC-18A) equipped with a fused silica capillary column, SUPELCOWAX 10 (30m 0.25mm ID). The carrier gas was helium (flow 1mL/min) with a split injection of 40:1. The temperature profiles were as follows: beginning temperature, 175°C; heating rate, 1°C/min; final temperature, 220°C (final time, 20 min); injector temperature, 250°C; and detector temperature, 270°C. The fatty acids were identified by comparison of the retention times with those of standard purified fatty acids (Zhang et al., 2019).

Organoleptic assessment

The rainbow trout roe samples were organoleptically evaluated at certain days of storage. They were rated between 1 and 5 points. Twenty-five panelists rated the samples based on their appearance, color, texture, odor, and flavor as follows: 1=very poor, 2=poor, 3=normal, 4=good, and 5=very good (Szterk and Jesionkowska, 2014).

Statistical analysis

Statistical analyses were performed using SAS (Statistical Analysis System). Variance analysis was conducted to compare the effects of different treatments ($P<0.05$). Duncan's multiple range test was performed to determine the mean differences. The results were presented as Mean±SD.

3. Results

Protein

The results of protein contents of fish roe of rainbow trout are presented in Table 1. The protein content of raw roe was not significantly different from the salted roe of rainbow trout. At the end of the storage, the amount of protein in all treatments decreased, which was statistically significant in raw roe but not salted roe.

Fat

The chemical composition of the fish roe depends on fish species and processing methods. The results of the fat content of rainbow trout roe are presented in Table 1. In this study, after salting, the amount of fat of the raw roe was not significantly different from the salted roe ($P>0.05$). During the cold storage, the amount of fat changed significantly in the raw roe on day 30, but in the salted roe, it did not change much over the refrigerator storage.

pH

The results of the pH of rainbow trout roe are presented in Table 1. The pH of the raw roe was significantly different from that of the salted roe of rainbow trout. At the end of storage, it escalated in all the treatments but was statistically significant in the raw roe and not in the salted one ($P>0.05$).

Moisture

The results of moisture of the roe are seen in Table 1. After the salting, the moisture content of the raw roe reduced at the end, and it was significantly different in all the treatments ($P<0.05$). During the cold storage, the amount of moisture decreased while it was statistically significant in the raw roe and not significant in the salted one.

Ash

The results of ash in rainbow trout roe are presented in Table 1. After salting, the amount of ash in rainbow trout roe increased. The amount of ash did not change in the raw and the salted roe samples during the cold storage.

TVB-N

TVB-N trends in the roe are presented in Table 1. TVB-N content increased in the raw roe from 5.97 to 30.00mg in the 100g sample and the salted roe from 6.05 to 23.18 mg in the 100g of the sample during the cold storage.

TBA

According to Table 1, the changes in the TBA trend showed significant differences, and the trend increased during cold storage. TBA index is widely used in sea products for evaluating lipid oxidation degree, demonstrating the quality of frozen products. The amount of TBA in the raw roe was about 0.73 to 6.45 mg MDA in the 1000g sample, and in the salted roe was about 0.84 to 1.96 mg MDA in the 1000g sample.

Microbial assay

Total count: According to Figure 1A, the total count increased in different treatments during the cold storage, and the differences were statistically significant. The salted roe showed the lowest total count compared to the raw roe.

Mold and yeast

The results of mold and yeast of rainbow trout roe are shown in Figure 1B. The amount of mold and yeast in the raw roe and the salted roe samples increased significantly during the cold storage. The salted roe showed the lowest mold and yeast content compared to the raw roe.

Fatty acid profile analysis

Eicosapentaenoic acid (C20:5n-3) EPA and Docosahexaenoic acid (C22:6n-3) DHA: According to Table 2, the amount of EPA and DHA in the raw roe decreased during the cold storage but in the salted row, it did not show any significant change. According to Table 4, DHA (C22:6n-3) was the most abundant of PUFA in the raw and the salted roes of rainbow trout.

