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USE OF NANOCLAY-CONTAINING LID PACKAGING FILM IN LAVENDER ESSENTIAL OIL PACKAGING

In this study, an environmentally friendly nanoclay-containing polymeric film (NPF) that can be used instead of environmentally damaging plastic lids used in food packaging was produced and its effect on the shelf life of lavender essential oil was examined by using it as a lid packaging film in the packaging of lavender essential oil.

For this purpose, lavender essential oil was covered with nanoclay-containing polymeric films and physicochemical analyzes were carried out in the control group, 2nd month, 4th month and 6th month. SEM analysis was applied to the produced nanoclay, and biodegradability, haze and FTIR analyzes were applied to the produced film. Then, acidity, peroxide, color, refractive index, viscosity and essential oil components analyzes were applied to the stored essential oil at specified intervals for 6 months.

As a result of these analyses, it was seen that the film showed a 31.74% deterioration in nature in the 6-month period, and the haze analysis result was determined as 87.17%. Acidity value (0.38%-0.68%), peroxide number (3.46-9.06), color results of lavender essential oil during storage *L (40.63-67.86), *a (–0.89/-1.56), *b (3.92- 5.23), refractive index results (1.4578-1.4632) viscosity results (2.78-6.87 mPa) and dominant essential oil components linalyl acetate (27.04%-31.74%) and linalool (42.80%-46.6%), lavandulyl acetate (1.25%-1.35%), 1-8 cineole (3.44%-4.29%), camphor (4.07%-5.26%) and borneol (2.18%-2.89%). In line with these results; It has been determined that the nanoclay-containing polymeric films produced as lid packaging have as much protective effect as the plastic lid.

Keywords: Biodegradable Film; *Lavandula Angustifolia*; Nanoclay; Pack; Physico-Chemical

1. Introduction

It has been reported that packaging materials are materials that cover food products, enable them to reach the consumer safely and economically without spoiling, are durable, protect the product from external factors, provide ease of loading, unloading and storage, and also promote the product [1]. It has been stated that the most commonly used packaging type in the food industry is petroleum-derived materials, which are known to cause environmental pollution [2]. It has been reported that there are problems in the packaging industry due to reasons such as the increase in the prices of petroleum-derived materials and their slow decomposition in natüre [3,4].

For this reason, studies on the development and use of biodegradable packaging have increased recently. Biodegradable plastic packaging has been reported to be nature-friendly materials that can be used instead of traditional plastic packaging [5]. Biodegradable polymers; It has been reported that microorganisms such as fungi, algae and bacteria undergo degradation in the bioactive environment due to their enzymatic activities. Examples of these substances are starch, poly-lactic acid and chitosan.

It was stated that starch is a natural polymer and is widely found in nature along with cellulose. It has been stated that starch has a heterogeneous structure and consists of two different microstructures: amylose and amylopectin [6]. It has been reported that starch can be used as an alternative option to petroleum-derived substances. It was stated that the reason for this was that it was a biodegradable and cheap polymer [7,8]. However, it has been determined that starch alone cannot chemically form biofilms with suitable mechanical properties without modification.

Therefore, it should be used together with plasticizers. One of these substances is PLA (poly-lactic acid). It has been reported that PLA is from the poly-alpha-hydroxy acid family and is obtained from sustainable sources such as starch, sugar cane and corn in nature [9]. It has been reported that films containing PLA

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have low moisture permeability and aroma loss of the product can be prevented thanks to their high barrier properties [10].

Another substance, chitosan, has been reported to be one of the most abundant biopolymers in nature. It has been stated that it is a natural polysaccharide obtained by partial denaturation of chitin [11,12]. Chitosan has been reported to have many different functions such as film formation, precipitation, moisture absorption, enzyme inhibition and antimicrobial effect [13]. It has been determined that nanotechnology applications are rapidly becoming widespread in the food packaging industry. Nanocomposites obtained by adding these substances and nano-sized particles to the packaging material are one of these applications [14]. One of the nanoparticles used in nanocomposite materials is nanoclay. It has been stated that nanoclays are used in the packaging industry due to their easy obtainability, simple processing properties and low costs. It has been reported that various gas transfers slow down when clay particles are dispersed on the packaging surface. It has been determined that nanoclay particles, which are biopolymer materials, positively affect the passage and speed of molecules such as water and oxygen coming out of the packaging. In this way, it has been reported that the barrier properties of the packages are improved [14,15].

It is known that essential oils, which have been known and used for centuries, have medicinal importance as well as strong sensory effects [16]. One of these essential oils is lavender essential oil. Lavender essential oil is widely used in aromatherapy, cosmetics and food industries due to its pleasant scent and antiseptic properties [17]. It has been stated that terpenoid compounds, which are chemically present in essential oils and cause changes in the structure, odor and taste of the oil, negatively affect the quality of the oil as a result of oxidation [18]. It has been reported that loss of volatile components may occur through oxidation reactions because essential oils are sensitive to conditions such as temperature, wind, humidity and light [19,20].

