Aquaculture International (2020) 28:187–197
https://doi.org/10.1007/s10499-019-00454-7

Impact of icing with potato, sweet potato, sugar beet, and red beet peel extract on the sensory, chemical, and microbiological changes of rainbow trout (*Oncorhynchus mykiss*) fillets stored at (3 ± 1 °C)

Emre Yavuzer[1] · Fatih Özogul[2] · Yesim Özogul[2]

Received: 1 March 2019 / Accepted: 7 August 2019 / Published online: 19August 2019

Abstract
The potential use of vegetable peels (potato, sweet potato, sugar beet, and red beet) as source of antioxidants was investigated. The sensory, chemical, and microbiological effects of icing with these peel extracts on rainbow trout fillets were monitored during 25 days of storage. Sensory results showed that the shelf life of the control group and fish fillets iced with red beet and sweet potato peel extracts were 21 days, while fish fillets iced with potato and sugar beet peel extracts had longer shelf life (25 days). Treatment of fish with potato and red beet peel extracts resulted in lower TVB-N, PV, and FFA values. The result of the study showed that icing with potato and red beet extracts increased the shelf life of rainbow trout and provided good quality parameters. Waste products as vegetable peels can be used in the food sector as new sources of antioxidants.

Keywords Potato · Sweet potato · Sugar beet · Red beet peel · Trout storage

Practical applications Icing with some plant extracts is an alternative technology for food preservation. This paper shows the using of waste peels of potato, sweet potato, sugar beet, and red beet on the quality properties of rainbow trout. Icing with peel extracts in this study showed positive features on sensory, chemical, and microbiological quality in comparison to the traditional ice. Experimental results indicated that icing with potato peel and red beet peel had many advantages over the other peels tested in this study. Plant peels that have phenolic components can be said to be effective and cheap for the preservation of foods.

✉ Emre Yavuzer
emreyavuzer@gmail.com

[1] Department of Food Engineering, Faculty of Engineering and Architecture, Ahi Evran University, 40100, Kırşehir, Turkey

[2] Department of Seafood Processing Technology, Faculty of Fisheries, Cukurova University, 01330 Adana, Turkey

Introduction

Storage with ice is a very important technique for reducing the rate of the deterioration and growth of the spoilage bacteria resulting in extending the shelf life of fish. However, new methods have to be applied to increase the shelf life of foods such as fish with extremely short duration of deterioration. Slurry ice (Egolf and Kauffeld 2005; Kılınç et al. 2007; Aubourg et al. 2007), ozonised slurry ice (Losada et al. 2004; Campos et al. 2005), and treatment of fish with natural preservative agents like plant extracts (tea polyphenols, aqueous extracts of oregano and rosemary, essential oil of laurel, cumin, and thyme) (Fan et al. 2008; Quitral et al. 2009; Niemal and Benjakul 2011; Attouchi and Sadok 2011) have been studied. On the other hand, some icing methods such as electrolyzed oxidizing ice can be used for reducing histamine-producing bacteria (Phuvasate and Su 2010). Also, effect of the icing with rosemary extract on the oxidative stability and biogenic amine formation in sardine (*Sardinella aurita*) during chilled storage was investigated by Özyurt et al. (2011).

Processing of fruits, vegetables, and oilseeds results in large amounts of waste materials such as peels, seeds, and stones. In fact, vegetables and fruits peels, which represent between 25 and 30% of non-edible products, could be used as a new source of antioxidants. Peels were proven to be rich in polyphenolic compounds carotenoids, flavonoids, anthocyanins, and vitamins, which are well known for their health-promoting activities and also as free radical scavenging agents. Usually, peels are considered as waste and are discarded, which is unfortunate since it is reported that the antioxidant activity is higher in peels than in pulps or tubers (Kalpna et al. 2011; Sonia et al. 2016). Potato (*Solanum tuberosum*), sweet potato (*Helianthus tuberosus*), sugar beet (*Beta vulgaris L.* var. *altissima*.), and red beet (*Beta vulgaris L.* var.) are the most commonly consumed vegetables throughout the world and their peels are not used by any industry. Besides, they are rich in phenolic acids especially chlorogenic, gallic, protocatechuic, and caffeic acids (Akyol et al. 2016; Wruss et al. 2015). For this reason, the aim of this study is to evaluate the effects of icing with potato, sweet potato, sugar beet, and red beet peel extracts on rainbow trout fillets as natural antioxidant over a 25-day storage period.

Materials and methods

Sample and ice preparation

Potato (*Solanum tuberosum*), sweet potato (*Helianthus tuberosus*), sugar beet (*Beta vulgaris L.* var. *altissima*), and red beet (*Beta vulgaris L.* var. *conditiva*) were purchased from a local market (Ahmet Tanrıverdi) in Niğde/Turkey and the producer stated that there were no pesticides in the vegetables. Plants were powdered using a grinder and 200 g of dry samples of plants were extracted with 1 L absolute ethanol for 48 h. After that, the ethanol-plant mixture was filtered using Whatman No. 1 filter paper and 40 g active carbon was added for bleaching. Also, active carbon was removed from the filtrate using Whatman filtration paper. Finally, all ethanol inside of extract was vaporized by using a vacuum evaporator, and the extract was kept at 18 °C in the dark place until application to fish.

