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Research Article

Fatty acid composition and qualitative changes of salted rainbow trout (*Oncorhynchus mykiss*) roe during refrigerator storage

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ABSTRACT

Fish roe is an important source of polyunsaturated fatty acids, protein and essential amino acids, minerals and vitamins. The amount of salt in salted fish roe brought about increasing its shelf life but it could also cause qualitative changes. After initial washing, the rainbow trout roes divided into two groups: raw roe (control) and salted roe (1.5% pure salts). The results showed that unsaturated fatty acids in the control were between 73.83 and 64.45% but in the salted roe, it was in the range of 71.06 to 70.46%, Qualitative factors in the control group showed significant difference over the time. Conversely, there were no significant differences in the salted roe during the cold storage. Thus, the salting can be a good way to increase shelf life with maintaining high quality in the roe. Practical application: Rainbow trout roe with low salt content showed both sensorial acceptance and shelf life extension. Hence, adding low salt into the roe could be marketed as compared with medium and high salt content of fish roe in market.

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Keywords: Fatty acid profile; Salting; Rainbow trout roe; Storage.

1. Introduction

Fish roe are used all over the world and the most famous of them is caviar (Bledsoe, Bledsoe, & Rasco, 2003). Fish roe is an important source of polyunsaturated fatty acids, protein and essential amino acids, minerals and vitamin. Caviar production mainly consists of a process of salting fish roe. In addition to the salting process, freezing, smoking, canning, and sausage production technologies are also used in caviar production (Al-sayed Mahmoud, Linder, Fanni, & Parmentier, 2008; Inanli, Oksuztepe, Ozpolat, & Coban, 2011; Olgunoglu & Olgunoglu, 2011).

Fish roe contains high amount of eicosapentaenoic acid (C20:5n-3), docosahexaenoic acid (C22:6n-3) and high percentage of phosphatidylcholine that play a pivotal role in the prevention and treatment of cardiovascular diseases and the improvement of learning ability and the lowering of plasma lipids (Shirai, Higushi, & Suzuki, 2006). Due to high price and uncomfortable accessibility to sturgeon caviar, taking fish roes from other species such as cod, mackerel, carp, grey mullet and especially salmon seems good alternative. Today, rainbow trout is one of the most important cultured commercial fish (Adli & Baghaei, 2013). Hence, the processing of its roes in order to produce fish caviar is of high importance. People use fish roe-based products because of its desirable flavor and taste and its nutritional value. Value added products from fish roes are valuable and consist of high-consumed products all over the world.

There are different ways for production of fish roes depending on fish's species that have considerable effect on its quality and marketing. To our knowledge, fish roes are not processed during production with novel or especial techniques and to the end; they are prone to chemical and microbial deterioration. Further, excessive salt upsets the taste of the product as well as causing digestive difficulty. Therefore, the salt level should be determined precisely.

Absorption and distribution of salt depends on many factors such as the roe properties (size, thickness), chemical composition, and method of salt grinding, salt

Table 1
Chemical analysis values in the raw and the salted rainbow trout roes during the cold storage[a]

Chemical indices	Sample	Storage period (day)		
		0	15	30
Protein (%)	Raw	22.6±0.10^{a}	22.31±0.20^{ab}	21.93±0.10^{c}
	Salted	22.6±0.20^{a}	22.40±0.10^{ab}	22.16±0.32^{bc}
Fat (%)	Raw	15.3±0.12^{qb}	15.13±0.11^{b}	14.7±0.17^{c}
	Salted	15.4±0.15^{a}	15.3±0.15^{ab}	15.1±0.14^{b}
Moisture (%)	Raw	59.5±0.11^{a}	59.3±0.12^{ab}	59.2±0.10^{b}
	Salted	58.1±0.20^{c}	58.1±0.05^{c}	58.0±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-N[b]	Raw	5.97±0.11^{e}	14.1±0.10^{c}	30.00±0.20^{a}
	Salted	6.05±0.17^{e}	10.7±0.38^{d}	23.18±0.31^{b}
TBA[c]	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}

[a] Raw roe (salt free) and salted roe (containing 2.5% salt). Values in the same row and column with different lowercase letters are statistically different (p<0/05)
[b] Total volatile basic nitrogen (TVB-N; mg100 g^{-1} sample)
[C] Thiobarbituric acid (TBA; mg malondialdehyde (MD) kg^{-1} sample)

concentration, temperature and duration of salting (Shirai et al., 2006; Inanli & Coban, 2010). Moreover, the composition of essential fatty acids in raw roe is more like the salted roe with a little salt (Basby, Jappesen, & Huss, 1998).