In line with this information, the aim of this study was to examine the effect of environmentally friendly nanoclay-containing polymeric film (NPF), produced as lid packaging, on the physicochemical properties of lavender essential oil stored for 6 months.

2. Materıals and methods

Nanoclay preparatıon

For this purpose, firstly, 5 grams of sodium bentonite clay sample was weighed and then added to 1000 ml of pure water. Clay and pure water were mixed homogeneously and rest along 24 hours for fall down precipitate impurities. Then, taken from upper part of the solution was removed and centrifuged at 1000 rpm to obtain nanoclay. The fall down nanoclay sample was poured into petri dishes and dried at 60°C. Then, dry nanoclay was ground to obtain powder [21].

Nanoclay-Containing Polymeric Film Preparation

In the preparation of biodegradable NPF, 1.25 g nanoclay, 2.5 g chitosan, 25 g starch, 30 ml 1% M acetic acid, 20 ml glycerin and 250 ml pure water were added to a 500 ml beaker. Then, it was mixed in the homogenizer for one and a half hours to obtain a homogeneous mixture. Then, the homogeneous mixture was mixed at 100°C and subjected to heat treatment to thicken. After this process, the film solution obtained was poured onto a flat surface with a thickness of 200 microns using a film applicator and waited for a day. The samples dried on the ground were removed and nanoclay-containing polymeric films that could be used for analysis were obtained [22].

Samples Preparation

Lavender essential oil (Lavandula angustifolia) obtained from a commercial company was placed in 50 ml amber containers. Then, the containers were covered with 200 micron NPF, produced in two layers. Lavender essential oil samples were stored with plastic cap for the month 0 control group (NPF packaging and plastic packaging). In order to examine the protective effect of the prepared NPF on lavender essential oil, physico-chemical analyzes were carried out at the 0th month (control group), 2nd month, 4th month and 6th month. After these processes, the following analyzes were applied to the produced nanoclay, NPF and stored lavender essential oils.

Analysis Applied to Clay

Scanning Electron Microscope Analysis (SEM)

SEM-EDX analysis of the nanoclay samples obtained in this study was performed with a ZEISS LEO 1430 VP model SEM device. SEM analysis was carried out at Afyon Kocatepe University Technology Application and Research Center (TUAM). Measurement of nanoclay samples was carried out by carbon coating [23].

Nanoclay-Containing Polymeric Film Applied Analyzes

Biodegradability

NPF samples cut in 2×2 dimensions were buried in the soil and kept for 6 months, and their weight losses were calculated [24]. % biodegradability was calculated using the formula below.

$$\%\text{Biodegradability} = \\ = (\text{first weight} - \text{final weight})/(\text{First weight}) \times 100$$

Haziness

The haziness values of the produced NPF in this study were carried out within the scope of the ISO 13468 standard. NPF samples were placed in the device as a square with a side length of 50 mm and measurements were made. The analysis was performed with a BYK Gardner-haze-gard dual light transmission device [25].

FTIR (Fourier Transform Infrared Analysis)

FT-IR spectra of produced NPF in this study were recorded with a spectrometer (IRAffinity-1S, Shimazdu Corporation, Kyoto, Japan) equipped with a high-sensitivity pyroelectric detector (deuterated L-alanine doped triglycine sulfate) and laboratory solutions connected to the software of the DBIR operating system. Measurements were recorded between 400 and 4000 cm^{-1}. Measurements were carried out at 22°C [26].

Lavender Essential Oil Applied Analyzes

Free Fatty Acidity

The free fatty acidity value of lavender essential oil according to months was calculated titrimetrically using the method specified in AOCS. Oil samples were weighed between 5-10 g. Then, the samples were dissolved in a mixture of 50-150 ml of diethyl ether and ethyl alcohol. 3-5 drops of phenolphthalein were added to the prepared solution and titrated with 0.1 N KOH solution [27].

Peroxide Number

Peroxide value of lavender essential oil according to months was used by AOCS's Cd 8-53 standard method and formula. For analysis, 10 ml of lavender essential oil sample was weighed, 10 ml of chloroform was added and dissolved. Then, 15 ml of acetic acid and 0.5 ml of saturated KI were added to the solution. After mixing for one minute, the mixture was left at room temperature and in the dark for 5 minutes. 1 ml of starch solution and 75 ml of water were added and the mixture was titrated with 0.01 N sodium thiosulfate until it reached a clear color. The results were calculated as $meqO_2/kg$ according to the formula below [28].

Peroxide Number ($meqO_2$/kg oil) = ((V1-V0) × N × 10)/m

- V0: Sodium thiosulfate consumption in the witness experiment (ml),
- V1: Sodium thiosulfate consumption seen in the sample experiment (ml),
- N: Sodium thiosulfate solution normality (N),
- m: Amount of sample used for analysis (g).

Refractive Index

Refractive index measurements of lavender essential oil samples were carried out with an Abbe refractometer. The analysis was carried out by dropping lavender oil samples taken with a pipette onto the prism of the refractometer at 20°C and taking three readings [29].