Fish samples of rainbow trout (*O. mykiss*) was obtained from an aquaculture farm (Ecemiş Trout Farm) located in Niğde/Turkey. Aquacultured fish were fed with pellet feed (Agromey, Izmir, Turkey) for 6 months with an average water temperature of 8–10 °C. The average weight and length of the samples were 248.976 ± 2.72 g and 27.21 ± 1.32 cm, respectively. Fish were delivered to the laboratory in ice within 2 h of harvesting. Before being placed in polystyrene boxes containing ice, fish were left ungutted and filleted. Fish were divided into 5 groups. The control group was iced with traditional ice using distilled water. For icing other groups, distilled water was treated with 0.1% (w/v) ice with potato, sweet potato, sugar beet, and red beet peel extracts and then frozen. After that, ice treated with plant extract was broken into small pieces to use for storage of fish.

In all treatment groups, fish-to-ice ratio was 1:1 (w/w). All boxes were placed in a refrigerated room (4 °C). From each treatment groups, fish were selected randomly (just by reaching into the box without looking) and all analyses were performed in triplicate on 0, 4, 7, 11, 14, 18, 21, and 25 days of storage.

pH value

The pH values of rainbow trout were determined using a calibrated pH meter (315i/SET, Weilheim, Germany). In distilled water conditions at a ratio 1:10 (w/v), the sample was homogenized using an Ultra-turrax.

Total volatile basic nitrogen

Total volatile basic nitrogen (TVB-N) data of rainbow trout were performed using the method of Antonocopoulus (1973) and emitted as mg of TVB-N per kilogram of muscle.

Thiobarbituric acid reactive substances

For thiobarbituric acid reactive substances (TBARS), values method of Tarladgis et al. (1960) was used. TBARS content was emitted as milligram of malondialdehyde (MDA)/kg fish muscle.

Free fatty acids

Free fatty acids (FFA) analysis, expressed as percent of oleic acid, was determined according to the AOCS method (1997). FFA determination is based on a titration method with a standard alkali (0.1MNaOH) using phenolphthalein as an indicator.

Peroxide value

Peroxide value (PV) was determined according to AOCS (1994) and expressed in milliequivalent of peroxide oxygen per kilogram fat.

Sensory analysis

Raw rainbow trout's sensory analyses were made by Quality Index Method (Bonilla et al. 2007) with some modification. The sensory analyze scheme included some quality parameters such as flesh-texture, flesh-blood, flesh-color, flesh-odor, flesh-bright, flesh-aroma, flesh-gaping, skin-brightness, skin-mucus, skin-scale, eye-iris, and eye-shape with the range of points 0 to 3. For each of these parameters, the scheme had 4 simple descriptors, scoring demerit points from 0 to a maximum of 3, where 0 represented the best quality and higher scores (e.g., 3) indicated poorer quality. Cooked rainbow trout's analyses were made by Paulus et al. (1979). For the analysis of cooked fish, samples were cooked for 2 min at 600 W in the microwave. Analyses were done on each test day in natural day conditions by the staff members of the Çukurova University Fish Processing Department who are familiar with fresh fish and fish products.

Microbiological analysis

Each sample which was analyzed in triplicate samples were taken for total *Enterobacteriaceae*, mesophilic, and psychrophilic bacteria counts. Table 1 shows the bacteria groups and their plates.

Statistical analyses

Analyses were run in triplicate and results were reported as mean values ± standard deviation (S.D). Data were subjected to analysis of variance (one-way ANOVA).

Results and discussion

Sensory analysis

Figure 1 a shows the differences between the total demerit points of rainbow trout stored in traditional ice and ice with potato, sweet potato, sugar beet, and red beet peel extracts (0.1%). In raw fishes, there were significant differences between the control and plants groups ($p < 0.05$) especially after the 14th storage day. The observed shelf life of rainbow trout was 21 days in the control, sugar beet, and red beet group and 25 days for the groups in ice with potato and red beet peel extracts.

Sensory analyses of cooked rainbow trout treated with plant extracts are given in Fig. 1b. The sensory score for flavor of the cooked fillets decreased with storage time. After 14 storage days, according to sensory scores, the most popular groups were potato and red beet groups. In a study conducted by Quitral et al. (2009), ice was prepared from vegetable extracts of rosemary and oregano and their effects were investigated on Chilean jack mackerel. The chemical changes during the 23-day chilling period with the extracts were delayed comparing to traditional water ice. Similarly, in the present study, the positive effect of icing with plant extract on chemical parameters had a positive effect on sensory scoring.

