INTRODUCTION

Fish is a very perishable food. Keeping seafood for as long as possible in a good condition is a very important objective for producers. The loss of seafood freshness is mainly due to the activity of endogenous enzymes, the oxidation of lipids and pigments, and bacterial putrefactions.

These factors can be controlled mainly by reducing temperature, reducing microbial contamination, controlling the humidity and composition of the atmosphere, and the addition of preservatives and other antimicrobial treatments. One way to retard microbial growth is with food additives; however, use of antimicrobial agents on fish for improving shelf life, quality and nutritional value has been limited. The ideal chemical preservative agent should be non-toxic, and not react with any other additives and food components; it should not exhibit a taste, odor or color; it must be able to inhibit the growth of microorganisms; it should be metabolized by the body without any side-effects; and it must be cheap.

It is known that lactates extend the shelf life and protect the taste of seafoods. A maximum limit of 2 g/kg of potassium lactate in foods has been proposed. Lactates are generally useful for extending the shelf life of meats and seafoods. They can also protect the sensory quality, appearance and the color of the fish, and retard the growth of pathogen bacteria. They are effective at around pH 6 and retard the bacterial spoilage of fish and other seafoods.

Chub mackerel is a common fish found in the Mediterranean Sea and Black Sea, and belongs to the family Scombridae. Statistical data show that 2203 tons of this fish was caught from the Black Sea and 2991 tons from the Marmara Sea in 1997. Its flesh is either fatty or very nutritious, which is why it can spoil in a very short time making the extension of its shelf life very important. The type of ideal preservative and its optimum ratio to be used is different for every food. The purpose of the present study was to evaluate the shelf life extension of refrigerated chub mackerel by immersing it in 0% (w/v), 2% (w/v), and 4% (w/v) potassium lactate.

ORIGINAL ARTICLE

Effect of potassium lactate on the quality and shelf life of chub mackerel *Scomber japonicus*

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**ABSTRACT:** The effect of potassium lactate treatment on the shelf life of vacuum-packaged fish was studied. Chub mackerel was treated with 2% and 4% potassium lactate solutions, and their shelf lives were compared with those of control (not treated) samples. Samples were stored at 4°C and sensory evaluation, and chemical and microbiological analyses were done every three days. Control group spoiled after six days of storage. The addition of potassium lactate decreased microbiological activity and treated samples remained in good quality until the ninth day of storage. There was no significant difference between the shelf life of samples treated with either 2% or 4% potassium lactate. These results indicate that treatment with potassium lactate extends the shelf life of vacuum-packaged and refrigerated chub mackerel.

**KEY WORDS:** chub mackerel, potassium lactate, preservatives, quality, shelf life.

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MATERIALS AND METHODS

Fish source, treatment and packaging

Fresh chub mackerel *Scomber japonicus* were obtained from a seafood whole market in Kumkapi, Istanbul, which had been harvested from the Marmara Sea. On arrival at the laboratory (laboratory temperature 16 ± 1°C), the fish were headed, eviscerated, and filleted. The lipid and moisture content were determined as 8.85 ± 0.18% and 76.89 ± 0.31%, respectively. The fillets, which were 100 ± 5 g in weight, 20 cm in length, and 5 cm in width, were divided into three groups, whereby each group was treated with either 0% (w/v), 2% (w/v), or 4% (w/v) potassium lactate solutions for 30 min at 4°C. After immersion in their respective solutions, the fillets were drained at ambient temperature (16 ± 1°C), placed in high-barrier film bags (O₂ transmission rate, 6.89 mL/m²; CO₂, 5.42 mL/m²; N₂, 2.48 mL/m² at 4°C; vapor permeability, 7.86 mL/m² at 37.8 ± 1°C, 90 ± 2% RH g/m² days.atm.) and packaged under vacuum for 20 s at 760 mmHg. Plastic film bags were obtained from UPM-Kymmene, Walki-Pack, Plastic Films Factory (Valkeakoski, Finland). A Röschermatic model vacuum packaging machine (Röschermatic AG, Germany) was used, and samples were stored at 4°C. Sensory evaluation, and physical, chemical and microbiological analyses were done every three days during storage, and all analyses were done in triplicate.

Sensory evaluation

Five judges assessed the sensory properties by using a hedonic scale. Samples were evaluated in their raw and cooked forms. General appearance, texture, taste and smell were used as criteria for acceptability. The mean values of these criteria were used for the sensory evaluation. A score of 9 was the highest possible value from the panel testing and a score of 4 was the limit of acceptability.