Colour

Color measurements of lavender essential oil coated with NPF cover part, (L*, a* and b* values) calorimeter (CR-400 model) with 8 mm illumination range in Diffuse/O mode with D65 illumination, with 2 observers in 2-month periods for a period of 6 months. Konica Minolta, Osaka, Japan). L* (brightness), a* (red, +60. Green –60) and b* (+60 yellow; –60 blue) color coordinates were determined according to the CIE L*, a*,b* color coordinate system [30].

Viscosity

For viscosity analysis, approximately 40 ml of lavender essential oil samples were taken and poured into the sample container of the device used. Then, it was measured with a Vibro (SV-190) viscometer at 22°C [31].

Essential Oil Composition Analysis

During storage, essential oil component analysis of the oils was carried out using a GC-MS (Gas chromatography (Agilent 7890A)-mass detector (Agilent 5975C)) device and a capillary column (HP Innowax Capillary; 60.0 m × 0.25 mm × 0.25 µm). Samples were diluted 1:100 with hexane for analysis. The injector temperature was kept at 250°C, the column temperature program was set as 60°C (10 minutes), 60°C to 220°C at 4°C/minute and 220°C (10 minutes). By applying this temperature program, the total analysis time lasted 60 minutes. The scanning range (m/z) 35-450 atomic mass units and electron bombardment ionization 70 eV were used for the mass detector, and the data of WILEY and OIL ADAMS libraries were taken as basis for the identification of the components of the essential oil. The component percentages of the results were made using the FID detector, and the components were diagnosed using the MS detector [32].

Statistical Analysis

Minitab program was used for the statistical results of the research results. No standard deviation was applied to single data. In evaluating multiple data obtained with at least two replications, One-Way ANOVA test was used to compare continuous data between more than two independent groups [33].

3. Results and discussion

Nanoclay Scanning Electron Microscope (SEM)

It has been reported that SEM analysis is one of the powerful and common methods used in the surface characterization of substances. It has been reported that it allows obtaining important findings about the chemical composition, morphological and topographic imaging of the surface of a sample [34]. Scanning electron microscope is a type of electron microscope that allows obtaining high-resolution surface images by scanning the surface of the samples to be analyzed with electron beams. It allows the very small pores or indentations and protrusions on the surface of the samples to be seen in detail. It has been stated that the samples to be examined have an electrically conductive structure, which will allow the results to be obtained to be of high quality. For this reason, it has been reported that the analysis is carried out by coating the surfaces of non-conductive samples with conductive materials (gold, carbon, palladium, etc.) before analysis [35,36].

In this regard, the samples obtained in this study were examined on the SEM device in order to see and define the morphology of the nanoclay. Fig. 1. shows the morphological images of the produced nanoclay sample at 10000× magnification are included. In creating the shape, the diameter of the nanoclay particle was determined to be 4.576 µm. It has been observed that the diameters of nanoclays are generally approximately 1.835 microns in size.

Echegoyen et al. (2016); they applied SEM analysis to nanoclay samples. As a result, they reported than nanoclay materials were examined in different ways: below 1 micron, between 1-10 microns and above 1 micron. In a study conducted by Mahvi and Dalvand (2019), they analyzed the morphology of nanoclay using SEM. As a result, they reported that the nanoclay had a smooth surface and a layered structure. As a result of SEM analysis of the nanoclay sample produced according to this literature information, it was determined that the morphological image and structure showed similar results to other studies.

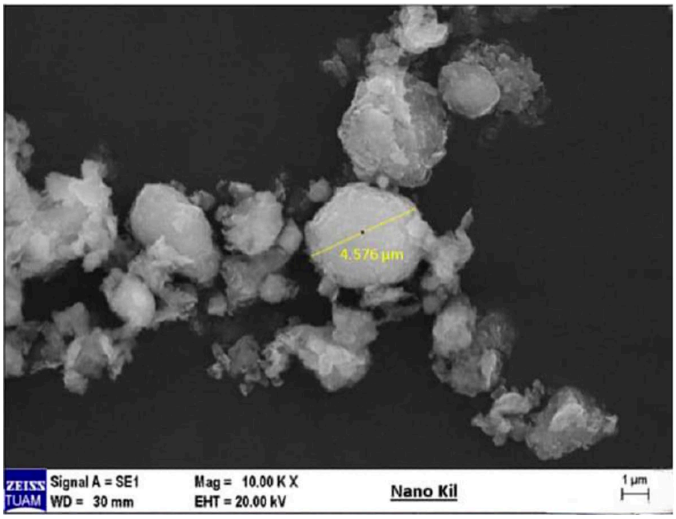

Fig. 1. 10000× SEM image of nanoclay

In addition; As seen in Fig. 2, the components of the elements in the nanoclay were examined and sodium, magnesium, aluminum, silicon, calcium, iron and oxygen elements were detected. Accordingly, nanoclay has 1.15% Na; 0.73% Mg; Al 3.33%; It was determined that it contained 10.13% Si, 0.42% Ca, 0.82% Fe, 83.81% O by mass.