Chemical analysis

TVB-N contains mainly ammonia, trimethylamine (TMA), and dimethylamine (DMA), and their levels increase with spoilage by either bacterial or enzymic degradation (Ozogul and

Table 1 Plates and methods used for microbiological analysis

Microorganism	Plate	Incubation time
Mesophilic aerobic bacteria	Plate count agar (PCA)	30 °C 72 h
Psychrophilic aerobic bacteria	Plate count agar (PCA)	6 °C 10 days
Enterobacteriaceae	Violet red bile glucose agar (VRBGA)	35 °C 24 h

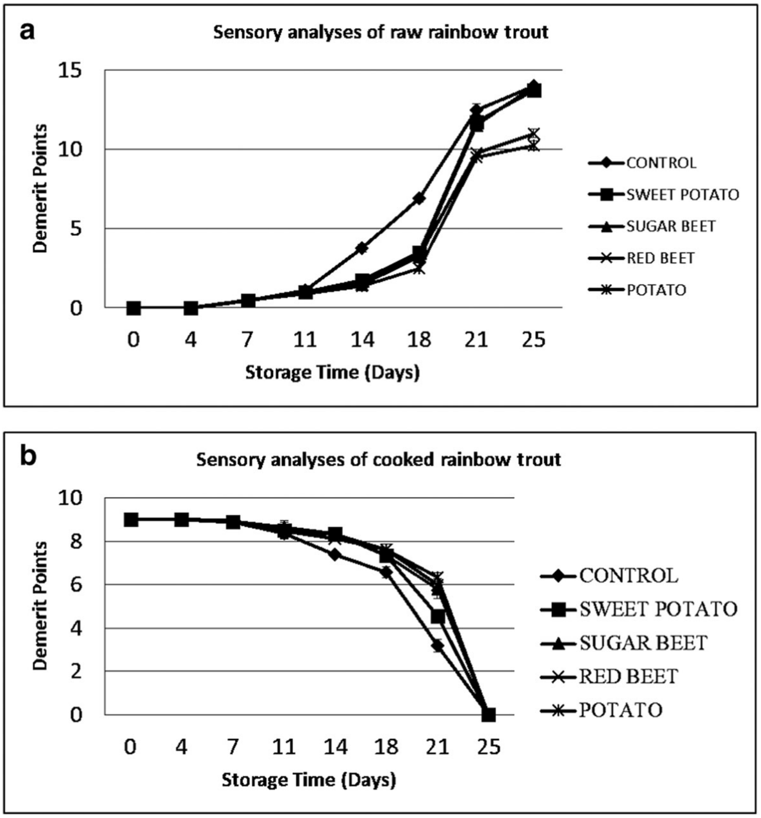

Fig. 1 **a** Sensory of raw trout stored in traditional ice and plant extract icing (0.1%). **b** Sensory of cooked trout stored in traditional ice and plant extract icing (0.1%)

Ozogul 2000). The TVB-N content ranged from 18.02 to 25.1 mg/100 g for the control group, from 12.77 to 21.83 mg/100 g for red beet group, 13.22 to 25.73 mg/100 g for sugar beet group, from 13.22 to 24.34 mg/100 g for sweet potato group, and from 10.69 to 21.87 mg/100 g for potato group (Table 2). At the beginning of the storage, TVB-N values were determined as 20.94 mg/100 g and increased with time of storage in all groups. At the 21th storage day which was the critical day for sensory analyses, TVB-N value of the control group was 21.33 mg/100 g when potato, sweet potato, sugar beet, and red peel were 14.4 mg/100 g, 16.46 mg/ 100 g, 17.45 mg/100 g, and 14.13 mg/100 g respectively. In TVB-N values, there were significant differences between the control and plant groups ($p < 0.05$). It seems that icing with potato and red beet peel extract reduced the TVB-N values.

TBARS values of the control and treatment groups are given in Table 2. TBARS values showed significant differences for the control and treatment groups. Initial TBARS value of samples was 0.49 mg MDA/kg. At the 21th day of storage, the highest TBARS value was found in the control group (1.11 mg MDA/kg). At the same time, TBARS values of potato, sweet potato, sugar beet, and red peel extracts were 0.76 MDA/kg, 0.86 MDA/kg, 0.95 MA/ kg, and 1.02 MA/kg respectively. Similarly, Rezaei and Hosseini (2008) reported that TBARS values increased throughout ice storage period of rainbow trout and the maximum was 0.06 mg MDA/kg at the 20th day. Kuş (2012) reported that initial TBARS value for rainbow

Table 2 Total volatile base-nitrogen (TVB-N), thiobarbituric acid value (TBA), and peroxide values (PV) of trout stored in traditional ice and plant extracts icing (0.1%)

