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# INVESTIGATION OF NUTRITIONAL, SOME QUALITY CHANGES OF MUSSELS COVERED WITH EDIBLE FILMS PREPARED USING EXTRACTS OF PERSIMMON, CHERRY LAUREL AND LIKAPA

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## ABSTRACT

One of the reasons of food stale is that they react with oxygen. In this event caused by free radicals called autooxidation. Antioxidants helps free radicals to stabilize and minimize the damage they cause. Extracts that can be obtained from natural sources, especially medicinal / aromatic plants, can be used as an aid to preserve foods by showing antioxidant and antimicrobial properties. This study was carried out to extend the shelf life of seafood products by using natural antioxidant and antimicrobial sources. For this purpose, the sepals and leaves obtained from persimmon (*Diospyros kaki*), cherry laurel (*Laurocerasus officinalis*) and Likapa (*Vaccinium myrtillus*) were dried and dried at 60 ° C and then 2.5% and 5% vegetable extracts were obtained. Then used in the specified proportions to cover the mussels with edible films. Coated products were stored at + 4 ° C. Quality changes were examined on days 0, 2 and 4. In the study, the characteristics of edible films used in coating the product were determined. The highest TS and EB values were respectively in the group HB (0.61MPa) and LA (34.07%), and the lowest WVP, WS and SD values were LA (0.34 $10^{-10}$ g $H_2O$ $Pa^{-1}s^{-1}m^{-1}$), HB (56.71%) and KA (35.79%). It was determined that TVB-N values of film-coated products exceeded the consumable limit value of the other groups on the 4th day, except HB, LB and KB groups. TBA values of products covered with edible film did not exceed the consumable limit values during storage. The lowest TBA values were determined in LA, LB and KB groups. On the 2nd day of storage, the highest and lowest total aerobic mesophilic and psychrophilic results were found 5.97 log CFU / g (HB) and 4.62 log CFU / g (LA) respectively, on day 4, all groups exceeded the 7 log CFU / g limit value. According to the results of analysis carried out during storage, it was observed that LB group had a positive effect on product quality compared to other groups.

**KEYWORSDS:**
Extract, antioxidant, mussel, edible film, persimmon, cherry laurel, likapa

## INTRODUCTION

The total amount of aquaculture production in the world is 211 million tons and approximately 10 million tons include mussels, oysters, scallops, and combs [1]. Turkey's aquaculture production is 780 thousand tons. Approximately 1170 tons of this production consist of black mussels (*Mytilus galloprovincialis*) [2]. Mussels are very popular mollusks that are harvested in the Mediterranean, Atlantic Coasts, Black Sea, Marmara Sea and Straits [3-5]. Due to the low cost of production, its cultivation has increased rapidly in the last few years [5, 6].

Seafood has always maintained its importance in terms of nutrition due to its high protein content and the main source of polyunsaturated fatty acids. Besides these nutritional properties, it has a short shelf life. Oxidation of fatty acids causes bitter taste and color changes. Microorganisms and enzymes change the structure of protein and fat during storage and processing stages, causing unwanted flavors and odors in the product [7-9]. Mussels (*Mytilus galloprovincialis*) are an ideal food source in terms of nutritional value. Selenium, calcium, iron, magnesium, phosphorus, vitamins (A, $B_1$, $B_2$, $B_6$, $B_{12}$ and C) and polyunsaturated fatty acids (PUFA, 37-48% of total fatty acids) are especially rich in omega-3 PUFA [10, 11].

Mussels and products can be marketed in plastic, vacuum, sealed packages, frozen, raw, cleaned and smoked. Due to the nutritional quality and consumer preferences, there is a trend towards fresh consumption instead of frozen mussels. It is an ideal product for the development of microorganisms due to high water activity, high glycogen, free amino acid content and high pH [12, 13]. The recommended shelf-life limit is 1-3 days for fresh mussels and 5-7 days for cooked mussels. Therefore, it is essential to improve processing, storage, and packaging to extend the mussel's shelf life [14].


**FIGURE 1**
**Black mussel (*Mytilus galloprovincialis* Lamarck, 1819) sampling region (Cayeli / Rize / Turkey)**

People are aware that balanced nutrition is an important issue today. For this reason, consumers prefer products prepared with natural additives, biodegradable films, and coating materials instead of foods preserved with synthetic and petroleum-derived packaging materials. Edible films and coatings are among these products. These films and coatings can be used to prevent the passage of moisture, oxygen, and carbon dioxide in foods, and to improve the mechanical properties of the product [15,16].

Plant sources may contain antioxidant and antimicrobial properties since it contains abundant phenolic substances [17, 18]. Antioxidants inhibit the formation of free radicals (FR) and reactive oxygen species (ROT). FR and ROTs damage the parts of the cell such as protein, fat, carbohydrate, and DNA, causing their structural properties to deteriorate. Antioxidants are substances that react very quickly with FR and ROTs and prevent autooxidation / peroxidation process [19, 20].

*Diospyros kaki* (Kaki Persimmon) is a species native to Korea, China, and Japan. It is widely grown in East Asia and is a fruit loved by Asians. *Diospyros kaki* contains substances such as sugar (such as glucose and fructose), vitamins (such as A and C) and tannins (with an astringent taste). Tannin is a functional substance with physiologically active properties that contribute to antitumor, antioxidant and antibacterial activity, lowering cholesterol and removal of heavy metal [21].

*Laurocerasus officinalis* (Cherry Laurel) is an extremely characteristic summer fruit of the Black Sea region. It is produced and consumed widely in Turkey's eastern Black Sea region, some Balkan countries, Northern Ireland, Western Europe, South and West Caucasus, Iran, Eastern Marmara the Eastern Black Sea region in some Mediterranean countries. In addition to its diuretic and antidiabetic properties, it is used in the treatment of many diseases such as ethnopharmacological uses, stomach ulcers, digestive system problems, bronchitis, eczema, and hemorrhoids [18, 22, 23]. *Laurocerasus officinalis*, as many plants do, can synthesize aromatic substances, most of which are phenols or their oxygen-substituted derivatives. *Laurocerasus officinalis* leaves are a natural source of antioxidants for the food industry and show antimicrobial properties due to their many phenolic ingredients [17, 18].

*Vaccinium myrtillus* (Likapa), especially berry is a fruit grown in the eastern Black Sea region of Turkey. *Vaccinium myrtillus* has high antioxidant capacity and contains abundant phenolic components. It is attributed to its antioxidant properties with a high protective effect against some chronic diseases such as cancer, cardio and cerebrovascular diseases, atherosclerosis, and diabetes [24, 25].

Edible films containing plant-based natural polymers, antioxidants, and antimicrobial components are being developed and used with new applications to extend the shelf life of foods and reduce the use of synthetic packaging materials [26, 27]. Many studies have focused on the development of edible films using natural antioxidants and antimicrobial sources and their use as packaging materials [7, 15, 27, 28].

In the literature, although there are many studies on the use of various additives and packaging techniques to extend the shelf life of foods, there are not enough studies for seafood products coated with biodegradable materials obtained by combining edible films and herbal extracts. This study was conducted to protect mussels, which are an important source of nutritional value, by using biodegradable materials obtained by combining herbal extracts containing antioxidant and antimicrobial properties and edible films, and to prolong shelf life.