Chemical analysis

pH Measurements were made with a Metrohm model 632 pH meter (Metrohm, Filderstadt, Switzerland). For estimating the total volatile bases nitrogen (TVB-N), the vapor distillation method was used. Samples were boiled and the vapor components held with 0.1 N HCl. Hydrochloric acid was titrated with 0.1 N NaOH and the TVB-N was expressed as mg/100 g of fish. Trimethylamine (TMA) concentrations were determined using a spectrophotometer. Moisture content was determined by oven-drying samples at 105°C to a constant weight. Lipid content was determined by method 948.15, as described described by the AOAC.

Microbiological analysis

Three packages from each group were opened aseptically in order to analyse the aerobic plate counts, total coliforms, and fecal coliforms. Samples were diluted in peptone water and mixed in a stomacher. Aerobic bacteria were counted by plating them on plate count agar (PCA) and incubating for 24 h at 37°C. Following incubation, colonies were counted and data reported as log colony forming units (c.f.u.). Total and fecal coliforms were conducted as described in the Mikrobiologische Untersuchung von Lebensmittel.

Statistical analysis

Statistical differences were determined by the method of Renner.

RESULTS AND DISCUSSION

Sensory evaluation

All samples were of good quality at the beginning of storage. Five trained judges assessed the sensory quality, whereby a mean score of 4 points was the limit of acceptability. At the sixth day all samples were still of good quality; but control samples (0% potassium lactate) had reached an unacceptable state after nine days of storage, whereas treated samples (2% and 4% potassium lactate) were still marketable at the ninth day, but had spoiled by the 12th day of storage (Table 1). There was a significant difference \( P<0.05, n=5 \) between the control and treated samples at the ninth day of storage. Oxidative odor was not detected in either the controls or the treated fillets during storage. There was no significant difference \( P\geq 0.05, n=5 \) between the sensory qualities of the two treated (2% and 4%) groups. The results of the present study are in accordance with those of previous studies on the effect of lactate on the shelf life of seafoods.

Kim *et al.* have studied the quality of catfish fillets treated with lactic acid and lactic cultures, and compared them with control samples. At the ninth day of storage, the control samples in air tasted typically ‘off’ and, hence, were evaluated as
spoiled, but the treated samples did not. Similarly, in another study in which catfish fillets were dipped in 1.5% and 2% sodium lactate, vacuum packaged and then stored at 1.11 ± 1°C, the control samples had spoiled by the fifth day, whereas the treated samples had lost their quality of appearance but had not spoiled after seven days of storage.6

**pH Analysis**

pH Values change during storage due to the activity of enzymes and bacteria. An increase in pH during storage indicates bacterial growth and possible spoilage.16 It has been reported that the pH value must be between 6 and 6.5 for fish to be fresh and that the acceptability limit is pH 6.8–7.0.17 Fresh chub mackerel fillets had a pH of 6.06 (Table 1). This value increased to 6.88 in control samples after 12 days of storage. The pH was 6.49 and 6.58 for the 2% and 4% potassium lactate treated samples, respectively, at the last day of storage (12 days). Control samples had exceeded the pH limits, and had a significantly (P < 0.05, n = 3) higher value compared with those of the treated samples after nine days of storage. The TVB-N values of the fillets treated with potassium lactate had exceeded the limits at the 12th day of storage and there was no significant difference between the two treatments (P ≥ 0.05, n = 3). Total volatile bases nitrogen analysis has been used previously as a quality indicator to evaluate the freshness of fish.19 Another important and common quality indicator of fish is K-value, which is expressed as a percentage amount of inosine and hypoxanthine in the total amount of adenosine triphosphate (ATP) and related compounds in fish muscle. The TVB-N content accumulates towards the end of the edible shelf life of the fish, but the K-value is adequate in the early stages after death.20 An increased TVB-N value in seafood coincides with bacterial spoilage. Some researchers have proposed 40 mg N per 100 g fish as the rejection limit,17,21 while others have proposed 35 mg N per 100 g fish.10 The species of fish, catching area, season, and maturity and age of fish are the affecting factors of this parameter.22