TVB-N (total volatile base-nitrogen)					
Days	Control	Red beet	Sugar beet	Sweet potato	Potato
0	20.94 ± 0.04^{c}	20.94 ± 0.04^{a}	20.94 ± 0.04^{b}	20.94 ± 0.04^{b}	20.94 ± 0.04^{a}
4	19.51 ± 1.42^{dx}	21.09 ± 1.02^{ax}	19.46 ± 0.64^{cx}	20.41 ± 1.56^{bx}	21.19 ± 0.83^{ax}
7	19.07 ± 0.77^{dex}	16.27 ± 0.80^{by}	16.03 ± 1.24^{ey}	16.51 ± 1.01^{cy}	16.27 ± 0.42^{by}
11	18.02 ± 0.06^{ex}	12.77 ± 1.02^{cy}	13.25 ± 0.7^{fy}	13.22 ± 0.04^{dy}	10.69 ± 0.42^{dz}
14	19.50 ± 0.03^{dx}	13.21 ± 1.23^{cy}	14.39 ± 0.77 ^{y}	13.91 ± 0.68^{dy}	13.02 ± 1.6^{cy}
18	22.30 ± 0.07^{bx}	12.79 ± 1.47^{cy}	13.22 ± 0.70^{fy}	13.93 ± 0.04^{dy}	13.70 ± 0.38^{cy}
21	21.32 ± 0.41^{bcx}	14.14 ± 0.44^{cz}	17.45 ± 0.71^{dy}	16.46 ± 0.42^{cy}	14.41 ± 0.85^{cz}
25	25.1 ± 0.71^{xay}	21.83 ± 0.83^{az}	25.73 ± 0.11^{ax}	24.34 ± 0.64 ^{y}	21.87 ± 0.82^{az}
TBA (thiobarbituric acid value, mgMA/100 g)					
0	0.49 ± 0.07^{e}	0.49 ± 0.07^{e}	0.49 ± 0.07^{e}	0.49 ± 0.07^{e}	0.49 ± 0.07^{c}
4	0.66 ± 0.060^{dx}	0.59 ± 0.02^{cby}	0.64 ± 0.03^{dx}	0.58 ± 0.03^{dy}	0.59 ± 0.04^{by}
7	0.69 ± 0.03^{dx}	0.59 ± 0.02^{bcy}	0.50 ± 0.014^{eq}	0.60 ± 0.03^{cdy}	0.54c ± 0.02^{bz}
11	0.70 ± 0.04^{dx}	0.56 ± 0.02^{cdz}	0.65 ± 0.03^{dy}	0.62 ± 0.01^{cdy}	0.57 ± 0.01^{bz}
14	0.87 ± 0.06^{cx}	0.55 ± 0.03^{dq}	0.62 ± 0.02^{dz}	0.68 ± 0.07^{by}	0.57 ± 0.02^{bzq}
18	0.96 ± 0.06^{bx}	0.60 ± 0.02^{bz}	0.81 ± 0.08^{by}	0.61 ± 0.03^{cdz}	0.56 ± 0.02^{bz}
21	1.11 ± 0.11^{ax}	1.02 ± 0.03^{ay}	0.95 ± 0.01^{az}	0.86 ± 0.03^{aq}	0.76 ± 0.01^{aw}
25	0.84 ± 0.11^{cx}	0.62 ± 0.01^{bz}	0.74 ± 0.01^{cy}	0.64 ± 0.03^{bcz}	0.59 ± 0.06^{bz}
PV (peroxide values)					
0	2.85 ± 0.51^{f}	2.85 ± 0.51^{e}	2.85 ± 0.51^{e}	2.85 ± 0.51^{e}	2.85 ± 0.51^{f}
4	5.34 ± 0.61^{ex}	4.21 ± 0.77^{dy}	5.12 ± 0.27^{dxy}	5.02 ± 0.55^{dxy}	4.12 ± 0.37^{ey}
7	6.27 ± 0.57^{dex}	5.02 ± 0.67^{cdy}	5.96 ± 0.55^{cdxy}	6.5 ± 0.39^{cx}	5.57 ± 0.03^{cxy}
11	7.19 ± 0.42^{cdx}	5.42 ± 0.23^{cz}	6.61 ± 0.33^{cxy}	6.20 ± 0.38^{cy}	4.65 ± 0.44^{dq}
14	5.69 ± 0.63^{ey}	4.89 ± 0.09^{cdy}	6.76 ± 0.75^{cx}	6.98 ± 0.44^{cx}	5.81 ± 0.23^{bcy}
18	7.79 ± 0.93^{cx}	6.65 ± 0.39^{by}	4.98 ± 0.58^{dz}	5.18 ± 0.25^{dz}	5.28 ± 0.37^{cz}
21	9.15 ± 0.60^{bx}	6.48 ± 0.31^{bz}	8.57 ± 0.40^{bxy}	8.40 ± 0.34^{by}	6.25 ± 0.17^{bz}
25	13.80 ± 0.55^{ax}	8.03 ± 0.39^{az}	11.26 ± 1.48^{ay}	12.86 ± 0.50^{ax}	8.26 ± 0.13^{az}

Values in a same column followed by different letters (a, b, c, d, e, f) indicate significant differences ($p < 0.05$) during storage periods. Values in a same row followed by different letters (x, y, z, q, w) indicate significant differences of the parameter with respect to the plant treatment

trout is 0.45 mg MDA/kg and maximum TBARS value is 0.65 mg MDA/kg during storage. In the current study, TBARS value increased during the storage time and at the end of storage period (25th day), it decreased in all groups. In the potato peel extract group, TBARS value is lower than those of all the others at the 18th, 21th, and 25th days of storage. Barros-Velázquez et al. (2016) investigated for 13 days the effects of icing systems with alga *Fucus spiralis* extracts on the biochemical properties of hake (*Merluccius merluccius*). Lower pH values, FFA content, and TBARS were reported when natural preservative were added to the ice.