Fatty acid profile analysis (Saturated fatty acids [SFA]): The results of total saturated fatty acids (SFA) of rainbow trout roe are presented in Table 3. As shown in Table 3, after the salting, the amount of fatty acids in raw roe reduced at the end of the salting. During the cold storage, the total SFA dropped in the raw roe, while in the salted roe, it did not change over time.

Monounsaturated fatty acids: The results of total monounsaturated fatty acids (MUFA) of rainbow trout roe are presented in Table 3. After the salting, the amount of MUFA in the raw roe decreased at the end of the salting. During the cold storage, the total MUFA declined in the raw roe but not in the salted roe over time.

Polyunsaturated fatty acids (PUFA)

The results of total polyunsaturated fatty acids (PUFA) of rainbow trout roe are shown in Table 3. As seen, the amount of total PUFA in the raw roe was not significantly different from the salted roe of rainbow trout, but at the end of storage, it was statistically different in the raw roe but not in the salted one.

Eicosapentaenoic Acid (C20:5n3) and Docosahexaenoic acid (C22:6n3)

According to Table 2, the amount of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in the raw roe decreased during the cold storage, but in the salted row, it did not show any significant change. According to Table 4, DHA (C22:6n-3) was the most abundant PUFA in the raw and salted roe samples of rainbow trout.

Organoleptic evaluation

The organoleptic results of rainbow trout roe are shown in Figure 1C-F. Quality of color, texture, taste, and smell in the raw and the salted roes decreased during the cold storage; it significantly changed in the raw roe but not in the salted roe.

The amount of salt influences the fatty acid composition in the rainbow trout salted roe. The results showed that after the salting, fatty acid composition declined in the raw roe, but it did not show any change during the storage. The preparation of the roe using low salt content had a positive effect on increasing shelf life, did not change the flavor and nutritional value of the product, and did not have a negative effect on the consumer's health. A significant amount of unsaturated fatty acids, especially DHA, in the fish roe, indicate that it is a valuable product that can provide the nutritional requirements of humans and create high value-added products.

4. Discussion

Protein

At the end of the storage, the amount of protein in all treatments decreased, which was statistically significant in raw roe but not salted roe. In addition, Bledsoe et al. (2003) reported that protein content in different salmon species was 21% to 27%, somewhat similar to the present results. After the salting, the protein content in the raw roe and salted roe in studies by Inanli et al. (2011) decreased. Their results were not consistent

Table 1. Chemical analysis values in the raw and the salted rainbow trout roes during the cold storagea

Chemical Indices	Sample	Mean±SD		
		Storage Period (Day)		
		0	15	30
Protein (%)	Raw	22.61±0.10^{a}	22.31±0.20^{ab}	21.93±0.10^{c}
	Salted	22.60±0.20^{a}	22.40±0.10^{ab}	22.16±0.32b^{c}
Fat (%)	Raw	15.33±0.12^{ab}	15.13±0.11^{b}	14.70±0.17^{c}
	Salted	15.44±0.15^{a}	15.33±0.15^{ab}	15.14±0.14^{b}
Moisture (%)	Raw	59.51±0.11^{a}	59.31±0.12^{ab}	59.20±0.10^{b}
	Salted	58.13±0.20^{c}	58.06±0.05^{c}	57.98±0.20^{c}
Ash (%)	Raw	2.07±0.06^{b}	2.06±0.05^{b}	2.04±0.04^{b}
	Salted	4.55±0.05^{a}	4.46±0.06^{a}	4.55±0.05^{a}
PH	Raw	6.47±0.21^{c}	6.65±0.12^{bc}	7.30±0.10^{a}
	Salted	6.15±0.04^{d}	6.33±0.05^{cd}	6.49±0.13^{c}
TVB-Nb	Raw	5.97±0.11^{e}	14.05±0.10^{c}	30.00±.20^{a}
	Salted	6.05±0.17^{e}	10.65±0.38^{b}	23.18±0.31^{b}
TBAc	Raw	0.73±0.09^{d}	1.80±0.05^{b}	6.45±0.75^{a}
	Salted	0.84±0.04^{d}	1.16±0.05^{c}	1. 96±0.20^{b}

Values in the same row and column with different lowercase letters are statistically significant (P<0.05).