Echegoyen et al. (2016) their study examined the elemental composition of the nanoclay sample. As a result, they determined that silicon, magnesium and aluminum were predominantly detected in the nanoclay, and also oxygen and carbon elements were present. In a study conducted by Mahvi and Dalvand (2019) found that, as a result of EDX analysis, nanoclay were contained 10.44% Al, 32.78% Si, 47.08% O, 5.53% Fe, 0.79% Na, 1.32% Mg, 1.56% Ca and 0.5% K at ratios elements. When compared with the elements and their ratios contained in the

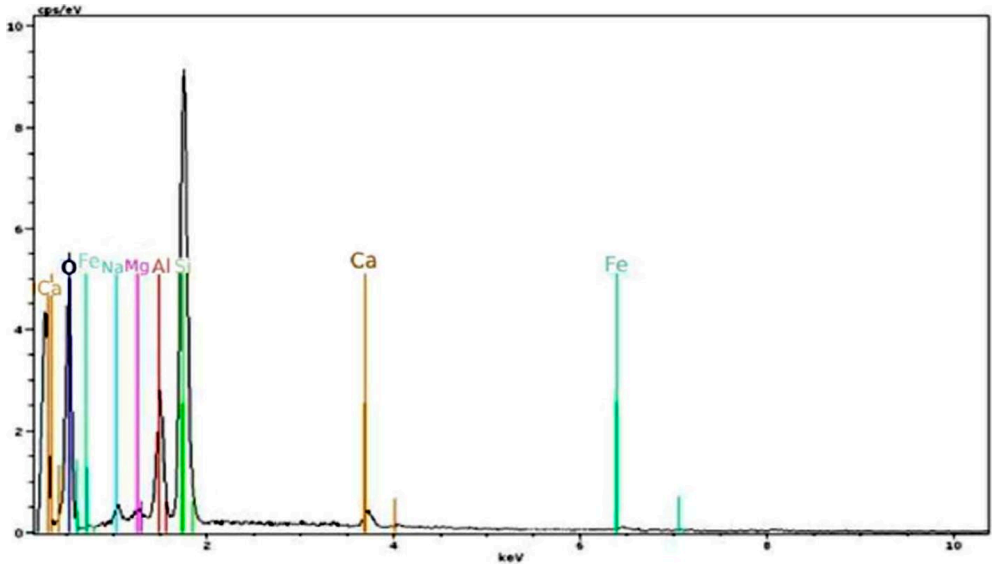

Fig. 2. Nanoclay Element Composition

nanoclay sample in the literature, it was determined that the amount of oxygen and sodium in the produced nanoclay sample was higher than in the literature, while the other elements were less than in the literature.

NPF Lid Pack Biodegradability

Biodegradability means the breakdown of a material or substance as a result of exposure to carbon dioxide, methane, water, biomass, inorganic compounds or enzymatic activities of microorganisms. It has been stated that the main reason why biopolymers are used in nanocomposite materials is that they can transfer their biodegradability properties to polymeric films [39].

In this regard, as shown in TABLE 1, it was concluded that NPF degraded at an average rate of 31.53% in a 6-month period. In line with these results, it is predicted that the total degradation time of NPF will be approximately 18 months.

TABLE 1

Biodegradability Analysis Result of Produced NPF

First Weight	Standard Deviation (±)	Last Weight	Standard Deviation (±)	Biodegradability (%)
0,111	0,002	0,076	0,003	31,53%

Ray et al. (2003) were found that the weight of PLA decreased by 40% in 2 months, while the PLA/nanoclay nanocomposite completely disappeared in 2 months. They also reported that the biodegradability rate of PLA increased with the addition of nanoclay. Compared to the literature, it was determined that the degradation time of NPF was much shorter than that of plastic packaging.

NPF Lid Pack Haziness

The haze or turbidity that occurs due to light passing through or on the surface of the film is defined as haziness. The transparency of the film is measured by the haze value. The lower the value, the more transparent the film is reported to be. It has been reported that the haze value increases in films with more additives [41,42].

Accordingly, according to the results in table 2, the haziness value of NPF was determined as 87.17%. In a study conducted by Aydınlı (1997), it was reported that the haziness analysis result was as 41.5% applied to renewable films made with carob seed polymer and containing PEG (polyethylene glycol). Jiménez et al. (2012); they were found to be 71.1% haziness rate of biopolymer films containing corn starch. When compared with the literature, it was determined that the haze value of the NPF in the study was high.

TABLE 2

Haziness Analysis Result of Produced NPF

Sample	Haziness Value (%)	Standard Deviation (±)
NPF	87,17	0,81

NPF Lid Pack FT-IR (Fourier Transform Infrared)

FTIR analysis is a method used to detect and characterize organic and inorganic components in substances. By measuring the frequencies of bonds between atoms in a sample, it detects the corresponding peaks and thus creates the fingerprint of the substance [43,44].