Table 2 shows the peroxide value of the control and the treatment group during storage of 25 days. There were significant differences ($p < 0.05$) in PV values between the control and other groups. The initial PV was 2.85 meq O_2 kg^{-1} and then increased for the control, potato, sweet potato, sugar beet, and red peel extracts to 13.80 meq O_2 kg^{-1}, 8.26 meq O_2 kg^{-1}, 12.86 meq O_2 kg^{-1}, 11.26 meq O_2 kg^{-1+}, and 8.03 meq O_2 kg^{-1} at 25th day, respectively. Çoban (2012) reported that initial PV value is 1.78 meg/kg for rainbow trout fillets. However, Mexis et al. (2009) reported that initial PV value is 11.4 meg/kg for vacuum-packed rainbow trout fillets. Siskos et al. (2007) found the PV value between 15.6 meq/kg and 22.5 meq/kg during storage time although Rezaei and Hosseini (2008) found PV value lower than 9.8 meq O_2/kg during storage. In the current study at the 18th day of storage when PV value was increasing rapidly, potato and red beet group values remained lower comparing to the other groups. The highest PV value was reported for the control group at 25th day of storage as 13.80 meq O_2/kg. At the same day sweet potato, sugar beet, potato, and red beet values were 12.86 meq O_2/kg, 11.26 meq O_2/kg, 8.26 meq O_2/kg and 8.03 meq O_2/kg, respectively.

Changes in FFA values of the control and treatment groups are given in Table 3. There were significant differences ($p < 0.05$) in FFA among groups. Generally, treatment of ice with potato and red beet peel extracts significantly affected the release of FFA in rainbow trout. Nowzari et al. (2013) reported that FFA value became higher during the storage and the highest value was 6.78% in the control group of rainbow trouts at the 16th day. In the current study, initial level of FFA was 2.44%, reaching maximum level of 13.17% in the control group, at the end of the storage period. The lowest FFA was observed for red beet and potato group. At the end of the storage period, FFA values were 8.40% for red beet, 8.63% for potato, and 10.97% and 11.22%, respectively, for sweet potato and sugar beet.

Initial pH of groups was 6.59 and it increased slightly during storage period (Table 3). The similar increase in pH for trout was reported in the research by Jasour et al. 2011. At the 25th day of storage, lower pH value in groups with potato, sweet potato, red beet, and sugar beet peel extracts were found in comparison to the control. The highest pH was reported for sweet potato (6.79) and the lowest was noticed for potato (6.54) at the end of the storage.

Microbiological analyses

Microbial counts on the control and treated rainbow trout are presented in Fig. 2a, b. Initial total aerobic mesophilic bacteria were 2.78 log cfu/g. During storage period, the control group had the highest value and potato group had the lowest value followed by the red beet group (Fig. 2a). The 7 log cfu/g value which is recommended for raw rainbow trout level by the

Table 3 Changes in free fatty acids (FFA) and pH of trout stored in traditional ice and plant extracts icing (0.1%)

FFA (free fatty acids)

Days	Control	Red beet	Sugar beet	Sweet potato	Potato
0	2.44 ± 0.21^{e}	2.44 ± 0.21^{e}	2.44 ± 0.21^{f}	2.44 ± 0.21^{e}	2.44 ± 0.21^{f}
4	4.85 ± 0.32^{dx}	4.34 ± 0.66^{dx}	3.50 ± 0.41^{ey}	3.57 ± 0.02$^{d\ y}$	2.90 ± 0.39^{fy}
7	4.72 ± 0.49^{dxy}	4.11 ± 0.43^{dy}	5.15 ± 0.18^{dx}	4.92 ± 0.17^{cx}	4.53 ± 0.29^{dexy}
11	6.10 ± 0.73^{cdx}	4.64 ± 0.88^{cdyz}	5.40 ± 0.56^{dxy}	5.20 ± 0.17^{cxy}	3.94 ± 0.30^{ez}
14	7.09 ± 0.42^{bcx}	5.42 ± 0.28^{bcdy}	6.56 ± 0.56$^{c\ x}$	7.02 ± 0.91^{bx}	5.26 ± 0.45^{cy}
18	7.08 ± 0.42^{bcx}	5.80 ± 0.78^{bcyz}	6.36 ± 0.33$^{c\ xy}$	6.59 ± 0.68^{bxy}	5.17 ± 0.18^{cdz}
21	8.23 ± 0.79^{bx}	6.57 ± 0.69^{bx}	7.60 ± 0.43$^{b\ x}$	7.37 ± 0.67^{bx}	6.28 ± 0.46^{bx}
25	13.17 ± 0.29^{ax}	8.40 ± 0.43^{az}	11.22 ± 0.78^{ay}	10.97 ± 0.35^{ay}	8.63 ± 0.70^{az}
pH					
0	6.59 ± 0.017^{b}	6.59 ± 0.017^{b}	6.59 ± 0.017^{d}	6.59 ± 0.017^{d}	6.59 ± 0.017^{a}
4	6.54 ± 0.017^{cy}	6.44 ± 0.017^{eq}	6.59 ± 0.01^{dx}	6.51 ± 0.00^{gyz}	6.49 ± 0.04^{cz}
7	6.53 ± 0.012^{cyz}	6.52 ± 0.01^{cz}	6.62 ± 0.013^{cx}	6.54 ± 0.00^{fy}	6.43 ± 0.017^{dq}
11	6.46 ± 0.012^{dy}	6.48 ± 0.01^{dy}	6.56 ± 0.013^{ex}	6.55 ± 0.017^{efx}	6.42 ± 0.018^{dz}
14	6.52 ± 0.01^{cz}	6.53 ± 0.01^{cz}	6.66 ± 0.013^{bx}	6.57 ± 0.014^{ey}	6.48 ± 0.01^{cq}
18	6.61 ± 0.012^{by}	6.62 ± 0.01^{by}	6.74 ± 0.017^{ax}	6.74 ± 0.013^{bx}	6.54 ± 0.03^{bz}
21	6.71 ± 0.04^{ax}	6.73 ± 0.04^{ax}	6.66 ± 0.017^{by}	6.71 ± 0.014^{cxy}	6.60 ± 0.01^{az}
25	6.61 ± 0.012^{bz}	6.71 ± 0.012^{ay}	6.62 ± 0.014^{cz}	6.79 ± 0.013^{ax}	6.54 ± 0.013^{bq}