* Raw roe (salt-free) and salted roe (containing 2.5% salt). ** Total volatile basic nitrogen (TVB-N; mg 100 g-1 sample). *** Thiobarbituric acid (TBA; mg malondialdehyde [MDA] kg-1 sample).

with the results of the present study, while during the cold storage, the protein did not show any significant change. The discrepancies in the present study and the above reports may be due to the preparation, salt amount, and processing method.

Fat

In this study, after salting, the amount of fat in the raw roe was not significantly different from the salted roe. During the cold storage, the amount of fat significantly changed in the raw roe at the end of storage, but in the salted roe, it did not change during the refrigerator storage. Bledsoe et al. (2003) reported that fat content in the salmon family was 8% to 25%, similar to the present study. The present results were consistent with Inanli et al. (2010) findings. According to the present survey, the utilization of low salt in rainbow trout roe processing prevented diminishing fat and fortifying it during cold storage. The latter is because adding low salt into the roe blocks enzymatic activities responsible for hydrolyzing fat (Yanar et al., 2006). The difference between the present study and the above reports may be due to the preparation, salt amount, processing method, time and maintenance condition, and kind of species.

pH

At the end of storage, pH increased in all treatments but was statistically significant in the raw roe and not in the salted one. The instant decrease in pH content after adding salt was due to the increasing ionic strength of the intracellular solution. However, its increase at the end of the cold storage results from producing alkali compounds, such as ammonia, trimethylamine, and volatile gases by spoilage bacteria (Goulas and Kontominas, 2005).

Table 2. Fatty acid composition (% of total fatty acids) of total lipid of the raw and salted roe of rainbow trout during the cold storage

Variables	Mean±SD					
	Salted Roe			Raw Roe		
	Storage Periods (day)			Storage Periods (day)		
Fatty acid	0	15	30	0	15	30
C14:0	0.81±0.01	0.81±0.01	0.79±0.01	0.91±0.02	0.90±0.03	0.75±0.04
C16:0	14.3±0.12	14.20±0.10	14.23±0.65	15.23±0.25	14.90±0.34	13.33±0.3
C17:0	0.52±0.02	0.52±0.02	0.49±0.02	0.51±0.02	0.51±0.02	0.35±0.03
C18:0	4.70±0.30	4.93±0.10	4.60±0.37	5.11±0.12	4.66±0.35	4.10±0.26
C24:0	0.32±0.02	0.29±0.01	0.28±0.02	0.31±0.01	0.29±0.01	0.22±0.03
C16:1	2.92±0.13	2.86±0.05	2.85±0.18	3.53±0.17	3.76±0.06	2.54±0.15
C17:1	0.22±0.02	0.20±0.02	0.19±0.01	0.25±0.02	0.23±0.01	0.19±0.01
C18:1	24.33±0.2	24.4±0.58	24.43±0.3	25.33±0.15	25.36±0.5	23.73±0.2
C20:1n9	1.78±0.10	1.73±0.05	1.76±0.15	2.06±0.15	1.96±0.11	1.50±0.10
C24:1n9	1.07±0.03	1.07±0.07	1.11±0.87	1.16±0.13	1.14±0.08	0.96±0.03
C18:2n6	7.70±0.10	7.43±0.11	7.49±0.09	7.43±0.2	7.27±0.16	6.46±0.35
C18:3n6	0.27±0.04	0.25±0.02	0.24±0.03	0.31±0.04	0.28±0.02	0.18±0.02
C18:3n3	0.39±0.01	0.38±0.03	0.37±0.03	0.48±0.02	0.44±0.05	0.26±0.10
C20:2n6	1.46±0.07	1.48±0.07	1.43±0.05	1.43±0.07	1.40±0.01	1.28±0.03
C20:3n6	1.42±0.09	1.36±0.10	1.38±0.02	1.45±0.11	1.43±0.07	1.09±0.09
C20:3n3	3.96±0.20	3.80±0.20	3.66±0.07	4.25±0.22	4.30±0.20	2.90±0.05
C20:5n3	3.01±0.10	2.95±0.13	2.90±0.10	3.05±0.05	2.90±0.10	2.32±0.100
C22:6n3	22.5±0.45	22.55±0.47	22.56±0.2	23.1±0.30	22.9±0.10	21.02±0.02