## MATERIALS AND METHODS

**Preparation of Samples.** The samples of black mussels (*Mytilus galloprovincialis* Lamarck, 1819) used in the study were collected by hand at a depth of 6-8 meters in the port of Cayeli district of Rize, a Black Sea coastal city. Dead and damaged mussels were separated. The mussels were stored in styrofoam boxes with an ice / mussel ratio of 3: 1.

Harvested mussels were brought to the Recep Tayyip Erdogan University Fisheries Faculty Processing Technology Laboratory within 1 hour. Foreign particles on it were brushed and cleaned under tap water. The average width was 74.01 ± 6.9mm and the average weight was 41.61 ± 12.9 g (MarCal 16 ER digital micrometer).

**Extraction of Plants and Formulation of Films.** Heaven persimmon (*Diospyros kaki*) sepals, cherry laurel (*Laurocerasus officinalis*) leaves and likapa (*Vaccinium myrtillus*) leaves were collected in Rize / Turkey (41°08'92.9"K; 40°72'10.7"D) in the months of April and May, and dried in the oven at 60°C. The samples were prepared by powdering with a laboratory type grinder and shaking in a water bath at 40°C for 24 hours at 2.5% and 5% concentrations with pure water. The prepared extracts were then filtered through coarse filter paper. The films were prepared by mixing and boiling 6.5 g starch, 6.5 g glycerol, 100 ml pure water and 100 ml extract. In forming films, glycerol and starch were used as thickeners. Mussels were divided into 8 groups, the first group control (K), the second group formed as products coated with edible films containing 5% vitamin C (C), the third group containing 2.5% heaven persimmon (HA), the fourth group containing 5% heaven persimmon (HB), the fifth group containing 2.5% likapa (LA), the sixth group containing 5% likapa (LB), the seventh group containing 2.5% cherry laurel (KA), and the eighth group containing 5% cherry laurel (KB). The films were rubbed onto the product surface with a brush without any gaps. They were then stored under refrigerator conditions (+ 4°C).

**Mechanical and Characteristic Properties of Edible Films.** The thickness of the films was determined from 5 different places using digital micrometer (MarCal 16 ER digital micrometer). The moisture content of edible films was determined according to [29]. Tensile strength (TS) and rupture elongation (EAB) of edible films were measured in the universal test device (Zwick Roell, Germany). The water vapor permeability (WVP) of the films was measured using the modified method of the ASTM (1989) method specified by [30]. The films were placed in a desiccant saturated with water vapor at 25°C, with the aid of the ring, fastening the mouth of the test tubes containing silica gel (0% RH). It was weighed at 24-hour intervals over a 7-day period and the WVP of the films was calculated according to the formula below.

$WVP = W \times A^{-1} \times t^{-1} \times (P_2\text{-}P_1)^{-1}$

W: weight gain of the container (g), A: exposed film area ($m^2$), t: time and ($P_2$-$P_1$): vapor pressure differential on the film (Pa) [31].

The water solubility of the film samples was determined according to the method modified by [32]. The film samples were cut homogeneously (2 cm x 2 cm) and dried at 105°C for 24 hours and weighed. The first dry weight-determined film was placed in a plastic petri dish containing distilled water and dried in an oven at 105°C for 24 hours. The resolution of the films was calculated using the equation [WS (%)] = [($W_0$- $W_f$) / $W_0$] × 100. ($W_0$: initial weight of the film, $W_f$: final weight of the films, WS: water solubility of the films).

**Nutritional Analysis.** The moisture, crude ash, crude protein, and moisture content of the coated mussel products were determined according to [29]. The crude oil value was determined using soxhlet methods [33].

**Biochemical Analysis.** The pH values of mussel samples were determined with a pH meter (Hanna, HI 3220) according to [34]. Color measurements were made with the spectral color meter Spectropen R (Dusseldorf, Germany). Before the samples were measured, the colorimeter was calibrated to a white standard (LZM 224). The color was measured on homogenates prepared from mussels. The homogenate was placed in glass petri dishes and the color measurement was repeated five times. In the CIELab system, L * indicates lightness at a scale of 0–100, from black to white; a *, (+) red or (-) green and b *, (+) yellow or (-) blue [35]. Total volatile basic nitrogen (TVB-N) was determined according to the [36] and using the thiobarbituric acid (TBA) analysis [37] method.

**Microbiological Analysis.** 25 grams of mussel meat was mixed with 225 ml of 0.8% physiological saline solution (FTS). All dilution series were prepared at 0.8% FTS. Total viable mesophilic and total psychrophilic microorganism numbers were determined by spreading plate counting method by incubating 48 hours at 37°C and 10 days at 4°C, respectively [38].

**Statistical analysis.** The data obtained in the study were taken as mean ± standard deviation of the parallels of the results (n: 2-3). To determine the difference between the samples, the groups were found to have homogeneous variance test. For this materiality test, the 'One Way Anova' test was applied and the degree of significance was used as $p<0.05$. JMP 5.0.1 SAS (SAS Instute Inc, NC, USA) package program was used in the statistical analysis [39].

## RESULTS

**Mechanical Properties and Values of Edible Films.** The moisture content, density and thickness values and tensile strength (TS), elongation (EB), water vapor permeability (WVP), water solubility (WS) and swelling degree (SD) values of the edible

**TABLE 1**
**Some Characteristic Features of Edible Films**

| | TS (MPa) | EB (%) | WVP×10$^{-10}$ (g $H_2O$ $Pa^{-1}s^{-1}m^{-1}$) | WS (%) | SD (%) |
|---|---|---|---|---|---|
| **K** | 0.40±0.03$^{bc}$ | 21.99±2.17$^{a}$ | 0.42±0.05$^{a}$ | 61.08±0.86$^{ab}$ | 46.73±0.51$^{b}$ |
| **HA** | 0.56±0.06$^{ab}$ | 39.09±6.81$^{a}$ | 0.57±0.38$^{a}$ | 62.92±0.50$^{a}$ | 40.18±0.27$^{c}$ |
| **HB** | 0.61±0.10$^{a}$ | 34.05±10.23$^{a}$ | 0.41±0.02$^{a}$ | 56.71±0.79$^{c}$ | 59.62±0.97$^{a}$ |
| **LA** | 0.32±0.03$^{c}$ | 34.07±7.15$^{a}$ | 0.34±0.01$^{a}$ | 60.01±0.59$^{b}$ | 36.11±0.85$^{de}$ |
| **LB** | 0.46±0.06$^{abc}$ | 31.97±3.63$^{a}$ | 0.49±0.08$^{a}$ | 63.10±0.59$^{a}$ | 38.91±0.83$^{cd}$ |
| **KA** | 0.52±0.04$^{ab}$ | 21.43±3.68$^{a}$ | 0.35±0.09$^{a}$ | 58.97±0.56$^{bc}$ | 35.79±0.62$^{e}$ |
| **KB** | 0.47±0.04$^{abc}$ | 27.54±0.66$^{a}$ | 0.38±0.04$^{a}$ | 61.30±0.57$^{ab}$ | 36.88±0.73$^{de}$ |

The different small subscript letters (a, b, c, …) in the same column represent statistical differences detected ($p<0.05$). Values are mean ± standard deviation. K: Control group, HA: Edible film containing %2.5 persimmon extract HB: Edible film containing %5 persimmon extract, LA: Edible film containing %2.5 blueberry extract, LB: Edible film containing %5 blueberry extract, KA: Edible film containing %2.5 cherry laurel extract, KB: Edible film containing %5 cherry laurel extract.