Hence, the objective of the present survey was 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

2.1. Fish roe preparation

The fish roe of rainbow trout was obtained from Ghezelala Parvar Company in Mazandaran province, Iran. Female fish with ripen roe selected and washed with clean water and dried. Afterward, they were transported to laboratory for further analysis. The fish roes were collected by pressing the ventral part of the fish and the roes were collected in clean and completely dried container. The roes were soaked in boiled water with 3 to 5 °C with salt (1.5%). Then, fish roes were washed by sieve for 10 to 20 minutes to eliminate waste particle, connective tissue and broken membrane. Afterwards, dry salt (2.5%) was added into the container and then blended for 20 minutes. Finally, the processed roe was filled in polyethylene bottles weighed to 40 g (Inanli & Coban, 2010) and was stored in refrigerator for measuring the chemical, microbial, sensorial and fatty acid parameters during 0, 15 and 30 day.

2.2. Chemical analysis

The proximate analysis of the samples was done according to the procedures of the Association of Official Analytical Chemists (AOAC, 2005). Moisture, ash, protein, and lipid contents were assayed by methods 934.01, 920.153, 954.01, and 991.36, respectively. pH was determined on homogeneous mixtures of roe sample and distilled water (1:10, w:v) using a digital pH-Meter accordance to Sallam and Samejima (2004). Total volatile basic nitrogen (TVB-N), was measured by Pearson's method (Egan, Krik, & Sawyer, 1997). Thiobarbituric acid reactive substances (TBA; mg malondialdehyde (MD) kg^{-1} sample) was measured according to Inanli and Coban (2010).

2.3. Fatty acid profile analysis

Lipids of rainbow trout roes were extracted according to the method of Bligh and Dyer (1959). Grated samples (20 g) were homogenized with a mixture of chloroform/methanol (50 mL, 2:1, v/v) at 11,000 rpm using an IKA homogenizer (Model T25, IKA-LAB, Milan, Italy) for 1 min. After addition of 25 mL of chloroform, the mixtures were homogenized for 30 s at the same speed and filtered through a Whatman No. 4 filter. The filtrate was transferred into a separating funnel. The chloroform phase was drained off into an Erlenmeyer flask and was evaporated at 30 °C using a rotary evaporator (Buchi, Milan, Italy). The residual solvent was removed by flushing with nitrogen. The lipid was transferred to an amber vial and the sample was stored under nitrogen

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 [a]

	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

[a] Raw roe (salt free) and salted roe (containing 2.5% salt)

atmosphere at 20 °C until analysis. The fatty acids profile was determined by gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS) analyses, after their derivatization to methyl esters following the procedure adopted by Kalogeropoulos, Nomikos, Chiou, Fragopoulou and Antonopoulou (2008) with some modifications. Fatty acid methyl esters (FAME) were prepared in screw-capped vials containing 20 mg of sample after hot saponification with 2 mL of 0.5 M KOH in methanol, for 15 min at 90 °C, followed by methylation with 1.5 mL of BF_3/MeOH for 5 min at 90 °C. A saturated sodium chloride solution (5 mL) was added, and after 10 min, FAMEs were extracted by n-hexane (2 mL). After vortexing and centrifuging at 800 g for 10 min, aliquots (1 mL) of the n-hexane extracts were transferred to GC vials and injected into the GC instrument. Methyl eicosanoate was used as an external standard. FAMEs were identified using a Hewlett-Packard 6890 gas chromatograph equipped with an HP-5 MS capillary column (5% phenyl/95% methyl siloxane, that was 30 m in length, 0.25 mm in internal diameter, and had a 250 mm coating thickness) and interfaced with a Hewlett Packard 5973 Mass Selective dector (EI, 70 eV). Helium was used as a carrier gas. The injector and detector temperatures were set at 250 and 280 °C, 154 respectively. The oven temperature program was as follows: initial temperature 60 °C and increase to 280 at 14 °C min 1, where it was held for 35 min. Identification of peaks corresponding to FAMEs was accomplished by means of a standard mixture of FAMEs purchased from Sigma (Milan, Italy).