In this direction, the FT-IR analysis result of NPF, as shown in Fig. 3, was obtained from Balau et al. (2004), the deformations of the peaks belonging to O-H with hydrogen bond located at 3293.22 cm^{-1}, the asymmetric bending of chitosan CH_2 at 2930.26 cm^{-1}; 1543.56 cm^{-1} strains in CO bonds in chitosan; N-H bonds in the structure of 1415.80 cm^{-1} chitosan; The peaks at 1331.29 cm^{-1}, 1151.23 cm-1 and 1104.51 cm^{-1} belong to the N-H stretching and O=H stretching (alcohol) peaks located in the break, respectively; 1076.40 cm^{-1} Si-O flexibility in the nanoclay structure; 924.04 cm^{-1} Al-OH flexibility; 859.40 cm^{-1} Al, Mg-O flexibility; 571.08 cm-1 and 522.58 cm-1 are Si-O-Al, which belong to the capacity involved in the octahedral reten-

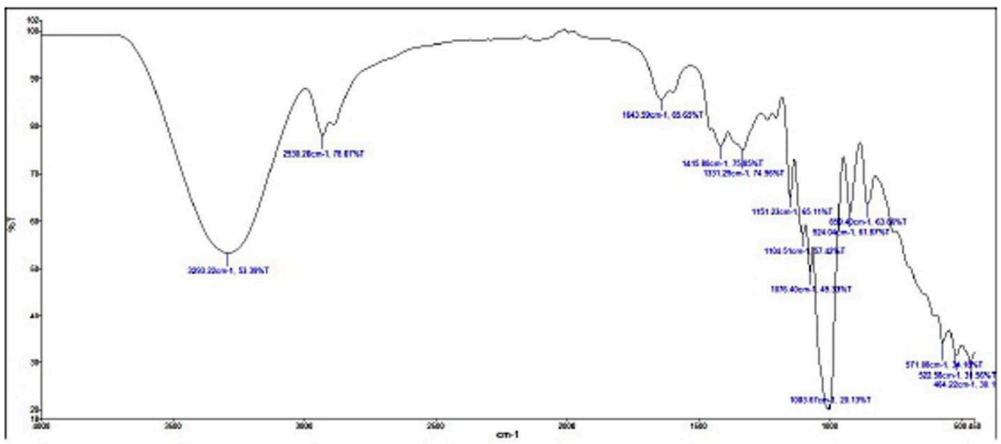

Fig. 3. NPF's FT-IR analysis result

tion of nanoclay; It was determined that a peak was given in the area representing the Si-O-Si tetrahedral bending in nanoclay at 464.22 cm^{-1}. In line with these results, it has been proven that the NPF produced from the study contains nanoclay, chitosan and PLA.

Lavender Essential Oil Free Fatty Acidity

Free fatty acids are fatty acids that become free by hydrolysis of the ester bonds of fatty acids in the oil as a result of factors such as heat, water and enzyme activity affecting the oils. Free fatty acidity is one of the parameters of rancidity and oxidation [46].

Accordingly, TABLE 3 shows the change in free fatty acidity of lavender essential oil coated with NPF lid pack in different periods during the storage period. Lavender oil 0-6. months analysis results were found to be 0.38-0.47-0.47-0.49%, respectively, and the 6th month control group result was 0.68%. According to the results obtained, an increase was seen in the free fatty acidity value of lavender essential oil stored for 6 months with NPF cap packaging from the control group to 2 months, and then no major change was observed in the other months. It has been observed that it is higher than lavender essential oil.

TABLE 3

Lavender Essential Oil Free Fatty Acidity Results

Sample	Free Fatty Acidity (%)	Standard Deviation (±)
0th Month Control Group (Lavender Oil with Plastic Packaging and NPF Packaging)	0,38[c]	0,01
2 months	0,47[b]	0,03
4 months	0,47[b]	0,00
6 months	0,49[b]	0,01
6th Month Control Group	0,68[a]	0,02

[a-c] Means marked with different letters are statistically different from each other ($p < 0.05$).

Statistical differences at the level of $p < 0.05$ were detected in the lavender essential oil stored with NPF cover packaging film for 6 months and the 6th month control group lavender essential oil in terms of free fatty acidity during the storage period.

Pop et al. (2016) reported that they found the free fatty acidity result of sage essential oil to be 1.11%. Ergene et al. (2023) determined that the acidity values of two lavender essential oils were 1.60% and 2.12% ,other samples were found below 1%. Also, they were reported in the pharmacopeia that the acidity value of the lavender essential oil sample should be at most 1.0%. Since there wasn't enough studies on the free fatty acidity values of lavender essential oil in the literature, also the free fatty acidity values of sage essential oil was included. When compared with sage essential oil, it was determined that lavender essential oil contained less free fatty acids than sage essential oil and the results were appropriate when compared with the pharmacopeia. It was determined that the free fatty acid value of lavender essential oil stored with NPF lid pack increased less during storage than that of lavender essential oil stored with plastic cap packaging.