Raw roe (salt-free) and salted roe (containing 2.5% salt)

The results are consistent with Inanli et al. (2011) findings. The difference between the present study and the above studies may be due to primary preparation, salt amount, processing method, time and maintenance condition, and kind of species. A jeotgal-like product was processed from Chinook salmon (Oncorhynchus tshawytscha) roe. Physicochemical, biochemical, and microbiological compositions were studied during 30 days of fermentation. Fermentation decreased water activity (aw) and pH value (Bunga et al., 2023).

Moisture

During the cold storage, the amount of moisture decreased, which was statistically significant in the raw roe and not in the salted one. In addition, Bledsoe et al. (2003) reported the moisture in different salmon species from 50% to 70%, somewhat similar to the present results. Protein denaturation due to adding salt and osmotic dehydration was the reason for the moisture drop in the roe across the cold storage (Barat et al., 2006). The present finding is similar to Inanli et al. (2010 and 2011) findings. The difference between the present study and the other reports may be due to the reasons mentioned in the previous sections.

Table 3. Fatty acid groups in rainbow trout roe during the cold storagea

Variables	Sample	Storage Periods (days)		
		Mean±SD		
		0	15	30
Total SFA	Raw	22.08±0.29^{a}	21.28±0.38^{b}	18.77±0.15^{d}
	Salted	20.61±0.41^{c}	20.75±0.12^{c}	20.39±0.17^{c}
Total UFA	Raw	73.83±0.8^{a}	73.41±0.23^{a}	64.45±0.75^{c}
	Salted	71.06±0.58^{b}	70.55±0.84^{b}	70.42±0.31^{b}
Total MUFA	Raw	33.35±0.54^{a}	32.47±0.63^{a}	28.92±0.44^{c}
	Salted	30.33±0.33^{b}	30.01±0.15^{b}	30.35±0.20^{b}
Total PUFA	Raw	41.48±0.36^{a}	40.94±0.39^{ab}	35.52±0.30^{c}
	Salted	40.72±0.73^{ab}	40.54±0.68^{ab}	40.06±0.25^{b}
Total n-3	Raw	30.85±0.43^{a}	30.54±0.17^{ab}	26.5±0.13^{d}
	Salted	29.86±0.74^{c}	29.68±0.53^{c}	29.51±0.15^{c}
Total n-6	Raw	10.63±0.42^{a}	10.40±0.22^{a}	9.01±0.32^{b}
	Salted	10.86±0.05^{a}	10.52±0.15^{a}	10.52±0.12^{a}
n-3/n-6	Raw	3.48±0.36^{a}	3.86±0.05^{a}	2.86±0.74^{c}
	Salted	2.72±0.8^{abc}	2.48±0.36^{a}	2.63±0.42^{a}

a SFA: saturated fatty acids; UFA: unsaturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids

humidity degree and pH. The results of this research are in accordance with Inanli et al.'s (2011) findings.

Mold and yeast

The salted roe showed the lowest mold and yeast content compared to the raw roe. Safari and Yosefian (2006) reported that microbial load increment in the salted roe depends on processing condition, roe quality, and preservatives. The decrease in the yeast and mold growth was obvious in the salted roe. The increase in the yeast and mold amounts in fish roe brings about changing its flavor properties and ultimately decreasing its commercial quality. Identifying the limiting factors on yeast and mold growth are important because they can reduce the contamination of the salty roe using the implementation of hygiene in different stages of roe processing with concomitant care due to the use of product ingredients such as salt density, pH degree and finally the employment of preservatives (Inanli et al., 2011). The results of the present study are consistent with Inanli et al. (2011) study results.