2.4. Microbial assay

Total bacterial count was performed according to AOAC (2005). Briefly, a ratio of 1 to 9 portion of roe sample and 0.1% peptone water (Difco, 0118- 17-0, Difco, Detroit, MI, USA) homogenized using a Stomacher Lab-Blender (Seward type 400, London, UK) for 1 min. From this dilution, other serial decimal dilutions were prepared. In this study, TVC were determined using plate count agar (PCA), according to AOAC, (2005) of counting the colony forming units (log10 CFU g^{-1}) after incubating the plates at 30 °C for 48 h. The yeast and mold population were assessed according to APHA (1976).

2.5. Sensorial assessment

The rainbow trout roe samples were Sensory evaluation at certain days of storage. They were rated between 1 and 5 points. The samples have been characterized by 5 panelists in appearance, color, texture, odor and flavor. 1= Very poor, 2= Poor, 3= Normal, 4= Good, 5= very good (Kurtcan & Gonul, 1987).

2.6. Statistical analysis

All experiments carried out in triplicate and the results expressed as mean±S.D. Analysis of variance performed using SPSS statistical package program (SPSS 16.0 for windows, SPSS Inc., Chicago, IL). Significance was performed using factorial, employing Duncan's multiple range tests at significance level ($p<0.05$).

Table 3
Fatty acid groups in rainbow trout roe during the cold storage[a]

		Storage periods (days)		
	Sample	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	0.36[a]±41.48	10.86±0.05[a]	29.86±0.74[c]
	Salted	40.72±0.8[abc]	41.48±0.36[a]	10.63±0.42[a]

[a] SFA, saturated fatty acids; UFA, unsaturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids

Table 4
Fatty acid composition of rainbow trout roe as compared with other fish and products derived from them[a&b]

	Pike RR	Kutum SR	Kutum RR	Golden mullet SR	Golden mullet RR	Rainbow Trout SR	Sturgeons SQ6	Sturgeons SB6	Kazunoko	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
C20:5n3	1.30	5.27	4.67	1.79	9.23	3	5.66	5.79	15	7	18.80	13.60
C22:6n3	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 refer to raw roe and SR refer to salted roe
[b] Ikura, salted salmon roe; Tarako, salted pollock roe; Tobiko, salted flying fish roe; Kazunoko, salted herring roe/ sturgeons (A/transmontanus Egg collection was carried out after 6 months (SB6, SQ6) liver squid oil (SQ diet) and a blend of 50% soybean oil and 50% fish oil (SB diet); SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids

3. Results and Discussion

3.1. Chemical analysis

The results of protein contents of fish roe of rainbow trout showed in Table 1. As shown in Table 1, the protein content between raw roe and salted roe of rainbow trout were not significant difference. At the end of the storage, the amount of protein in all treatments decreased that it was statistically different in raw roe but not in salted roe. In addition, Bledsoe et al. (2003) declared protein content in different salmon species was 21 to 27 %, somewhat similar to the present results. After the salting, the protein content between raw roe and salted roe in studies of Sengor, Cihaner, Erkan, ozden, and Varlık (2000), Inanli and Coban (2010), and Inanli et al. (2011) decreased that their results were not consistent with the results of the present study while during the cold storage did not show any significant difference. The discrepancies in the present study and the aforementioned reports may be due to primary preparing, salt amount and processing method. The chemical composition of the fish roe depends on fish species and processing method. The results of lipid contents of rainbow trout roe showed in Table 1. In this study, after salting, the amount of lipid between the raw roe and the salted roe was not significant difference. Within the cold storage, the amount of lipid changed statistically significant in the raw roe at the end of storage but in salted roe, it did not change over the refrigerator storage. Bledsoe *et al.* (2003) illustrated that lipid content in salmon family was 8 to 25%, similar to present study. The present outcomes were not consistent with Sengor et al. (2000), and Gessner, Wirth, Kirschbaum, and Patriche (2010) while the ones were in accordance to Inalli and Coban (2010), and Ozpolat and Patir (2010). According to the present survey, the utilization of low salt in rainbow trout roe processing prevented from diminishing lipid and fortifying it during the cold storage. The reason for the latter is that adding low salt into the roe, blocks enzymatic activities that are responsible for hydrolyzing lipid. Further, the low salt content not only does not change the amount of carbon across fatty acid chain in the duration of oxidation but also replace saturated fatty acids with unsaturated fatty acids without any change in the lipid content (Yasemen, Celik, & Akamca, 2005). The difference in the present study and the above reports may be due to primary preparing, salt amount, processing method, and time and maintenance condition and kind of species. The results of pH of rainbow trout roe showed in Table 1. As depicted in Table 1, pH between the raw roe and salted roe of rainbow trout was significant difference. At the end of storage, it escalated in all the treatments but statistically different in the raw roe and not different in the salted one. The instant decrease in pH content after adding salt was on the account of increasing ionic strength of intracellular solution. Conversely, its increase at the end of the cold storage, derived from producing alkali compounds such as ammonia, trimethylamine and volatile gases by spoilage bacteria (Goulas & Kontominas, 2005). The outcomes are in consistent with Inanli and Coban (2010), Ozpolat and Patir (2010), and Inanli et al. (2011). The difference in the present study and the aforementioned authors may be due to primary preparing, salt amount, processing method, and time and maintenance condition and kind of species. The results of moisture of the roe showed in Table 1. After the salting, the moisture content of the raw roe reduced at the end of the salting and it was significant different in all the treatments. 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. In addition, Bledsoe et al. (2003) declared moisture in different salmon species, 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, Gallart, Anderes, Akse, Carlehog, et al., 2003; Jittinandana, Kenney, Slider, & Kiser, 2002). The present finding is the similar to Sengor et al. (2000), Gessner et al. (2010), Inanli and Coban (2010), Ozpolat and Patir (2010), and Inanli et al. (2011). The difference in the present study and the other reports may be due to the proofs mentioned in the previous sections. The results of ash in rainbow trout roe showed in Table 1. As shown 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 roes within the cold storage. After salting, the mineral content of the salted roe increased dramatically (Inanli & Coban, 2010). The present finding is similar to Sengor et al. (2000), Gessner et al. (2010), Inanli and Coban (2010), Ozpolat and Patir (2010), and Inanli et al. (2011). The discrepancies of findings derive from the different salt amount, processing method and fish species. TVB-N trends in the roe illustrated in Table 1. TVB-N content increased in the raw roe from 5.97 to 30.00 mg into 100 g sample and in the salted roe from 6.05 to 23.18 mg into 100 g of sample during the cold storage. According to Varlik, Ugur, Gokoglu, and Gun (1993) TVB-N to 25 mg into 100 g sample showed very good quality, 30mg into 100g sample is good, 35 mg into 100 g sample is salable and more than 35 mg into 100 g sample was unacceptable. Accordingly, in the present study, the results of TVB-N demonstrated significant difference between the raw and salted roes (Table 1). As shown in Table 1, the top quality of the raw roe maintained by day 15 and most interestingly in the salted roe it retained by day 30. TVB-N content would increase during maintenance of sea products due to their spoilage that its amount depends upon species and changes after catching. TVB-N in the salted roe was significantly less than the raw roe regarding to restricting bacterial growth and enzymatic activities. The present finding is the similar to Periago, Rodrigo, Ros, Rodriguez-Jerez, and Hernandez-Herrero (2003), Safari and Yosefian (2006), Inanli and Cobans (2010), and Inanli et al. (2011). The difference in the present study and the other reports may be due to primary preparing, salt amount, processing method and time maintenance condition and kind of species. According to Table 1, the changes of TBA trends showed significant difference and trend increased during cold storage. TBA index is widely used in seafood products for evaluating lipid oxidation degree, demonstrating the quality of frozen products.