**TABLE 2**
**Moisture, Density and Thickness Values of Edible Films**

| | Moisture (%) | Density (g/cm$^3$) | Thickness (Mm) |
|---|---|---|---|
| **K** | 42.27±0.69$^{ab}$ | 2.45±0.26$^{a}$ | 0.02±0.00$^{a}$ |
| **HA** | 41.72±0.39$^{ab}$ | 1.73±0.01$^{a}$ | 0.03±0.00$^{a}$ |
| **HB** | 34.44±0.37$^{d}$ | 1.97±0.11$^{a}$ | 0.04±0.00$^{a}$ |
| **LA** | 37.58±0.54$^{c}$ | 1.78±0.12$^{a}$ | 0.03±0.00$^{a}$ |
| **LB** | 41.70±0.63$^{ab}$ | 2.12±0.27$^{a}$ | 0.04±0.00$^{a}$ |
| **KA** | 43.09±0.21$^{a}$ | 2.11±0.04$^{a}$ | 0.03±0.00$^{a}$ |
| **KB** | 40.21±0.68$^{b}$ | 2.07±0.37$^{a}$ | 0.03±0.00$^{a}$ |

The different small subscript letters (a, b, c, …) in the same column represent statistical differences detected ($p<0.05$). Values are mean ± standard deviation. K: Control group, HA: Edible film containing %2.5 persimmon extract HB: Edible film containing %5 persimmon extract, LA: Edible film containing %2.5 blueberry extract, LB: Edible film containing %5 blueberry extract, KA: Edible film containing %2.5 cherry laurel extract, KB: Edible film containing %5 cherry laurel extract.

films used in lining of mussels are given in Table 1. In the prepared films, it has been observed that extracts used except LA herbal extract increase strength and LA extract decreases strength. Tensile strength values of films were found to be HB> HA> KA> KB> LB> K> LA, respectively. It was observed that there were statistical differences between the tensile strength values of the prepared films ($p<0.05$). In the study conducted, the elongation at break varies between 39.09% and 21.43%. The lowest rupture elongation is seen in the control and KA groups. It can be said that vegetable extracts are resistant to rupture by looking at the values of rupture elongation. Breaking elongation values are listed as HA> LA> HB> LB> KB> K> KA. There was no statistical difference between the breaking elongation values of the prepared films ($p>0.05$).

The lowest water vapor permeability value was observed in the LA group with 0.34 g $H_2O$ $Pa^{-1}s^{-1}$ $m^{-1}$. The highest group is in the HA group with 0.57 g $H_2O$ $Pa^{-1}s^{-1}m^{-1}$. Water vapor permeability values were found to be HA>LB>K>HB>KB>KA>LA, respectively. There was no statistical difference between water vapor permeability of edible films ($p>0.05$). The solubility values in water were found to be 63.10% at the highest level and 56.71% at the lowest level. It can be said that the herbal extracts added to the films do not affect the water solubility of the films much. In the study, a statistically significant difference was found between water solubility values ($p<0.05$).

It can be said that the herbal extracts added to the films reduce the degree of swelling relatively. The lowest value (35.79%) was found in edible films with KA and the highest value (59.62%) was added in HB. From a statistical point of view, the difference between the swelling degrees of edible films was found to be significant ($p<0.05$). The moisture, thickness and density values of edible films are given in Table 2.

When the moisture content of edible films was examined, the highest moisture content was determined to be 43.09% in KA doped film and the lowest moisture content was determined to be 34.44% in HB doped film. When the density values of the films were compared, the highest and lowest amounts were determined to be 2.45 g / cm$^3$ and 1.73 g / cm$^3$ in Control (K) and HA doped films, respectively. Looking at the thickness values of the films, it can be said that they vary between 0.02 mm and 0.04 mm. While a difference was observed between the moisture content of the edible films statistically ($p<0.05$), it was determined that the vegetable extract additive did not affect the density and thickness values statistically ($p>0.05$). Color values of mussels covered with edible films with herbal extract additives are given in Table 3. L, a, and b color values of edible film without extract additive could not be measured because it did not fall within the measuring range of the device. In additive films, the L value

**TABLE 3**
**Color Values of Edible Films**

| | L | a | b |
|---|---|---|---|
| **K** | Measurement failed | Measurement failed | Measurement failed |
| **HA** | $63.68\pm0.76^{b}$ | $25.04\pm0.46^{d}$ | $28.46\pm0.48^{e}$ |
| **HB** | $59.90\pm0.34^{c}$ | $27.82\pm0.89^{c}$ | $33.37\pm0.29^{d}$ |
| **LA** | $54.46\pm0.99^{e}$ | $36.17\pm0.87^{b}$ | $57.68\pm0.81^{b}$ |
| **LB** | $50.86\pm0.49^{f}$ | $39.47\pm0.41^{a}$ | $62.88\pm0.77^{a}$ |
| **KA** | $57.62\pm0.57^{d}$ | $21.08\pm0.45^{e}$ | $36.08\pm0.63^{c}$ |
| **KB** | $67.44\pm0.78^{a}$ | $25.73\pm0.37^{d}$ | $32.60\pm0.63^{d}$ |

The different small subscript letters (a, b, c, …) in the same column represent statistical differences detected ($p<0.05$). Values are mean ± standard deviation. K: Control group, HA: Edible film containing %2.5 persimmon extract HB: Edible film containing %5 persimmon extract, LA: Edible film containing %2.5 blueberry extract, LB: Edible film containing %5 blueberry extract, KA: Edible film containing %2.5 cherry laurel extract, KB: Edible film containing %5 cherry laurel extract.