Fatty acid profile analysis

Saturated fatty acids

During the cold storage, the amount of total SFA dropped in the raw roe, while in the salted roe, it did not show a difference over time. The difference in the present study and other reports may be due to primary preparation, salt amount, and processing method. Razavi Shirazi (2006) expressed that high salt content in fish roe caused diminishing fatty acids groups and, conversely, increased saturated fatty acids. According to Table 2, the predominant fatty acids of SFA were C16:0 in the raw and salted roes of rainbow trout. According to Table 4, the outcome of the present study is consistent with Shirai et al. (2006) findings. The difference in the amount of total SFA and C16:0 in the present study and other reports may be due to primary preparation, salt amount, product method and time and maintenance condition, kind of species, differences in diet, and biological species.

Table 4. Fatty acid composition of rainbow trout roe compared with other fish and fish products a & b

Variales	Pike RR	Kutum SR	Kutum RR	Golden Mullet SR	Golden Mullet RR	Rainbow Trout SR	SQ6	SB6	Kazu-noko	Tobiko	Tarako	Ikura
C16:0	11.20	30.02	18.33	9.45	10.56	14.25	21.04	20.62	26.3	25.50	21.80	11.60
ΣSFA	14.70	40.75	25.96	24.92	17.78	20.61	25.6	25.72	32	39.60	26.90	21.60
C16:1	11.30	7.80	7.99	25.80	30.10	2.92	4.54	4.57	4.80	1.90	3.30	5.60
C18:1	16.50	14.95	30.57	15.18	8.58	24.33	30.52	28.54	12.10	8.90	9.30	17.90
ΣMUFA	28.70	27.57	42.80	43.29	42.02	30.33	41.02	39.42	25	14.40	25	33.10
C20:5 w3	1.30	5.27	4.67	1.79	9.23	3	5.66	5.79	15	7	18.80	13.60
C22:6 w3	0.30	11.69	10.15	6.70	12	22.50	16.72	16.48	22.60	27.90	22.20	17.40
ΣPUFA	8.60	18.15	16.41	13.32	23.17	40.72	33.12	34.86	42.70	45.50	47.50	44.60

a: RR raw roe and SR refers to salted roe. b: Ikura, salted salmon roe; Tarako, salted pollock roe; Tobiko, salted flying fish roe; Kazunoko, salted herring roe.

SQ6, sturgeons (A/transmontanus Egg collection was carried out liver squid oil diet after 6 months; SB6, sturgeons (A/transmontanus Egg collection was carried out blend of 50% soybean oil and 50% fish oil diet after 6 months. SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

Ash

The amount of ash did not change in the raw and the salted roes during the cold storage. After salting, the mineral content of the salted roe increased dramatically (Inanli et al., 2010). The present finding is similar to Inanli et al. (2010 and 2011) findings. The discrepancies in findings may result from the different salt amounts, processing methods, and fish species.

TVB-N

According to Cheng et al. (2014), TVB-N of 25 mg in a 100g sample showed very good quality, 30 mg in a 100g sample is good, 35 mg in a 100g sample is salable, and more than 35 mg in a 100g sample was unacceptable. Accordingly, in the present study, the results of TVB-N demonstrated a significant difference between the raw and salted roe samples (Table 1). As shown in Table 1, the top quality of the raw roe was maintained by day 15, and most interestingly, in the salted roe, it was retained by day 30. TVB-N content would increase during the maintenance of sea products due to their spoilage; its amount depends upon species and changes after catching (Razavi Shirazi, 2006). TVB-N in the salted roe was significantly less than in the raw roe because of restricting bacterial growth and enzymatic activities (Barat et al., 2006). The present finding is similar to Inanli et al. (2010 and 2011) findings. The difference in the present study and the other reports may be due to the preparation, salt amount, processing method, time and maintenance condition, and kind of species.