**Trimethylamine**

In the present study, the initial value of the TMA-N value was 3.51 mg per 100 g fish, which reached 6.23 mg per 100 g fish for the control group after nine days and 9.01 mg per 100 g fish at the 12th day of storage (Table 1). For the samples treated with 2% and 4% potassium lactate, TMA was 4.08 mg per 100 g fish and 4.00 mg per 100 g fish at the ninth day, respectively, and 6.25 mg per 100 g fish and 6.29 mg per 100 g fish, respectively, at the 12th day of storage. Trimethylamine levels of the control group were significantly higher than those of the treated samples during storage (P < 0.05, n = 3). The increase in the TMA content of fish correlated with the increased bacterial count and the sensory score. The TMA rejection limit is usually 5–10 mg

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**Table 1** Sensory, pH, total volatile bases nitrogen (TVB-N) and trimethylamine (TMA) values of samples

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sensory</th>
<th>pH</th>
<th>TVB-N (mg/100 g)</th>
<th>TMA-N (mg/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>9.0</td>
<td>6.06</td>
<td>9.96</td>
<td>3.51</td>
</tr>
<tr>
<td>2%</td>
<td>8.6</td>
<td>6.20</td>
<td>11.41</td>
<td>3.60</td>
</tr>
<tr>
<td>4%</td>
<td>6.4</td>
<td>6.31</td>
<td>22.61</td>
<td>4.26</td>
</tr>
<tr>
<td>6</td>
<td>3.6</td>
<td>6.67</td>
<td>39.17</td>
<td>6.26</td>
</tr>
<tr>
<td>9</td>
<td>2.0</td>
<td>6.88</td>
<td>50.29</td>
<td>4.26</td>
</tr>
<tr>
<td>12</td>
<td>7.5</td>
<td>6.24</td>
<td>14.74</td>
<td>3.37</td>
</tr>
<tr>
<td>3</td>
<td>5.2</td>
<td>6.29</td>
<td>29.14</td>
<td>3.33</td>
</tr>
<tr>
<td>6</td>
<td>4.5</td>
<td>6.37</td>
<td>31.13</td>
<td>4.08</td>
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<td>9</td>
<td>1.9</td>
<td>6.49</td>
<td>49.90</td>
<td>6.25</td>
</tr>
<tr>
<td>12</td>
<td>7.0</td>
<td>6.49</td>
<td>14.74</td>
<td>3.51</td>
</tr>
<tr>
<td>3</td>
<td>5.0</td>
<td>6.29</td>
<td>21.45</td>
<td>3.56</td>
</tr>
<tr>
<td>6</td>
<td>4.7</td>
<td>6.33</td>
<td>26.98</td>
<td>4.00</td>
</tr>
<tr>
<td>9</td>
<td>2.1</td>
<td>6.35</td>
<td>44.70</td>
<td>6.29</td>
</tr>
</tbody>
</table>

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per 100 g fish. However, in many fatty fish it never reaches the limit of 5 mg/100 g fish. Stockemer and Nieper have proposed a TMA rejection limit in fish of 12 mg per 100 g fish, whereas Connell has proposed 10–15 mg per 100 g fish. Ludorff and Meyer have accepted the marketable TMA level as 10 mg per 100 g fish and the TMA limit of spoilage as 12 mg per 100 g fish.

Villemure et al. have accepted a limit of 5 mg per 100 g fish as acceptable for lean fishes, hence, achieving a shelf life of three days for gutted cod and four days for fillet stored at 0 ± 1°C. Jhaveri et al., who have studied the shelf life of dressed and steak Atlantic mackerel stored in ice, observed that the TMA-N content did not exceed 3 mg per 100 g fish until the sixth day and was below 5 mg per 100 g fish between the seventh and ninth days of storage. They detected a strong fishy odor between the 10th and 11th days with TMA levels exceeding 6 mg per 100 g fish. This value is higher than the 6 mg per 100 g fish observed in the present study after the 12th day of storage. Similar to the results of the present study, Reddy et al. also found that the TMA level on the day of spoilage was below 6 mg per 100 g fish; that is, 5.47 mg per 100 g fish, for cold-stored (4°C) tilapia fillets.