Lavender Essential Oil Peroxide Number

Peroxide value is defined as the amount of milliequivalent oxygen contained in one kg of oil. Peroxides are formed as a result of oxygen contacting the unsaturated bonds in the oils, and the peroxide value indicates the degree of oxidation in the oils [28].

As seen in TABLE 4, peroxide values were measured in different periods during the storage of lavender essential oil. Lavender essential oil 0-6. months analysis results were determined as 3.46-5.02-6.10-8.24, respectively, and the 6th month control group result was as 9.06 meq O_2/kg.

TABLE 4

Lavender Essential Oil Peroxide Number

Sample	Peroxide Value (meqO_2/kg)	Standard Deviation (±)
0th Month Control Group (Lavender Oil with Plastic Packaging and NPF Packaging)	3,46[e]	0,22
2 months	5,02[d]	0,24
4 months	6,10[c]	0,09
6 months	8,24[b]	0,12
6th Month Control Group	9,06[a]	0,17

[a-e] Means marked with different letters are statistically different from each other ($p < 0.05$).

Statistical differences at the level of $p < 0.05$ were detected in the lavender essential oil stored with NPF cover packaging film for 6 months and the 6th month control group lavender essential oil in terms of peroxide number during storage.

In a study conducted by Turek and Stintzing (2011), they reported that the peroxide value of lavender essential oil changed between 1-3.5 meq O_2/kg after being stored in glass packaging for 12 months. As a result, they reported that large increases were observed in peroxide values in the first months of storage. They found that there was not much change in the values in later periods of storage. Pop et al. (2016) were reported that the peroxide analysis result of sage essential oil was determined as 0.15 meq O_2/kg. In our study were determined higher compared to the studies of lavender and sage essential oil peroxide values in the literature. When the results were examined, it was observed that the percentage peroxide values increased as the storage time increased. According to the analysis results, it was determined that there was an increase in the peroxide values of lavender essential oils stored with nanoclay-containing polymeric film over a 6-month period. It was determined that there was a greater increase in lavender essential oil stored with a plastic cap compared to lavender essential oil stored with NPF.

Lavender Essential Oil Color

Color is an important quality that affects the presentation and appearance of products and influences the purchasing decision by consumers. Color analysis includes color parameters designated as L*, a* and b*. The L* value determines the brightness level of the oil; The a* value detects the color scale changing from red to yellow, and the b* value detects the color scale changing from yellow to blue [51].

As shown in TABLE 5, the 0-6 months color analysis results of lavender essential oil was determined as 45.23; 40.63; 56.92; 67.86 L* values; (-) 0.89; (-) 1.56; (-)0.90; (-) 1.27 at a* values, 4.18; 3.92; 5.14; 4.97 at b* values respectively. According to the these results, an increase was observed in the L* values of lavender essential oil after a decrease in the first month. An increase was observed in the a* value (from red to yellow) in 2nd and 6th months, while a decrease was observed in the b* value (from yellow to blue) in the 2nd and 6th months.

In a study by Turek and Stintzing (2011), they examined the total color differences during storage of lavender essential oil. They reported that lavender had a pale yellow color and that the total color difference value increased in direct proportion to the storage time. They stated that there was a visually distinguishable change in the color of lavender essential oil as a result of storage. As a result of our study, it was determined that there was a visible color change. Šoji´ et al. (2021) determined color analysis on sage essential oil; the L* value as 51.2, the a* value as 13.3 and the b* value as 7.80. Since there weren't enough studies on the color values of lavender essential oil in the literature, also the color values of sage essential oil were included. When compared to literature information, it was determined that the b* value was lower in lavender essential oil than in sage essential oil. According to the results obtained, no significant difference was observed in the L*, a* and b* values of the color analysis of the lavender essential oil stored for 6 months with the NPF cap packaging compared to the essential oil stored with the plastic cap.

Lavender Essential Oil Refractive Index

Refractive index is stated as a physical quality criterion in oils according to Turkish and European standards [54].

In this study, the change in refractive index values during storage of lavender essential oil coated with NPF lid pack is shown in TABLE 6. The 0-6 months results of the refractive index values of lavender essential oil was 1.4578; 1.4624; 1.4632; 1.4624 n_d respectively; It was determined as 1.4600 n_d in final control group 6th. month.

Statistical differences at the $p < 0.05$ level were detected in the lavender essential oil stored with NPF cover packaging film for 6 months and the 6th month control group lavender essential oil in terms of refractive index values during storage.

Alatrache et al. (2007) reported that the refractive index value of lavender essential oil to be 1.4600 n_d. Turek and Stintzing (2011) reported that the refractive index value of lavender essential oil during storage was determined as 1.4985 n_d as a result of their study, and no significant change was observed in the refractive index during storage. It was determined that the 6th month refractive index results of lavender essential oil stored with NPF increased more than the 6th month control group results of lavender essential oil stored with a plastic cap. The results showed parallelism when compared to the literature, and there was no notable change in the refractive index of lavender essential oil coated with NPF lid pack during storage.