TBA

TBA index is widely used in sea products for evaluating lipid oxidation degree and demonstrating the quality of frozen products. The amount of TBA in the raw roe was about 0.73 to 6.45 mg MDA in a 1000g sample, and in the salted roe was about 0.84 to 1.96 mg MDA in a 1000g sample. According to Inanli et al. (2010), the amount of TBA less than 3 mg MDA in roe shows very good quality, 3 to 5 mg MDA indicates good quality, and the allowable consumption level is 7 to 8 mg MDA in a 1000g of roe. Based on the TBA values in the raw roe at the end of storage, it exceeded the limit of good material. During secondary phases of fat oxidation, carbon compounds such as aldehyde and ketones appeared. The existence of such compounds in sea products indicates the development of fat oxidation and changes in fish flavor, such as taste and smell. The color of oxidized products is brownish, and their taste is bitter (Goulas and Kontominas, 2005).

On the one hand, low salting processing resulted in fats stability of rainbow trout roe against oxidation, and on the other hand, it diminished TBA content in the roe. Based on the TBA values in the raw roe at the end of the storage, it exceeded the limit of good material. The differences between the other authors and the present study are due to primary preparation, salt amount, product method, time and maintenance condition, and kind of species.

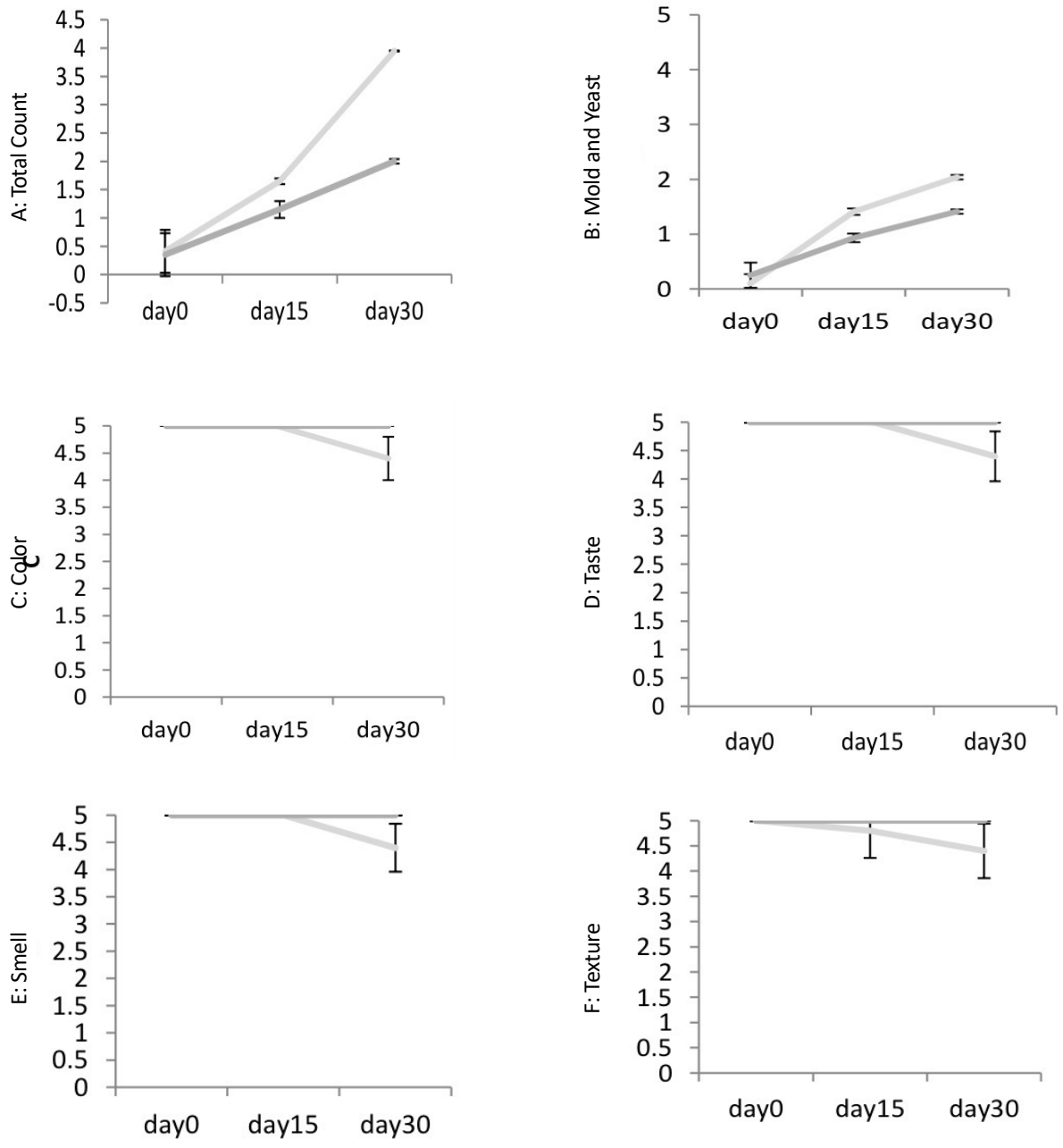

Figure 1. Total count increased in different treatments during the cold storage

A and B: Microbiological values of the raw and the salted roes of rainbow trout during the cold storage; C, D, E, and F: Sensorial values of raw and salted roes of rainbow trout during the cold storage.

The pale gray line indicates raw fish roes, and the dark gray line indicates salted fish roes.

Microbial assay

Total count

The initial microbial load of raw roe and storage temperature plays an important role in determining the shelf life of roe products (Chen et al., 2019). The initial microbial load of freshwater fish may change regarding water and temperature conditions. Fish roe is completely sterile while depositing into the ventral zone of fish. So, secondary pollution can be produced during the processing of roe. In the present study, the low primary microbial load of the roe indicated its high quality. The salty treatment caused decrease microorganism growth and increased shelf life of the roe due to inhibitory specifications of salt by decreasing