**TABLE 4**
**Biochemical Changes of Mussels Coated with Edible Film Containing Different Herbal Extracts**

| Days | Groups | Moisture (%) | Glycogen (%) | Crude Ash (%) | Crude Protein (%) | Crude Fat (%) |
|---|---|---|---|---|---|---|
| **Fresh** | **K** | $76.94\pm0.30_{A}$ | $1.95\pm0.88_{B}$ | $1.62\pm0.25_{A}$ | $16.42\pm0.64_{A}$ | $2.36\pm0.04_{A}$ |
| **2** | **K** | $77.32\pm0.64^{bc}{}_{A}$ | $3.82\pm0.91^{a}{}_{B}$ | $1.50\pm0.12^{a}{}_{A}$ | $16.30\pm0.63^{ab}{}_{A}$ | $2.42\pm0.31^{a}{}_{A}$ |
| | **C** | $79.66\pm0.39^{ab}{}_{A}$ | $2.62\pm0.79^{ab}{}_{B}$ | $1.41\pm0.23^{a}{}_{A}$ | $13.65\pm0.87^{bcd}{}_{A}$ | $2.10\pm0.10^{a}{}_{A}$ |
| | **HA** | $77.13\pm0.58^{c}{}_{A}$ | $4.95\pm0.52^{a}{}_{A}$ | $1.58\pm0.16^{a}{}_{A}$ | $13.66\pm0.71^{bcd}{}_{A}$ | $2.32\pm0.08^{a}{}_{A}$ |
| | **HB** | $76.32\pm0.74^{c}{}_{A}$ | $3.68\pm0.74^{ab}{}_{B}$ | $1.43\pm0.10^{a}{}_{A}$ | $15.47\pm0.53^{abc}{}_{A}$ | $2.05\pm0.44^{a}{}_{A}$ |
| | **LA** | $79.71\pm0.82^{ab}{}_{A}$ | $4.49\pm0.57^{a}{}_{B}$ | $1.45\pm0.51^{a}{}_{A}$ | $11.65\pm0.91^{d}{}_{A}$ | $2.30\pm0.08^{a}{}_{A}$ |
| | **LB** | $78.64\pm0.66^{abc}{}_{A}$ | $3.74\pm0.05^{ab}{}_{B}$ | $1.18\pm0.04^{a}{}_{A}$ | $14.20\pm0.67^{abcd}{}_{A}$ | $2.25\pm0.00^{a}{}_{A}$ |
| | **KA** | $78.47\pm0.16^{abc}{}_{A}$ | $1.69\pm0.52^{b}{}_{B}$ | $1.36\pm0.08^{a}{}_{A}$ | $16.46\pm0.54^{a}{}_{A}$ | $2.38\pm0.25^{a}{}_{A}$ |
| | **KB** | $80.21\pm0.76^{a}{}_{A}$ | $3.29\pm0.73^{ab}{}_{A}$ | $1.44\pm0.44^{a}{}_{A}$ | $13.16\pm0.63^{cd}{}_{A}$ | $1.93\pm0.34^{a}{}_{A}$ |
| **4** | **K** | $73.41\pm0.80^{d}{}_{B}$ | $9.45\pm0.66^{a}{}_{A}$ | $2.45\pm0.85^{a}{}_{A}$ | $13.37\pm0.55^{a}{}_{B}$ | $1.43\pm0.26^{b}{}_{A}$ |
| | **C** | $77.83\pm0.52^{ab}{}_{B}$ | $7.68\pm0.57^{ab}{}_{A}$ | $1.26\pm0.47^{a}{}_{A}$ | $12.38\pm0.06^{a}{}_{A}$ | $1.26\pm0.49^{b}{}_{A}$ |
| | **HA** | $75.81\pm0.^{85bc}{}_{A}$ | $6.15\pm0.53^{b}{}_{A}$ | $1.94\pm0.15^{a}{}_{A}$ | $13.67\pm0.15^{a}{}_{A}$ | $2.42\pm0.02^{a}{}_{A}$ |
| | **HB** | $78.34\pm0.65^{a}{}_{A}$ | $7.33\pm0.63^{ab}{}_{A}$ | $1.86\pm0.50^{a}{}_{A}$ | $13.47\pm0.65^{a}{}_{A}$ | $1.74\pm0.30^{ab}{}_{A}$ |
| | **LA** | $79.59\pm0.53^{a}{}_{A}$ | $7.88\pm0.66^{ab}{}_{A}$ | $1.80\pm0.79^{a}{}_{A}$ | $9.65\pm0.50^{b}{}_{A}$ | $1.76\pm0.32^{ab}{}_{A}$ |
| | **LB** | $76.01\pm0.40^{bc}{}_{B}$ | $7.82\pm0.42^{ab}{}_{A}$ | $1.80\pm0.06^{a}{}_{A}$ | $12.55\pm0.14^{a}{}_{A}$ | $1.82\pm0.22^{ab}{}_{A}$ |
| | **KA** | $74.79\pm0.54^{cd}{}_{B}$ | $6.86\pm0.58^{b}{}_{A}$ | $2.42\pm0.16^{a}{}_{A}$ | $13.90\pm0.34^{a}{}_{B}$ | $2.01\pm0.32^{ab}{}_{A}$ |
| | **KB** | $77.79\pm0.37^{ab}{}_{A}$ | $5.70\pm0.45^{b}{}_{A}$ | $1.53\pm0.11^{a}{}_{A}$ | $13.10\pm0.59^{a}{}_{A}$ | $1.88\pm0.11^{ab}$ |

The different subscript capital letters (A, B, C, …) in the same column represent statistical differences detected within the same group in different storage period ($p<0.05$). The different small subscript letters (a, b, c, …) in the same column represent statistical differences detected among groups in the same storage day ($p<0.05$). Values are mean ± standard deviation. K: Control group, C: Edible film covered group with vitamin C, HA: Mussels covered with edible film containing %2.5 persimmon extract HB: Mussels covered with edible film containing %5 persimmon extract, LA: Mussels covered with edible film containing %2.5 blueberry extract, LB: Mussels covered with edible film containing %5 blueberry extract, KA: Mussels covered with edible film containing %2.5 cherry laurel extract, KB: Mussels covered with edible film containing %5 cherry laurel extract.

was highest in the KB group with 67.44 and the lowest in 50.86. Considering a value, it was found in the LB group with the highest value of 39.47 and in the KA group with the lowest value of 21.08. Considering b value, it was found in the LB group with the highest value of 62.88, and in the HA group with the lowest value of 28.46. When the statistical findings were examined, it was found that there were differences between the color values of edible films ($p<0.05$).

**Nutritional, Biochemical and Microbiological Analysis Values.** The average height and weight of the mussels we used in the study were measured as 74.02 ± 6.9 mm and 41.61 ± 12.6g, respectively, and the meat yield was determined to be 18.68%. In the study, biochemical analysis of mussel meat covered with edible films with herbal extract added was performed. Moisture, glycogen, crude ash, crude protein, and crude oil values are given in Table 4, pH, water activity ($a_w$), total volatile basic nitrogen (TVB-N) and thiobarbituric acid (TBA) values are given in Table 5. Mussels were found in the HB group with the lowest rate of 76.32% on the 2nd day, while the highest moisture was found in the KB group with the rate of 80.21%. On the 4th day of the study, the lowest moisture rate was found in the control group with 73.41%, while the highest moisture rate was found in the LA group with 79.59%. When analyzed statistically, the difference both within the group and between the groups was found to be significant ($p<0.05$). However, it is predicted that the observed changes do not express clearness and clarity. When the % glycogen values obtained because of the analysis are examined, the highest and lowest values of the 2nd day were found in the HA group with 4.95% and KA with 1.69%, respectively. On the 4th day of the study, the lowest and highest values were determined in the KB group with 5.70% and K group with 9.45%, respectively. When the glycogen amounts were analyzed statistically, the difference between the group and within the groups was found

to be significant ($p<0.05$). The highest and lowest values in the raw ash values of the mussels covered with edible film were observed in the control group with 2.45% and in the C group with 1.26%, respectively, on the 4th day of the study. There was no statistically significant difference in crude ash values ($p>0.05$). The lowest protein rate of mussels was seen on the 2nd day of the LA group with 11.65%, and the highest protein rate was in the KA group with 16.46%. On the 4th day, the amount of protein was determined to be in the KA group with the highest rate of 13.90% and the lowest rate of 9.65% in the LA group. When protein ratios were analyzed statistically, it was found that intra-group differences were significant on the 2nd and 4th days ($p<0.05$), but the difference between the groups was not significant ($p>0.05$). Considering the crude oil values, the highest oil values were found to be 2.42% in the K and HA groups, on the 2nd and 4th days, while the lowest oil values were 1.93% and 1.26% in the KB and C groups, respectively. When the crude oil values were analyzed statistically, it was determined that the difference in the group was significant on the 4th day ($p<0.05$), and the difference between the groups and on the 2nd was not significant ($p>0.05$).