Values in a same column followed by different letters (a, b, c, d, e, f) indicate significant differences ($p < 0.05$) during storage periods. Values in a same row followed by different letters (x, y, z, q, w) indicate significant differences of the parameter with respect to the plant treatment

International Commission on Microbiological Specification for Foods (ICMSF 1986) was reached at the 14th day in the control and sugar beet groups although potato and red beet groups reached this value at the 18th day of storage (Fig. 2a). Microbial spoilage of rainbow trout was delayed by 4 days when potato and red beet peel extracts were used, extending fish shelf life. In other studies, chilled storage of megrim (*Lepidorhombus whiffiagonis*) in traditional ice was compared with the addition of extract of brown alga *Bifurcaria bifurcata* in the medium (Miranda et al. 2016). Antimicrobial and inhibition of trimethylamine were observed with the incorporation of algal extract over a 14-day storage period. Increase of foodborne spoilage and pathogenic bacteria were noticed with the extending of storage time. However, the presence of algal extract in the icing medium was able to limit the growth of various pathogenic organisms including *Escherichia coli*, *Klebsiella pneumoniae*, *Vibrio parahaemolyticus*, *Pseudomonas fluorescens*, and *Salmonella enteric*.

Total *Enterobacteriaceae* counts are presented in Fig. 2b. The initial number of bacteria in rainbow trout was 1.39 log cfu/g. In all storage days, potato group inhibited the microbial growth. During storage period, the control group had the highest *Enterobacteriaceae* value.

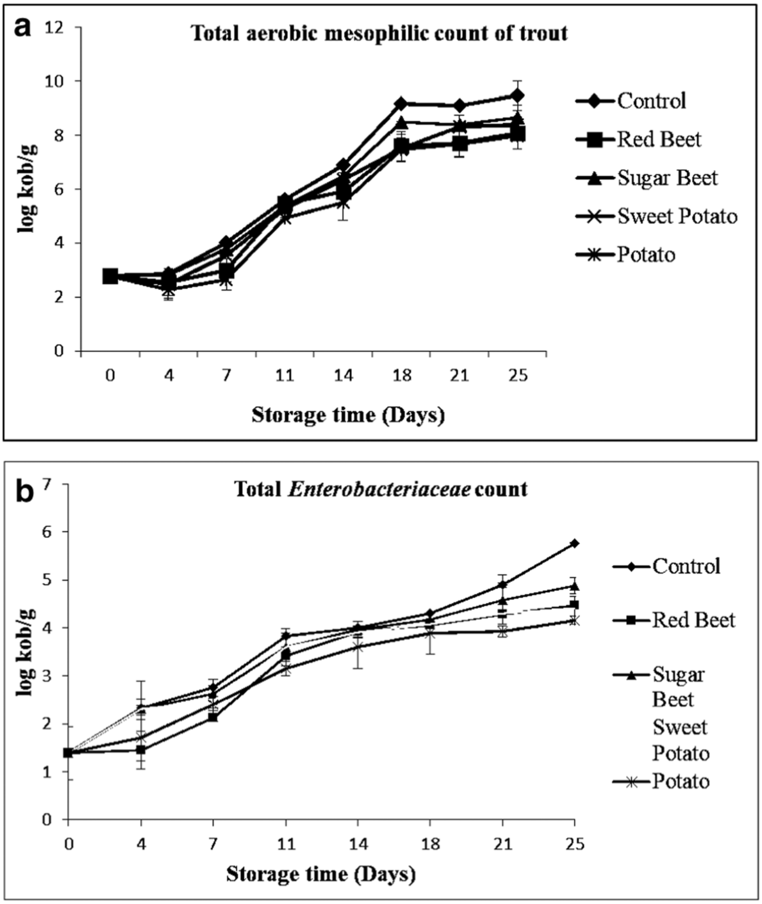

Fig. 2 **a** Total aerobic mesophilic bacteria (TAMB) on the control and treated rainbow (0.1%). **b** Total *Enterobacteriaceae* on the control and treated rainbow (0.1%)

When the value of the control group was 5.77 log cfu/g at the 25th day of storage, *Enterobacteriaceae* values of potato, sweet potato, sugar beet, and red peel extracts were 4.16, 4.47, 4.41, and 4.88 log cfu/g respectively. In accordance with the other results, potato and red beet peel extracts were the most effective in inhibiting bacterial growth followed by sweet potato and sweet beet groups.