TABLE 5

Color Analysis Results of Lavender Essential Oil

Colour	L*	Standard Deviation (±)	a*	Standard Deviation (±)	b*	Standard Deviation (±)
0th Month Control Group (Lavender Oil with Plastic Packaging and NPF Packaging)	45,23^{bc}	1,096	–0,89^{b}	0,06	4,18^{a}	1,31
2 months	40,63^{c}	0,3	–1,56^{a}	0,05	3,92^{a}	0,00
4 months	56,92^{ab}	4,18	–0,90^{b}	0,06	5,14^{a}	0,03
6 months	67,86^{a}	9,12	–1,27^{ab}	0,29	4,97^{a}	0,01
6th Month Control Group	63,51^{a}	3,49	–1,21^{ab}	0,20	5,23^{a}	0,42

$^{a-c}$ Means marked with different letters are statistically different from each other ($p < 0.05$).

TABLE 6

Lavender Essential Oil Refractive Index Results

Sample	Refractive Index (n_d)	Standard Deviation (±)
0th Month Control Group (Lavender Oil with Plastic Packaging and NPF Packaging)	1,4578^{d}	0,0002
2 months	1,4624^{b}	0,0001
4 months	1,4632^{a}	0,0001
6 months	1,4624^{b}	0,0002
6th Month Control Group	1,4600^{c}	0,0002

$^{a-d}$ Means marked with different letters are statistically different from each other ($p < 0.05$).

Lavender Essential Oil Viscosity

Viscosity is defined as the resistance of the fluid to flow due to its internal resistance. One of the important physical quality standards in oils is viscosity [55,56].

The change in viscosity values of lavender essential oil coated with NPF lid pack during in 0-6 th. months storage can be seen in TABLE 7. The viscosity value was determined 2.78; 3.38; 4.16; 6.87; 5.67 mPa in the 0-6 months, respectively. Statistical differences at the level of $p < 0.05$ were detected in the lavender essential oil stored for 6 months with NPF cover packaging film and the 6th month control group lavender essential oil in terms of viscosity values during storage.

TABLE 7

Lavender Essential Oil Viscosity Results

Sample	Viscosity (Mpa)	Standard Deviation (±)
0th Month Control Group (Lavender Oil with Plastic Packaging and NPF Packaging)	2,78[e]	0,02
2 months	3,38[d]	0,01
4 months	4,16[c]	0,11
6 months	6,87[a]	0,07
6th Month Control Group	5,67[b]	0,08

[a-c] Means marked with different letters are statistically different from each other ($p < 0.05$).

Badr et al. (2021) were reported that the viscosity value of lavender essential oil was determined as 5.67 mPa. Duman et al. (2017) found the viscosity value of sage essential oil to be 4.73; Also, they reported that the viscosity value of rosemary essential oil was 6.87. Since there weren't enough studies on the viscosity values of lavender essential oil in the literature, the viscosity values of sage and rosemary essential oils were included. When the viscosity analysis result of lavender essential oil stored with NPF was compared with the studies in the literature at the end of the 6-month period, it was determined that the result was higher than the literature. It was determined that the viscosity of lavender essential oil was higher than that of sage essential oil and the same result was obtained with rosemary essential oil, and the viscosity changed during storage. It was determined that the 6th month viscosity results of lavender essential oil stored with NPF increased more than the 6th month control group viscosity results of lavender essential oil stored with a plastic cap.

Lavender Essential Oil Composition

It is stated that the most important factor determining the quality of the product in aromatic plants is the ratio of essential oil components in the plant [58,59]. It has been reported that the essential oil components contained in the essential oil obtained from the plant are an important factor in determining its intended use and economic value [60,61]. Therefore, it has been reported that it is of great importance to know the factors that cause changes in the volatile oil content of aromatic plants and to manage these factors positively [62,63].

In this regard, regarding our research, Figs. 4 and 5 give the 6th month GC-MS chromatogram shapes of the 6th month control group stored in plastic packaging and the 6th month GC-MS chromatograms of lavender essential oil covered with NPF cover packaging film, respectively, as examples.

TABLE 8 shows the change of essential oil components during the storage of lavender essential oil coated with NPF lid pack. Accordingly, the major components of lavender essential oil in the control group were linalool (46.6%), linaly acetate (31.74%), lavandulyl acetate (1.27%), borneol (2.89%), camphor (5.26%), 1-8 cineole (4.06%), 3-octanone (1.11%), alpha terpineol (1.46%). Its minor components were determined as geranyl acetate (0.93%) and limonene (0.99%).