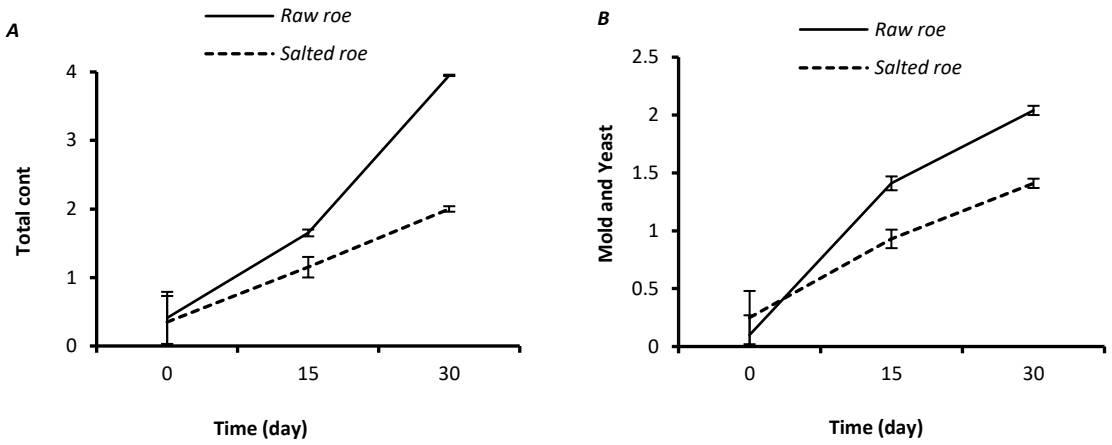

Figure 1
Microbiological values of the raw and the salted roes of rainbow trout during the cold storage.