The pH values of the mussels used in the study were determined to be 6.05 in the highest fresh product, while the lowest one was in the LA group at 4.53 and 4 days (Table 5). Considering the water activity values, which are called suitable water environments in which microorganisms can reproduce, the lowest value was seen in the LA group with value of 0.9885 on the 2nd day, while the highest value was found in the KA group with the 0.9960 on the 2nd day. TVB-N and TBA values obtained from the analyzes for black mussels covered with edible film are given in Table 5. TVB-N value determined for fresh mussels is 5.60 mg / 100g. TVB-N increased significantly on the 4th day of storage. At the end of the storage period, the highest TVB-N value detected in mussels covered with edible film was in the group covered with KA with a value of 49.73 mg / 100g. On the last day of storage, the lowest TVB-N value was found in the LB group with a value of 33.20 mg / 100g. According to the data obtained, it was observed that HB, LB and KB samples were not exceeded the consumable limit value on TVB-N and K, C, HA, LA, KA samples exceeded the consumable limit value on TVB-N of 35 mg / 100 on the 4th day. When the TBA values of the mussels were analyzed, it was seen that the TBA values increased on the last day of storage. On the 4th day of the study, the highest TBA value was found in the HA group as 2.52 mg MA / kg, while the lowest TBA value was found in the LB group as 1.49 mg MA / kg. In terms of TBA values, it was seen that all results did not exceed the good value of 3 mg MA / kg consumable limit. In the study, when the pH, water activity and TVB-N findings were analyzed statistically, it was determined that the differences between the groups and within the groups were significant ($p<0.05$). Although the statistical difference in TBA findings was not significant ($p>0.05$), when TBA values were examined, it was observed that some groups showed lower values than other groups.

**TABLE 5**
**The Results of Ph, TVB-N and TBA Analysis of Mussels Covered with Edible Film**

| Days | Groups | pH | Water Activity ($a_w$) | TVB-N (mg/100g) | TBA (mgMA/kg) |
|---|---|---|---|---|---|
| **Fresh** | **K** | $6.05\pm0.01^{A}$ | $0.9867\pm0.00^{A}$ | $5.60\pm0.00^{C}$ | $0.55\pm0.15^{C}$ |
| **2** | **K** | $5.40\pm0.02^{bc}{}_{B}$ | $0.9892\pm0.00^{cd}{}_{A}$ | $21.01\pm0.00^{bc}{}_{B}$ | $1.58\pm0.03^{a}{}_{B}$ |
| | **C** | $5.04\pm0.00^{d}{}_{A}$ | $0.9894\pm0.00^{bcd}{}_{A}$ | $14.71\pm0.99^{d}{}_{B}$ | $1.65\pm0.05^{a}{}_{A}$ |
| | **HA** | $5.49\pm0.06^{ab}{}_{A}$ | $0.9946\pm0.00^{ab}{}_{A}$ | $14.71\pm0.99^{d}{}_{B}$ | $1.86\pm0.25^{a}{}_{A}$ |
| | **HB** | $5.32\pm0.02^{c}{}_{A}$ | $0.9941\pm0.00^{abc}{}_{A}$ | $14.01\pm0.00^{d}{}_{B}$ | $1.37\pm0.39^{a}{}_{A}$ |
| | **LA** | $5.52\pm0.04^{a}{}_{A}$ | $0.9885\pm0.00^{d}{}_{A}$ | $24.52\pm0.99^{e}{}_{B}$ | $1.35\pm0.13^{a}{}_{A}$ |
| | **LB** | $5.52\pm0.01^{a}{}_{A}$ | $0.9934\pm0.00^{abcd}{}_{A}$ | $18.83\pm0.62^{ab}{}_{B}$ | $0.83\pm0.09^{a}{}_{A}$ |
| | **KA** | $5.46\pm0.00^{ab}{}_{A}$ | $0.9960\pm0.00^{a}{}_{A}$ | $7.00\pm0.00^{a}{}_{B}$ | $1.61\pm0.50^{a}{}_{A}$ |
| | **KB** | $5.44\pm0.01^{ab}{}_{A}$ | $0.9896\pm0.00^{bcd}{}_{A}$ | $22.41\pm0.00^{c}{}_{B}$ | $1.68\pm0.06^{a}{}_{A}$ |
| **4** | **K** | $4.76\pm0.01^{ab}{}_{C}$ | $0.9877\pm0.00^{a}{}_{A}$ | $39.05\pm0.74^{d}{}_{A}$ | $2.48\pm0.03^{a}{}_{A}$ |
| | **C** | $4.75\pm0.11^{ab}{}_{A}$ | $0.9885\pm0.00^{a}{}_{A}$ | $46.23\pm0.00^{b}{}_{A}$ | $2.18\pm0.28^{a}{}_{A}$ |
| | **HA** | $4.77\pm0.07^{a}{}_{A}$ | $0.9907\pm0.00^{a}{}_{B}$ | $42.69\pm0.81^{c}{}_{A}$ | $2.52\pm0.60^{a}{}_{A}$ |
| | **HB** | $4.67\pm0.02^{ab}{}_{B}$ | $0.9896\pm0.00^{a}{}_{B}$ | $33.45\pm0.74^{e}{}_{A}$ | $2.21\pm0.65^{a}{}_{A}$ |
| | **LA** | $4.53\pm0.02^{b}{}_{B}$ | $0.9914\pm0.00^{a}{}_{A}$ | $46.93\pm0.99^{a}{}_{A}$ | $1.63\pm0.30^{a}{}_{A}$ |
| | **LB** | $4.68\pm0.06^{ab}{}_{B}$ | $0.9933\pm0.00^{a}{}_{A}$ | $33.20\pm0.40^{e}{}_{A}$ | $1.49\pm0.24^{a}{}_{A}$ |
| | **KA** | $4.68\pm0.04^{ab}{}_{B}$ | $0.9893\pm0.00^{a}{}_{A}$ | $49.73\pm0.99^{ab}{}_{A}$ | $2.18\pm0.21^{a}{}_{A}$ |
| | **KB** | $4.68\pm0.07^{ab}{}_{B}$ | $0.9915\pm0.00^{a}{}_{A}$ | $34.50\pm0.74^{e}{}_{A}$ | $1.94\pm0.18^{a}{}_{A}$ |

The different subscript capital letters (A, B, C, …) in the same column represent statistical differences detected within the same group in different storage period ($p<0.05$). The different small subscript letters (a, b, c, …) in the same column represent statistical differences detected among groups in the same storage day ($p<0.05$). Values are mean ± standard deviation. K: Control group, C: Edible film covered group with vitamin C, HA: Mussels covered with edible film containing %2.5 persimmon extract HB: Mussels covered with edible film containing %5 persimmon extract, LA: Mussels covered with edible film containing %2.5 blueberry extract, LB: Mussels covered with edible film containing %5 blueberry extract, KA: Mussels covered with edible film containing %2.5 cherry laurel extract, KB: Mussels covered with edible film containing %5 cherry laurel extract