Conclusions

Icing with potato, sweet potato, sugar beet, and red peel extract improved the sensory and chemical quality of fish, which resulted in a significant extension of the shelf life of rainbow trout from 21 to 25 days. Icing with potato and red beet peel extracts were the most effective, causing low TVB-N, PV, and FFA values. Consequently, the addition of potato and red peel extracts to ice improved the quality of rainbow trout, which is quite promising for the food industry. Since they are usually discarded, vegetable wastes should be considered as by-products as they represent a source of highly value components. Reuse of such materials could be very beneficial economically since they are a low-cost raw material available in large amounts. The fact that these wastes are effective as a preservative in a perishable food such as fish indicates that they can be used in the preservation of different foods in the future. The use of ice containing extracts of aromatic plants at higher concentrations would probably result in a further increase of shelf life of food, but its effect on sensory properties should be investigated in further studies.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical statement This article does not contain any studies with animals performed by any of the authors.

References

Akyol H, Riciputi Y, Capanoglu E, Caboni MF, Verardo V (2016) Phenolic compounds in the potato and its byproducts: an overview. Int J Mol Sci 17(6):835. https://doi.org/10.3390/ijms17060835

AOCS Method Ja 8-87. (1994) Peroxide value. In D. E. Firestone (Ed.), Official methods and recommended practices of the american oil chemists' society, 4th edn. AOCS Press, Champaign, Illinois, USA

AOCS Official Method Ca 5a-40. (1997) Free fatty acids. In D. E. Firestone (Ed.), Official methods and recommended practices of the american oil chemists' society, 5th edn. AOCS Press, Champaign, Illinois, USA

Attouchi M, Sadok S (2011) The effects of essential oils addition on the quality of wild and farmed sea bream (*Sparus aurata*) stored in ice. Food Bioprocess Technol 5(5):1803–1816. https://doi.org/10.1007/s11947-011-0522-x

Aubourg PS, Losada V, Prado M, Miranda JM, Barros-Velázquez J (2007) Improvement of the commercial quality of chilled Norway lobster (*Nephrops norvegicus*) stored in slurry ice: effects of a preliminary treatment with an antimelanosic agent on enzymatic browning. Food Chem 103(3):741–748. https://doi.org/10.1016/j.foodchem.2006.09.022

Barros-Velázquez J, Miranda JM, Ezquerra-Brauer JM, Aubourg SP (2016) Impact of icing systems with aqueous, ethanolic and ethanolic-aqueous extracts of alga Fucus spiralis on microbial and biochemical quality of chilled hake (*Merluccius merluccius*). Int J Food Sci Technol 51(9):2081–2089. https://doi.org/10.1111/ijfs.13182

Bonilla A, Sveinsdottir K, Martinsdottir E (2007) Development of quality index method (QIM) scheme for fresh cod (*Gadus morhua*) fillets and application in shelf life study. Food Control 18(4):352–358. https://doi.org/10.1016/j.foodcont.2005.10.019

Campos CA, Rodriguez O, Losada V, Aubourg SP, Barros-Velazquez JT (2005) Effects of storage in ozonised slurry ice on the sensory and microbial quality of sardine (*Sardina pilchardus*). Int J Food Microbiol 103(2): 121–130. https://doi.org/10.1016/j.ijfoodmicro.2004.11.039

Çoban ÖE (2012) Evaluation of essential oils as a glazing material for frozen rainbow trout (*Oncorhynchus mykiss*) fillet. J Food Process Preserv 37(2013):759–765. https://doi.org/10.1111/j.1745-4549.2012.00722.x

Egolf PW, Kauffeld M (2005) From physical properties of ice slurries to industrial ice slurry applications. Int J Refrig 28(1):4–12. https://doi.org/10.1016/j.ijrefrig.2004.07.014

Fan W, Chi Y, Zhang S (2008) The use of a tea polyphenol dip to extend the shelf life of silver carp (*Hypophthalmicthys molitrix*) during storage in ice. Food Chem 108(1):148–153. https://doi.org/10.1016/j.foodchem.2007.10.057

International Commission on Microbiological Specification for Foods (1986) Microorganisms in foods 2. Sampling for microbiological analysis: principles and specific applications, 2nd edn. University of Toronto Press, Toronto

Jasour MS, Rahimabadi EZ, Ehsani A, Rahnama M, Arshadi A (2011) Effects of refrigerated storage on fillet lipid quality of rainbow trout (*Oncorhynchus mykiss*) supplemented by a-tocopheryl acetate through diet and direct addition after slaughtering. J Food Process Technol 2:124. https://doi.org/10.4172/2157-7110.1000124