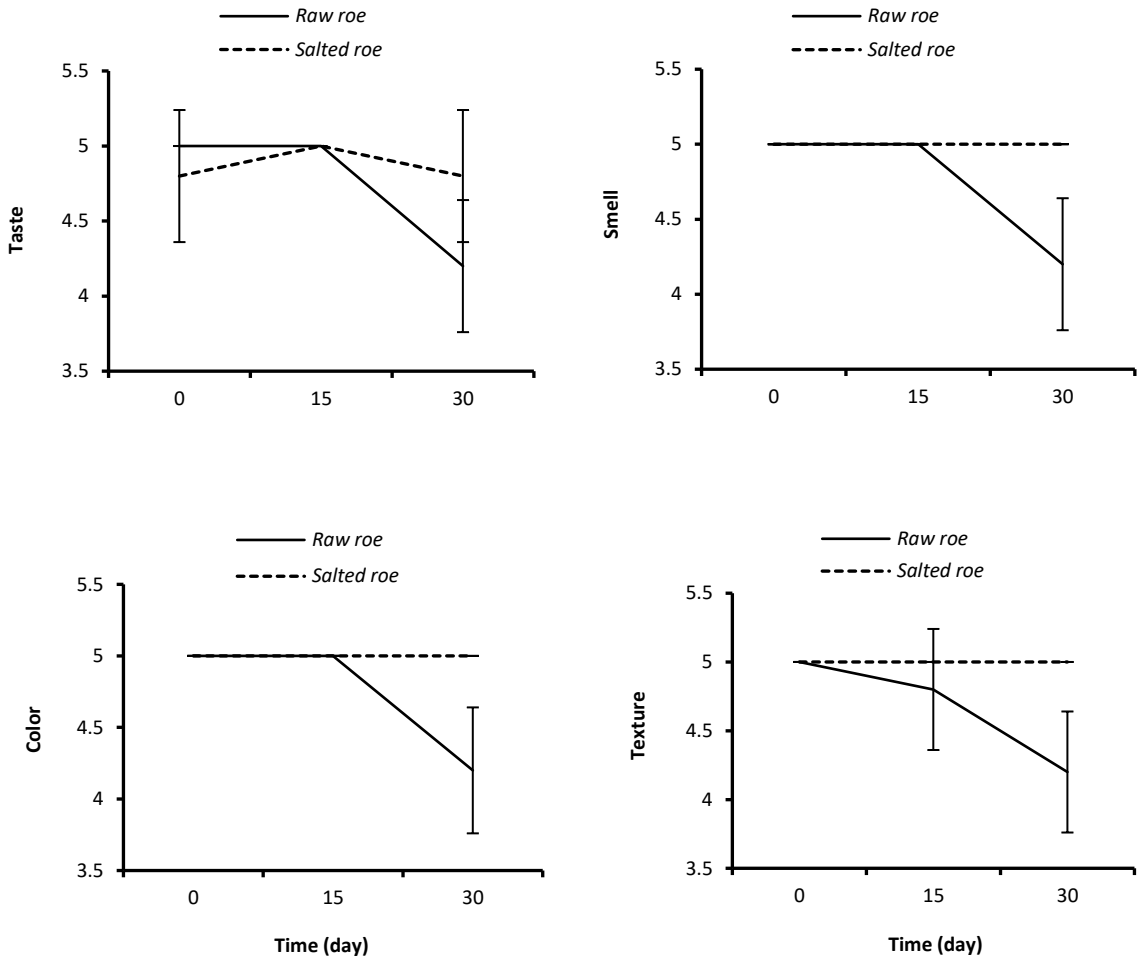

Figure 2
Sensorial values of raw and salted roes of rainbow trout during the cold storage.

The amount of TBA in the raw roe was from 0.73 to 6.45 mg malonaldehyde into 1000 g sample and in the salted roe was from 0.84 to 1.96 mg malonaldehyde into 1000 g sample. According to Inanli and Coban (2010) the amount of TBA less than 3 mg malonaldehyde in roe shows very good quality, 3 to 5 mg malonaldehyde, indicates good quality and the authorized consumption level is 7 to 8 mg malonaldehyde into 1000 g of roe. Based on the TBA in the raw roe values at the end of storage, it exceeded the limit of a good material. During secondary phases of lipid oxidation, carbon compounds such as aldehyde and ketones appeared. Existence of such compounds in seafood products showed development of lipid oxidation and resulted in changes in sensory properties of fish such as taste and smell. The color of oxidized products is brownish and their taste is bitter (Goulas & Kontominas, 2005). One the one hand, low salting processing resulted in lipids stability of rainbow trout roe against oxidation and on the other hand, it diminished TBA content in the roe. Based on the TBA in the raw roe values at the end of the storage, it exceeded the limit of a good material. The differences between the other authors and the present study are due to primary preparing, salt amount, product method, time and maintenance condition and kind of species.

3.2. Total viable count

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

Preliminary microbial load of raw roe and storage temperature play an important role in determining shelf life of roe products. Preliminary microbial load of freshwater fish may change with consideration of water and temperature conditions. Fish roe are completely sterile while depositing into ventral zone of fish. Therefore, secondary pollution can cause during processing of roe. In the present study, low primary microbial load of the roe indicated its high quality. The salty treatment caused decreasing microorganism growth and increasing shelf life of the roe due to inhibitory specifications of salt by decreasing humidity degree and pH (Altug & Bayrak, 2003). The results of this research are in accordance to Safari and Yosefian (2006), and Inanli et al. (2011).

The results of mold and yeast of rainbow trout roe showed in Figure 1B. The amount of mold and yeast in the raw and the salted roes increased statistically in the different time during the cold storage. The salted roe showed the lowest mold and yeast content as compared with the raw roe. Safari and Yosefian (2006) demonstrated that microbial load increment in the salted roe depend on processing condition, roe quality and preservatives. The decrease of yeast and mold growth was more obvious in the salted roe. The augment of yeast and mold amounts in fish roe brings about changing its sensory properties and ultimately decreasing its commercial quality. Identification of limiting factors on yeast and mold growth are of importance which can reduce the contamination of the salty roe using implementation of hygiene in different stages of roe processing with concomitant of care to product ingredients such as salt density, pH and finally the employment of preservatives (Altug & Bayrak, 2003; Inalli et al., 2011). The outcome of the present study is with consistent of Altug and Bayrak (2003), and Inalli et al. (2011).