**TABLE 6**
**The Results of Color Analysis of Mussels Covered with Edible Film**

| Days | Groups | L | a | b |
|---|---|---|---|---|
| **Fresh** | **K** | $48.06\pm0.86_{C}$ | $13.9\pm0.6_{A}$ | $27.1\pm0.7_{B}$ |
| **2** | **K** | $58.14\pm0.75^{a}_{A}$ | $11.2\pm0.4^{d}_{B}$ | $26.4\pm0.7^{c}_{B}$ |
| | **C** | $47.37\pm0.66^{c}_{A}$ | $13.0\pm0.7^{c}_{B}$ | $24.0\pm0.5^{d}_{B}$ |
| | **HA** | $50.48\pm0.97^{b}_{A}$ | $13.9\pm0.3^{bc}_{A}$ | $28.8\pm0.4^{a}_{A}$ |
| | **HB** | $57.52\pm0.91^{a}_{A}$ | $14.4\pm0.4^{b}_{A}$ | $29.3\pm0.6^{a}_{A}$ |
| | **LA** | $45.76\pm0.83^{c}_{A}$ | $13.5\pm0.8^{bc}_{A}$ | $28.3\pm0.7^{ab}_{A}$ |
| | **LB** | $43.99\pm0.94^{d}_{B}$ | $12.8\pm0.6^{c}_{A}$ | $24.0\pm0.5^{d}_{B}$ |
| | **KA** | $51.65\pm0.80^{b}_{A}$ | $15.9\pm0.7^{a}_{A}$ | $28.4\pm0.8^{ab}_{A}$ |
| | **KB** | $51.63\pm0.85^{b}_{A}$ | $12.8\pm1.0^{c}_{A}$ | $27.3\pm0.6^{bc}_{A}$ |
| **4** | **K** | $53.30\pm0.90^{a}_{B}$ | $13.9\pm0.8^{b}_{A}$ | $28.1\pm0.4^{a}_{A}$ |
| | **C** | $49.06\pm0.55^{b}_{B}$ | $17.1\pm0.7^{a}_{A}$ | $26.8\pm0.9^{ab}_{A}$ |
| | **HA** | $48.93\pm0.98^{b}_{B}$ | $13.8\pm0.6^{b}_{A}$ | $28.0\pm1.0^{a}_{A}$ |
| | **HB** | $41.03\pm0.82^{e}_{B}$ | $13.5\pm0.5^{bc}_{B}$ | $23.4\pm0.9^{d}_{A}$ |
| | **LA** | $44.56\pm0.86^{d}_{A}$ | $14.4\pm0.8^{b}_{A}$ | $25.0\pm0.6^{c}_{B}$ |
| | **LB** | $47.05\pm0.98^{c}_{A}$ | $13.0\pm0.9^{bc}_{A}$ | $25.5\pm0.8^{bc}_{A}$ |
| | **KA** | $47.22\pm0.46^{c}_{B}$ | $12.3\pm0.7^{c}_{B}$ | $23.3\pm0.4^{d}_{B}$ |
| | **KB** | $44.20\pm0.59^{d}_{B}$ | $13.5\pm0.6^{bc}_{A}$ | $22.4\pm1.0^{d}_{B}$ |

The different subscript capital letters (A, B, C, …) in the same column represent statistical differences detected within the same group in different storage period ($p<0.05$). The different small subscript letters (a, b, c, …) in the same column represent statistical differences detected among groups in the same storage day ($p<0.05$). Values are mean ± standard deviation. K: Control group, C: Edible film covered group with vitamin C, HA: Mussels covered with edible film containing %2.5 persimmon extract HB: Mussels covered with edible film containing %5 persimmon extract, LA: Mussels covered with edible film containing %2.5 blueberry extract, LB: Mussels covered with edible film containing %5 blueberry extract, KA: Mussels covered with edible film containing %2.5 cherry laurel extract, KB: Mussels covered with edible film containing %5 cherry laurel extract

**TABLE 7**
**Microbiological Changes of Edible Film Packaged Mussels**

| | **Total Mezofil bacteria counts (log CFU/g)** | | **Total Psychrophilic bacteria counts (log CFU/g)** | |
|---|---|---|---|---|
| **Fresh** | 2.24 | | 2.00 | |
| | **2. day** | **4. day** | **2. day** | **4. day** |
| **K** | $5.53\pm0.05^{cd}$ | >7 | $4.53\pm0.05^{a}$ | >7 |
| **C** | $5.91\pm0.05^{ab}$ | >7 | $4.51\pm0.05^{a}$ | >7 |
| **HA** | $5.48\pm0.16^{d}$ | >7 | $4.59\pm0.05^{a}$ | >7 |
| **HB** | $5.97\pm0.04^{ab}$ | >7 | $4.48\pm0.02^{a}$ | >7 |
| **LA** | $5.74\pm0.03^{ab}$ | >7 | $4.62\pm0.02^{a}$ | >7 |
| **LB** | $5.83\pm0.01^{ab}$ | >7 | $4.58\pm0.05^{a}$ | >7 |
| **KA** | $5.72\pm0.03^{a}$ | >7 | $4.58\pm0.04^{a}$ | >7 |
| **KB** | $5.84\pm0.02^{bc}$ | >7 | $4.54\pm0.10^{a}$ | >7 |

The different small subscript letters (a, b, c, …) in the same column represent statistical differences detected among groups in the same storage day ($p<0.05$). Values are mean ± standard deviation. K: Control group, C: Edible film covered group with vitamin C, HA: Mussels covered with edible film containing %2.5 persimmon extract HB: Mussels covered with edible film containing %5 persimmon extract, LA: Mussels covered with edible film containing %2.5 blueberry extract, LB: Mussels covered with edible film containing %5 blueberry extract, KA: Mussels covered with edible film containing %2.5 cherry laurel extract, KB: Mussels covered with edible film containing %5 cherry laurel extract

Color analysis results of mussels covered with edible films with herbal extract additives are given in Table 6. L, a, and b color values of fresh mussel samples were found to be 48.6, 13.9 and 27.1, respectively. Considering the results of the analysis on the 2nd day, the highest and lowest L values were found in the K group to be 58,14 and LB with 43.99, respectively. Considering the "a values" on the 2nd day, the highest and the lowest values were found in the groups KA and K to be 15.9 and 11.2, respectively. On the 2nd day, the lowest b values were found in the groups C and LB to be 24,0 and highest values were found in the groups HB to be 29.3. On the 4th day, L values were between 41.03 and 53.30, a value were between 12.3 and 17.1, and b values were between 22.4 and 28.1. There was a statistically difference between color analysis results ($p<0.05$).