Kalpna R, Mital K, Sumitra C (2011) Vegetable and fruit peels as a novel source of antioxidants. J Med Plant Res 5(1):63–71

Kılınç B, Çaklı S, Cadun A, Dinçer T, Tolasa S (2007) Comparison of effects of slurry ice and flake ice pretreatments on the quality of aquacultured sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*) stored at 4 C. Food Chem 104(4):1611–1617. https://doi.org/10.1016/j.foodchem.2007.03.002

Kuş B (2012) Investigation of antibacterial and antioxidant effect of strawflower and mistletoe plant extract on rainbow trout fillets. Çukurova University Institute Of Natural And Applied Sciences Department Of Fishing And Fish Processing, Msc Thesis.P. 49.

Losada V, Barros-Velázquez J, Gallardo JM, Aubourg SP (2004) Effect of advanced chilling methods on lipid damage during sardine (*Sardina pilchardus*) storage. Eur J Lipid Sci Technol 106(12):844–850. https://doi.org/10.1002/ejlt.200400991

Mexis SF, Chouliara E, Kontominas MG (2009) Combined effect of an oxygen absorber and oregano essential oil on shelf life extension of rainbow trout fillets stored at 4 C. Food Microbiol 26(6):598–605. https://doi.org/10.1016/j.fm.2009.04.002

Miranda JM, Trigo M, Barros-Velázquez J, Aubourg SP (2016) Effect of an icing medium containing the alga Fucus spiralis on the microbiological activity and lipid oxidation in chilled megrim (*Lepidorhombus whiffiagonis*). Food Control 59(1):290–297. https://doi.org/10.1016/j.foodcont.2015.05.034

Niemal NP, Benjakul S (2011) Effect of green tea extract in combination with ascorbic acid on the retardation of melanosis and quality changes of Pacific white shrimp during iced storage. Food Bioproc Tecnol 5(8):1–11. https://doi.org/10.1007/S11947-010-0483-5

Nowzari F, Shabanpour B, Ojagh SM (2013) Comparison of chitosan–gelatin composite and bilayer coating and film effect on the quality of refrigerated rainbow trout. Food Chem 141(3):1667–1672. https://doi.org/10.1016/j.foodchem.2013.03.022

Özoğul F, Özoğul Y (2000) Comparison of methods used for determination of total volatile basic nitrogen (TVB-N) in rainbow trout (*Oncorhynchus mykiss*). Turk J Zool 24(1):113–120

Özyurt G, Kuley E, Balıkcı E, Kaçar C, Gökoğlan S, Etyemez M, Özoğul F (2011) Effect of the icing with rosemary extract on the oxidative stability and biogenic amine formation in sardine (*Sardinella aurita*) during chilled storage. Food Bioprocess Technol 5(7):2777–2786. https://doi.org/10.1007/s11947-011-0586-7

Paulus K, Zacharias R, Robinson L, Geidel H (1979) Kritische betrachtungen zur Bewetenden Prufung mit skale" Als Einem Wesentlichen Verfahren Der Sensorichen Analyse. LWT 12(1):52–61.

Phuvasate S, Su YC (2010) Effects of electrolyzed oxidizing water and ice treatments on reducing histamine-producing bacteria on fish skin and food contact surface. Food Control 21(3):286–291. https://doi.org/10.1016/j.foodcont.2009.06.007

Quitral V, Donoso ML, Ortiz J, Herrera MV, Araya H, Aubourg SP (2009) Chemical changes during the chilled storage of Chilean jack mackerel (*Trachurus murphyi*): effect of a plant-extract icing system. LWT 42(8): 1450–1454. https://doi.org/10.1016/j.lwt.2009.03.005

Rezaei M, Hosseini SF (2008) Quality assessment of farmed rainbow trout (Oncorhynchus mykiss) during chilled storage. J Food Sci 73(6):93–96. https://doi.org/10.1111/j.1750-3841.2008.00792.x

Siskos I, Zotos A, Melidou S, Tsikritzi R (2007) The effect of liquid smoking of fillets of trout (*Salmo gairdnerii*) on sensory, microbiological and chemical changes during chilled storage. Food Chem 101(2):458–464. https://doi.org/10.1016/j.foodchem.2006.02.002

Sonia NS, Mini C, Geethalekshmi PR (2016) Vegetable peels as natural antioxidants for processed foods-a review. Agric Rev 37(1):35–41. https://doi.org/10.18805/ar.v37i1.9262

Tarladgis B, Watts BM, Yonathan M (1960) Distillation method for determination of malonaldehyde in rancid food. J Am Oil Chem Soc 37(1):44–48. https://doi.org/10.1007/BF02630824

Wruss J, Waldenberger G, Huemer S, Uygun P, Lanzerstorfer P, Müller U, Höglinger O, Weghuber J (2015) Compositional characteristics of commercial beetroot products and beetroot juice prepared from seven beetroot varieties grown in Upper Austria. J Food Compos Anal 42(7):46–55. https://doi.org/10.1016/j.jfca.2015.03.005