3.3. Fatty acid profile analysis

The results of total SFA of rainbow trout roe showed in Table 3. As shown in Table 3, after the salting, the amount of raw roe reduced at the end of the salting. During the cold storage, the amount of total SFA dropped in the raw roe, while in the salted roe it did not show difference over the time. Hedayatifard and Nemati (2009) demonstrated that after the salting, total SFA between the raw and the salted roe increased within refrigerator storage. The difference in the present study and other reports may be due to primary preparing, salt amount, and processing method. Razavi- Shirazi (2006) expressed that high salt content in fish roe caused diminishing fatty acids groups and conversely increasing saturated fatty acids. According to Table 2, the predominant fatty acids of SFA were C16:0 in the raw and the salted roes of rainbow trout. According to Table 4, the outcome of the present study is in consistent with Jurkowski (1976), Sengor, Ozden, Erkan, Tuter, and Aksoy (2003), Shirai et al. (2006), and Caprino et al. (2008). The difference in the amount of total SFA and c16:0 in the present study and other reports may be due to primary preparing, salt amount, product method and time and maintenance condition, kind of species, differences in diet and biological species.

The results of total monounsaturated fatty acids (MUFA) of rainbow trout roe showed in Table 3. As depicted in Table 3, after the salting, the amount of MUFA in the raw roe decreased at the end of the salting. During the chilled storage, the amount of total MUFA declined in the raw roe and but not in the salted roe over the time. The results of Jurkowski (1976), Sengor et al. (2003), Shirai et al. (2006), and Caprino et al. (2008) were in accordance to 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 outcome of the present study is with consistent of Jurkowski (1976), Shirai et al. (2006), Caprino et al. (2008), and Hedayatifard and Nemati (2009). Conversely, in the study of Sengor et al. (2003) predominant fatty acids of MUFA were C16:1. The difference for total MUFA, C18:1 and C16:1 in the present study and other reports may be due to the aforementioned proofs cited in the previous sections.

The results of total polyunsaturated fatty acids (PUFA) of rainbow trout roe showed in Table 3. The Table illustrated that the amount of total PUFA between the raw and the salted roe of rainbow trout weren't significant difference but at the end of storage in the raw roe, it was statistically different in the raw roe and but not in the salted one. The outcome of the present study is in consistent with Jurkowski (1976), Sengor et al. (2003), and Hedayatifard and Nemati (2009).

According to Table 2, the amount of eicosapentaenoic acid (EPA; C20:5n-3) and

docosahexaenoic acid (DHA; C22:6n-3) in the raw roe decreased during the cold storage but in the salted row, it did not show any significant change. According to Table 2, DHA was the most abundant of PUFA in the raw and the salted roes of rainbow trout. The outcome of the present study is in accordance to Jurkowski (1976), Sengor et al. (2003), Shirai et al. (2006), Caprino et al. (2008), and Hedayatifard and Nemati (2009).

According to Table 2, PUFA consists of the maximum amount of fatty acid compositions among all the fatty acids groups in rainbow trout roe. The outcome of the present study is in consistent with Shirai et al. (2006) but it was not similar to study of Jurkowski (1976), Sengor et al. (2003), Caprino et al. (2008), and Hedayatifard and Nemati (2009). The difference in the present study and the above reports may be due to primary preparing, salt amount, product method and time and maintenance condition, kind of species, differences in diet and biological species.

3.4. Sensorial evaluation

The sensorial results of rainbow trout roe depicted in Figure 2. Quality of color, texture, taste and smell in the raw and the salted roes decreased during the cold storage that it was significant difference in the raw roe and but not in the salted roe. Oxidative deterioration and high amount of TBA in raw roe resulted in low sensorial scores. The color and smell of roe indicated its quality from sanitary and health perspective. In addition, total acceptance of roe affected by its color. Therefore, characteristics relating to color play an important role in evaluating products quality (Bekhit, Morton, Dawson, & Sedcole, 2009). 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 lipids such as lutein, astaxanthin, cantaxanthin, zeaxanthin, betacorothin. These compounds are very sensitive to processing conditions such as heat and oxidation. The present finding is the similar to Inalli and Coban (2010), and Inalli et al. (2011).

4. Conclusions

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 positive effect on increasing shelf life, did not change any sensorial and nutritional value of the product, and did not have negative effect on the health of the consumer. Significant amount of unsaturated fatty acids, especially DHA in the fish roe, indicates that it is a valuable product that can cover nutritional requirements of human and presents high value-added products.

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