Microbiological analysis results of mussels used in the study are given in Table 7. The total number of aerobic mesophilic bacteria of fresh mussels was 2.24 log CFU / g. On the 2nd day of storage, the lowest total number of bacteria was 5.48 log CFU / g in the HA group with, and the highest total number was 5.97 log CFU / g in the HB group with. On the 4th day of storage, all groups exceeded the limit val-

ues that can be consumed. The total aerobic psychrophilic number of fresh mussels was 2.00 log CFU / g. On the second day of storage, the lowest total aerobic psychrophilic number was 4.48 log CFU / g in the HB group with, and the highest total aerobic psychrophilic number was 4.62 log CFU / g in the LA group with. When analyzed statistically, on the 2nd day, there was a significant difference between the total number of mesophyll bacteria ($p<0.05$), but no difference was observed between the total number of psychrophile bacteria ($p>0.05$).

## DISCUSSION AND CONCLUSION

In addition to the contribution of edible films to be used in food coating to the shelf life, it should be in a structure that will protect it from external influences and ensure its structural integrity during the transportation of food [40]. [40] determined that herbal extracts reduce the TS and EB properties of edible films, but [41] found that they increased their elastic properties, and this situation may be due to the structures formed by the covalent cross-links of phenolic compounds in herbal extracts. [42] stated in their study that using gelatin with high molecular weight increases the flexibility of edible films. In the study, it was observed that herbal extracts increase elastic properties similarly with this situation. It cannot be said that herbal extracts have a positive or negative contribution to the water vapor permeability of edible films in our study. [40] stated that they obtained results like this situation in their study. Similar results have been found in literature studies [41, 43-45]. Considering the studies conducted in the literature, the lowest and highest values for TS were found between 11,10 MPa and 46.96 MPa by [44], between 27.7 MPa and 35.1 MPa by [45], and between 1.7 MPa and 4.2 MPa by [41]. TS results obtained in the study ranged between 0.32 MPa and 0.61 MPa. Considering the highest and lowest EB values, respectively, [44] found it between 1.68% and 5.92%, [45] found it between 22.2% and 36.5%, and [41] found it between 0.1% and 65%. The EB results we obtained in the study ranged between 21.43% and 39.09%. When looking at the thickness values of edible films, [44] found it between 0.029mm and 1.05mm, while [45] found it between 0.075mm and 0.080mm. The thickness results obtained in the study ranged between 0.02 mm and 0.04 mm. Edible films can be obtained in many ways and applied to the product. These come out as pouring, spraying, dipping, dripping, and foaming. In these methods, the thickness of the film may differ. Edible films in the study were thinner and consequently TS results were lower compared to the literature, while EB values showed similar results with other studies. Considering the resolution values (WS), [46] in his study, revealed that the lowest and highest resolution value were 49.9% and 75.3%, [30] found these values to 75.1% and 76.9%, while [47] found them to be % 37.33 and 50.85%. The resolution values of our study were found to be between 56,71-63,10%, and it was found that they did not differ from other studies. The degree of swelling (SD) was found between 98% and 233% by [48], between 52.9% and 109% by [49], and between 11.30% and 52.82% by [50]. In our study, the degree of swelling was found to be the highest in the HB group with the rate of 59.62% and the lowest in the KA group with the rate of 35.79%. The results obtained were in line with the literature studies. The moisture content of the edible films obtained in the study varies between 34.44% and 43.09%. [51] found the moisture between 32% and 52% in their study, while [52] determined it between 5.44% and 27.92% in their study. In the findings obtained, similarity was observed compared to some studies, while in some studies differences were determined. This difference is thought to have occurred due to film production and techniques. Density values of the films prepared in the study vary between 1.73 g / $cm^3$ and 2.45 g / $cm^3$. Although there is no statistically significant difference in the density values in the study, it can be said that the vegetable extracts have a low effect on the density value. It is seen that there are very small characteristic differences between the films and this difference is expected to occur depending on the pouring method of the films and other applied methods. When analyzed statistically, it is seen that there is no difference between EB, WVP, density and thickness values of edible film groups with vegetable extract additives ($p>0.05$), and the difference between TS, WS, SD and % moisture values is significant ($p<0.05$).

In the study of edible films by [44], they found the highest and lowest L, a and b color values between 91.29-88.13, 1.32-0.21 and 7.61-2.71, respectively. In the study by [45], they found the highest and lowest L, a and b color values between 93.3-76.0, 9.0-15.4 and 116.6-2.1, respectively. L, a and b color values obtained in the study were found between 67.44-50.86, 39.47-21.08 and 62.88-28.46 respectively. Due to the herbal extracts used, LA and LB groups were found to differ from other groups. The results obtained are similar to those obtained from the studies in the literature. When analyzed statistically, the difference between edible film groups was found significant ($p<0.05$).

[53] determined that average length and weight of the *Mytilus galloprovincialis* samples obtained from the sampling from the Rize region in the summer months were 81,19 mm and 38,85gr respectively, and the meat yield was 30,81% and 18,60% respectively. The average height and weight of mussels used in this study were measured as 77.02mm and 41.61g, respectively, and meat yield was calculated as 18.60%. It was observed that the average height, weight, and meat yield values in the literature

are compatible with the results we obtained. Mussels are creatures that feed on water. For this reason, differences in length-weight values can be seen according to the nutritional composition of the regions where they are located. [54,55], in their modified atmosphere packaging study with mussels from commercial enterprises, the moisture rate was highest in 82.63% and lowest in 79.23% while, [56] revealed that the moisture rate was 83.72%. On the other hand, [53] determined the moisture content of mussels hunted in summer to be 71.81%. In this study, the moisture of mussels varies in the range of 75.81-80.21%. The decrease in the amount of moisture in the product causes an increase in the amount of dry matter. The data obtained in the study are compatible with the literature. The difference between the groups and within the group was found statistically significant ($p<0.05$). The glycogen number of mussels covered with edible film was found in the range of 1.69% to 9.45%. It has been revealed in previous studies that the amount of glycogen in mussels varies according to the seasons and the mussel environment. Considering the studies conducted, [57] determined glycogen amount in mussels to be in the range of 12.7-24.8%, [58] determined glycogen amount between 1-7%, and [53] determined the amount of glycogen to be 3.38% in mussels from Rize in the summer season. The amount of glycogen increased on the 4th day of storage compared to the 2nd day. This increase is estimated to be caused by glucose or microorganisms operating in the environment in edible films with herbal extract supplement covered with mussels. The difference between the glycogen values was statistically significant ($p<0.05$). According to the results found in the study, the amount of ash varies between 1.18 and 2.45%. When the studies on mussels were examined, the amount of ash was found to be between 11-21% [57], to be 0.95% by [58] and to be 1.70% by [53]. The data obtained contain similar results with the studies in the literature and there is not statistically difference between the groups ($p>0.05$). No significant difference was found between the ash amounts obtained in the study. When looking at the mussel studies, [58] determined the protein amount of fresh mussels to be 10.30% and the protein amount of smoked mussels to be 22.22%. [53] found that the protein amount of mussels sampled from Rize in summer was 13.60%, and [59] found that the amount of mussels grown in the Black Sea ranged between 9.42% and 12.43%. In this study, the protein content of mussels covered with edible film varies between 9.65% and 16.46%. When the statistical results of the change between protein amounts were examined, the difference observed in the study was significant ($p<0.05$). The amount of crude oil in the study varies between 1.26% and 2.42%. When looking at the studies, the crude oil values of fresh mussel samples were determined to be 1.14% by [58], 1.82% by [53] and 1.22% by [3]. The distribution of the amount of fat obtained for mussels in the study is similar to the values in the literature studies. The difference was statistically significant in the group on the 4th day ($p<0.05$), but not on the 2nd day ($p>0.05$). It is predicted that the changes in the nutritional composition are due to the biological structure of the creature. When the pH values related to the mussels were examined in the studies in the literature, [3] determined the pH values of the mussels in the range of 6.10-6.80 and [60] determined them between 4.67 and 6.65. In the studies of [61], pH values of mussels were determined between 5.19 and 6.81, while [62] determined the pH value of raw mussels to be 6.38. The pH values determined for mussels in the study show compatibility with the data in the literature. It was observed that the decrease in pH values was caused by the loss of quality in the product. In their study, [60] found the water activity values in mussels between 0.971 and 0.982 and [63] found them between 0.992 and 0.993. In this study, it was determined that the water activity values varied between 0.9867 and 0.9960. It was determined that the water activity values of mussels in the study were similar to those in the literature. When the pH and water activity findings were statistically analyzed in the study, it was found that the difference between the groups and between the groups was significant ($p<0.05$). In the study of clams by [61], they found the min-max L, a and b color values to be 34.3-48.2, 6.1-7.9 and 17-24.8, respectively. L, a and b values we obtained in this study were found between 41.03-58.14, 11.2-17.1 and 22.4-29.3, respectively. While the results were observed to be compatible with the study in the literature, it was determined that the changes in color values based on herbal extract additives and mussel meat content show a significant difference ($p<0.05$) but this difference within the color values was not considered to be due to a particular effect.