Microbiological analysis

The activity of microorganisms is the most important factor limiting the shelf life of fish. Total viable count (TVC) of fresh fish is usually $10^2$–$10^6$ c.f.u./g. At the point of sensory rejection the TVC limit is $10^7–10^8$ c.f.u./g. Nevertheless, standards, guidelines and specifications often use a much lower TVC value, whereby the range $10^5–10^7$ c.f.u./g was considered acceptable for fresh and chilled fish. In the present study, the TVC of treated samples (2% and 4% potassium lactate) had not exceeded this limit by the 12th day of storage. Similar to the rejection limits of 160–210 c.f.u./g of coliform bacteria and 9–12 c.f.u./g of E. coli, total aerobes remained unaffected by treatment. A study whereby catfish fillets were treated with 0%, 1%, or 2% sodium lactate and stored at 1.11 ± 1°C for 8 days has shown that the aerobic plate counts were lower ($P<0.05$) for those fillets treated with 2% sodium lactate compared with the control, but that number of total and fecal coliforms remained unaffected by treatment. Similarly, in the present study, the number of fecal coliforms was not affected by treatment.

In the present study, the addition of potassium lactate decreased microbial activity but there was no significant difference between the shelf life of storage. The microbial load of the control group was significantly ($P<0.05$, $n=3$) higher than that of the treated samples. The initial microbial load was 3.70 log c.f.u./g, and had reached 5.43 log c.f.u./g for samples treated with 2% potassium lactate and 5.10 log c.f.u./g for samples treated with 4% potassium lactate on the 12th day of storage.

Rehbein et al. found that the bacterial load of redfish was $16^4$ c.f.u./g after 12 days, and that when the fish had spoiled, the bacterial count had not exceeded $10^6$ c.f.u./g. In other studies, the total aerobic count of cold-stored (4°C) tilapia fillets was reported as 9.6 log c.f.u./g on the day of spoilage; an the microbial load of ice-stored Atlantic mackerel was 7 log c.f.u./g on the 11th day of storage.

In the present study, the initial load of total coliforms was 1.32 log c.f.u./g at the beginning of storage. It reached 3.66 log c.f.u./g for the control group, 4.04 log c.f.u./g for those samples treated with 2% potassium lactate, and 1.96 log c.f.u./g for those samples treated with 4% potassium lactate by the 12th day of storage. The fecal coliform count of fresh samples was 0.47 log c.f.u./g and remained below 1.47 log c.f.u./g for all samples during storage. As is commonly known, the numbers of coliform bacteria indicate the degree of contamination. Table 2 shows that the low numbers of these bacteria in the fish indicates that they were captured and studied under hygienic conditions.

The rejection limits of 160–210 c.f.u./g of coliform bacteria and 9–12 c.f.u./g of E. coli have been proposed for fish. A study whereby catfish fillets were treated with 0%, 1%, or 2% sodium lactate and stored at 1.11 ± 1°C for 8 days has shown that the aerobic plate counts were lower ($P<0.05$) for those fillets treated with 2% sodium lactate compared with the control, but that number of total and fecal coliforms remained unaffected by treatment. In the present study, the addition of potassium lactate decreased microbial activity but there was no significant difference between the shelf life of storage.

<table>
<thead>
<tr>
<th>Storage time (days)</th>
<th>Control</th>
<th>Potassium lactate</th>
<th>Potassium lactate</th>
<th>Potassium lactate</th>
<th>Potassium lactate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 3 6 9 12</td>
<td>3 6 9 12</td>
<td>3 6 9 12</td>
<td>3 6 9 12</td>
<td>3 6 9 12</td>
</tr>
<tr>
<td>Parameters</td>
<td>Total aerobes (log c.f.u./g)</td>
<td>3.70 5.45 5.90 6.00 6.39</td>
<td>2%</td>
<td>5.24 4.42 4.90</td>
<td>5.43 4.57 5.10</td>
</tr>
<tr>
<td></td>
<td>Total coliform (log c.f.u./g)</td>
<td>1.32 2.36 1.47 2.54 3.66</td>
<td>3.38 2.97 2.54</td>
<td>4.04 2.63 1.96</td>
<td>2.17 1.96</td>
</tr>
<tr>
<td></td>
<td>Fecal coliform (log c.f.u./g)</td>
<td>&lt;0.47 1.47 1.47 1.47</td>
<td>&lt;1.47 &lt;1.47 &lt;1.47</td>
<td>&lt;1.47 &lt;1.47 &lt;1.47</td>
<td>&lt;1.47 &lt;1.47 &lt;1.47</td>
</tr>
</tbody>
</table>
samples treated with 2% and 4% potassium lactate. According to these results, treatment with 2% potassium lactate might be recommended because of economic factors and to so that the minimum amount of chemical components are ingested by consumers. The results of the present study suggest that using potassium lactate extends the shelf life of vacuum-packaged and refrigerated chub mackerel.

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