Monounsaturated fatty acids (MUFA)

During the cold storage, the total MUFA declined in the raw roe but not in the salted roe over time. The results of Shirai et al. (2006) were in line with the present study. According to Table 2, the dominant fatty acids of MUFA were C18:1 in the raw and salted roes of rainbow trout. According to Table 4, the result of the current study is consistent with Shirai et al. (2006) results. However, in the study of Sengor et al. (2003), the predominant fatty acid of MUFA was C16:1. The difference for total MUFA, C18:1, and C16:1 in the present study and other reports may be due to the reasons mentioned above in the previous sections.

Polyunsaturated fatty acids (PUFA)

Table 4 illustrated that the amount of total PUFA between the raw and the salted roe of rainbow trout was not significantly different, but at the end of storage in the raw roe, it was statistically different in the raw roe and not in the salted one. The outcome of the present study is consistent with Sengor et al. (2003) results.

Eicosapentaenoic acid (C20:5n3) and docosahexaenoic acid (C22:6n3)

The results of the present study agree with Shirai et al. (2006) results. According to Table 4, PUFA consists of the maximum amount of fatty acid compositions among all the fatty acid groups in rainbow trout roe. The result of the present study is consistent with Shirai et al. (2006) results, but it was not consistent with the Sengor et al. (2003) results. The difference in the present study and the above reports may be due to primary preparation, salt amount, product method, time and maintenance condition, and differences in diet and biological species.

Organoleptic evaluation

Oxidative deterioration and a high amount of TBA in raw roe resulted in low organoleptic scores. The color and smell of roe indicate its quality from a sanitary and health perspective. In addition, total acceptance of roe is affected by its color. Therefore, characteristics relating to color play an important role in evaluating product quality (Spence, 2019). The color of fish roe is different according to fish species, diet, and age (Bledsoe et al., 2003). Coloring agents in fish roe are carotenoids pigments dissolved in fats such as lutein, astaxanthin, cantaxanthin and zeaxanthin. These compounds are very sensitive to processing conditions, such as heat and oxidation. The present finding is similar to Inanli et al. (2010 and 2011) results.