Nitrogen compounds, which have an important role in determining the quality criteria of seafood, are among the criteria that should be considered for the quality changes of mussels. The limit value for TVB-N amount was determined to be 35mgN / 100g and it is stated that products exceeding this limit are outside the quality limits [64, 65]. According to the data we obtained in the study, it was determined that the storage time of mussels coated with edible film did not exceed the consumable limit value on the 2nd day, and on the 4th day of storage. All products, except HB, LB and KB groups, exceeded the consumable limit value. [61] stated that on the 8th day of his modified atmosphere packaging work, others excluding only one group exceeded the limit value. [66] stated in their study that salted mussels remained below TVB-N consumable limit values for 4 months. In their modified atmosphere package study, [12] stated that mussel products were below the consumable limit value on the 11th day, and that all groups exceeded the consumable limit value on the 15th day. [3] stated that the mussels preserved in the

modified atmosphere package study at 4°C remained below the limit value for 13 days. It was determined that there was a difference in the distribution of TVB-N values depending on the studies / processes performed on mussel products. In this study, it was found that especially the HB, LB and KB groups from the applied mussels showed more protective properties in terms of TVB-N values than the other groups. There was a statistically significant difference between TVB-N values ($p<0.05$).

Looking at the studies, it can be said that lipid oxidation is an important quality criterion in seafood. Oxidation of oils causes the formation of unwanted flavors and odors in the product. Considering the studies, it can be stated that acceptable TBA values in seafood are 7-8 malonaldehyde / kg [61,67-71]. In their study, [61] found the TBA value to be 1.55 malonaldehyde / kg on the lowest day 0 and 3.7 malonaldehyde / kg on the 12th day. In his study, [6] found the lowest TBA value to be 0.31 malonaldehyde / kg on day 1, and the highest TBA value to be 1.60 malonaldehyde / kg on day 15. In his study, [3] determined the TBA values of mussels packaged by air as control group to be 3.56 malonaldehyde / kg, 5.37 malonaldehyde / kg and 4.92 malonaldehyde / kg on days 1, 3 and 5, respectively. When comparing with literature data, lower TBA values were obtained. It was determined that mussels coated with edible films containing herbal extract were below 3-5 malonaldehyde / kg value, which was considered good quality for TBA, even on the last day of the storage period. It has been determined that the products covered with LB are more protective against oxidation than the other groups. Compared to the literature data, with the low TBA values obtained it was revealed that the plant extracts used in bulk film exhibit oxidative inhibitory / inhibitory properties. Although the difference between TBA values was not statistically significant ($p>0.05$), some groups showed lower values than other groups.

Looking at the previous studies on mussels, [61] determined that the total number of aerobic mesophilic bacteria to be 2.98 log CFU / g, 5.35 log CFU / g and 7.20 log CFU / g on day 0, 8 and 12, respectively, ant the total aerobic psychrophile bacteria to be 2.92 log CFU / g, 5.23 log CFU / g and 7.10 log CFU / g on the 0th, 8th, and 12th days, respectively. In the study conducted by [3], the total number of aerobic mesophilic bacteria of the control group was 1.17 log CFU / g, 1.00 log CFU / g and 1.17 log CFU / g on the 1st, 3rd and 5th days, and the total number of aerobic psychrophile bacteria was 1.00 log CFU / g, 1.39 log CFU / g, and 2.04 log CFU / g on days 3 and 5, respectively. [63] in their study, determined that the total number of aerobic mesophilic bacteria was 3.94 log CFU / g, 4.38 log CFU / g, 5.43 log CFU / g and 7.54 log CFU / g on days 0, 1, 2 and 3, respectively. The number of bacteria was 3.23 log CFU / g, 3.75 log CFU / g, 4.92 log CFU / g and 6.07 log CFU / g on days 0, 1, 2 and 3, respectively. In the study, the total number of aerobic mesophilic bacteria was determined to be 2.24 log CFU / g in fresh product, 5.48 log CFU / g in the lowest HA group and 5.97 log CFU / g in the highest HB group. When the total number of aerobic psychrophile bacteria in the study was examined, 2.00 log CFU / g in fresh product was determined to be 4.48 log CFU / g in the lowest HB group and 4.62 log CFU / g in the highest LA group. The bacterial load in seafood varies depending on the seasons, the region and hunting conditions, and the consumable limit value, which is recommended as 7 log CFU / g for the total bacterial load [72-74]. On the 4th day of the study, it was determined that the total number of aerobic mesophile / psychrophile bacteria of all groups exceeded the 7 log CFU / g limit value. When the results of the literature were analyzed, it was found that there were differences between the studies conducted by [63] and other studies whose data were similar to this study data. It will be beneficial to perform different applications on the films to be made to increase the antimicrobial effectiveness of plant extracts. On day 2, the difference in the number of mesophilic bacteria was statistically significant ($p<0.05$), while there was no difference in the total number of psychrophile bacteria ($p>0.05$).

Natural protective materials play an important role in the healthy preservation of nutritious foods, especially in the developing world. The use of natural plant extracts in edible films is important in this respect. As a result of our study data, no positive or negative effect of edible films on nutritional composition and other physical analysis was observed. In terms of microbiological values, it was found that plant extracted films had no significant effect. It has been determined that the films exhibit protective properties in preserving the effectiveness of unsaturated fatty acids in seafood, especially the LB group exhibits antioxidant properties more effectively than other groups. Again, the inhibitory effect of the LB group on TVB-N, which is one of the indicators of significant deterioration parameters, was determined. As a result, it is thought that the use of plant extracts in edible films has particularly beneficial antioxidant results and such applications can be developed and applied for industrial purposes.

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