5. Conclusion

The amount of salt influences the fatty acid composition in the production of rainbow trout salted roe. The results showed that after the salting, fatty acid composition declined in the raw roe, but it did not show any change during the storage. The preparation of the roe using low salt content had a positive effect on increasing shelf life, did not change the taste and nutritional value of the product, and did not have a negative effect on the consumer's health. A significant amount of unsaturated fatty acids, especially DHA, in the fish roe, indicates that it is a valuable product that can provide the nutritional necessitates of humans and creates high value-added products.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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مقاله پژوهشی

اثر نمک سود کردن و نگهداری در یخچال بر کیفیت تخم ماهی قزل آلای رنگین کمان (Oncorhynchus mykiss) : تغییرات شیمیایی و میکروبی

حجت میرصادقی [۱]، *علیرضا عالیشاهی [۱]، بهاره شعبانپور [۱]، رضا صفری [۲]، مریم دانشور [۱]

۱. گروه فرآوری غذاهای دریایی، دانشکده شیلات و علوم محیطی، دانشگاه علوم کشاورزی و منابع طبیعی گرگان، گرگان، ایران.
۲. پژوهشکده اکولوژی دریای خزر، ساری، ایران.

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چکیده

زمینه مطالعه: در سال‌های اخیر تخم قزل آلا یکی از محصولات با ارزش و پرطرفدار در بین مصرف‌کنندگان بوده است.

هدف: در این مطالعه، وضعیت کیفیت و بهداشت این محصول در طی پروسه نمک سود کردن و نگهداری در یخچال مورد مطالعه قرار گرفت.

روش کار: مقایسه اثرات نمک سود کردن تخم قزل آلا بر زمان ماندگاری، نیتروژن فرار و تغییرات پروفایل اسید چرب در طی زمان نگهداری در یخچال. بعد از شستشوی اولیه تخم ماهی‌ها به ۲ گروه تقسیم شدند: تخم خام (گروه شاهد) و تخم نمک سود (۱/۵ ٪ نمک خالص). به مدت ۰، ۱۵ و ۳۰ روز در یخچال نگهداری شده و از لحاظ آنالیز شیمیایی، میکروبی، حسی و اسیدهای چرب بررسی شدند.

نتایج: نتایج نشان داد که مقدار نمک بر روی پروفایل اسید چرب در طی فرآوری تخم نمک سود ماهی تاثیر گذار است اما تفاوت معنی‌داری بین ۲ تیمار از لحاظ میزان اسید چرب مشاهده نشد. شمارش کل باکتری در بین تیمارهای مختلف طی نگهداری در یخچال به صورت معنی‌داری افزایش یافت. تخم ماهی نمک سود شده در مقایسه با تخم خام کمترین مقدار باکتریایی کل را داشت. بازهای نیتروژن در تخم ماهی خام از ۳۰/۰۰-۵/۹۷ میلی‌گرم در ۱۰۰ گرم و در تخم ماهی نمک سود شده از ۲۳/۱۸-۶/۰۵ افزایش یافت.

نتیجه‌گیری نهایی: نمک سود کردن (۱/۵ ٪) تخم ماهی یک روش بسیار مناسب جهت افزایش مدت ماندگاری آن به همراه کیفیت بالا می‌باشد. پس از نمک سود کردن مقدار اسید چرب کاهش یافت اما در طی نگهداری تغییر چندانی مشاهده نشد.

کلیدواژه‌ها: پروفایل اسید چرب، تغییرات میکروبی، تغییرات کیفی، تخم قزل آلای رنگین کمان، نیتروژن فرار.

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* **نویسنده مسئول:**
علیرضا عالیشاهی
نشانی: گرگان، دانشگاه علوم کشاورزی و منابع طبیعی گرگان، دانشکده شیلات و علوم محیطی، گروه فرآوری غذاهای دریایی.
تلفن: ۱۴۴۲۷۰۴۰ (۱۷) ۹۸+
رایانامه: *seafood1144@yahoo.com*