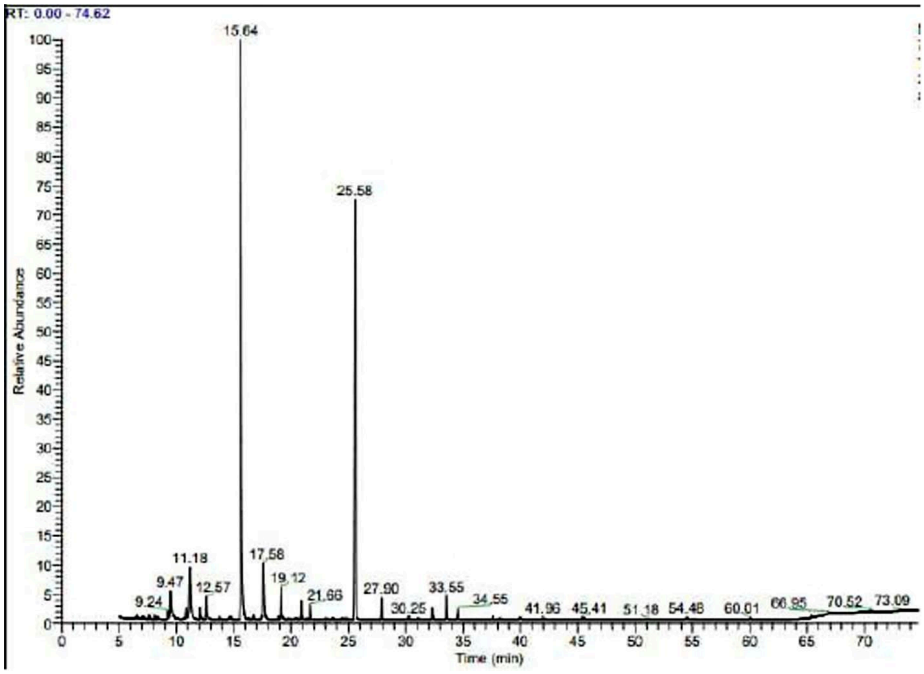

Fig. 4. 6th month control group GC-MS chromatogram view of lavander essential oil stored in plastic packaging

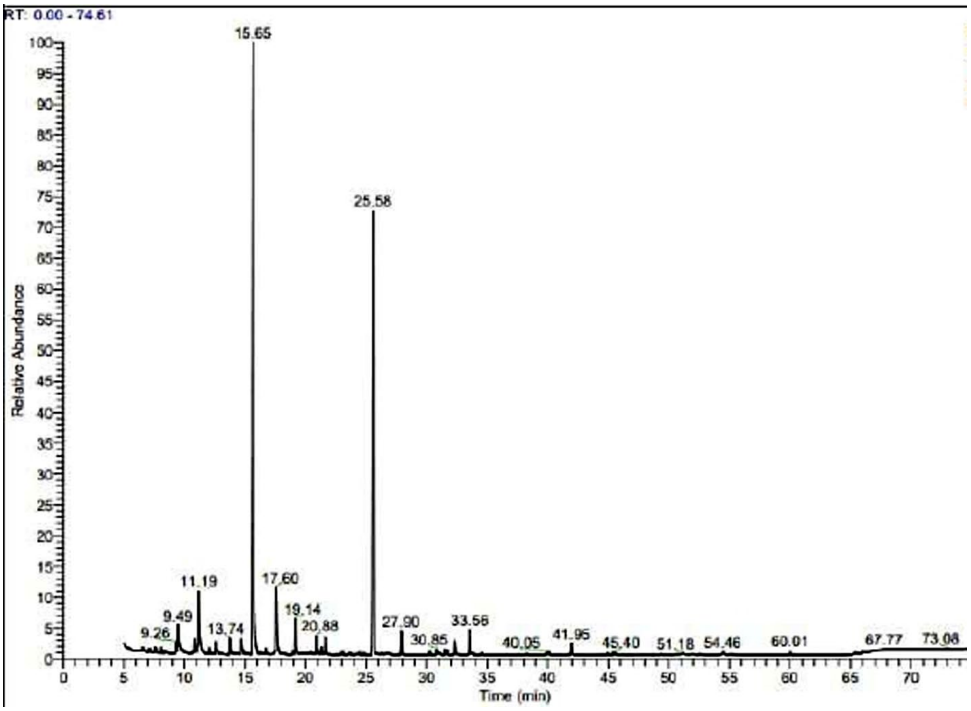

Fig. 5. 6th month GC-MS chromatogram view of lavander essential oil covered with NPF cover packaging film

TABLE 8

Essential Oil Components of Lavender Essential Oil

Component	Control Group (%)	Standard Deviation (±)	2 months	Standard Deviation (±)	4 months	Standard Deviation (±)	6 months	Standard Deviation (±)	6th Month Control Group	Standard Deviation (±)
Limonene	0,99^{a}	0,06	1,01^{a}	0,04	0,89^{a}	0,09	0,28^{b}	0,02	0,45^{b}	0,07
1,8-Cineole	4,06^{ab}	0,01	4,06^{ab}	0,23	3,89b	0,09	4,29^{a}	0,18	3,44^{c}	0,15
3-Octanone	1,11^{a}	0,02	1,12^{a}	0,02	0,96^{a}	0,05	0,57^{b}	0,15	0,46^{b}	0,20
Cis-Linalool Oxide	0,45^{b}	0,05	0,47^{b}	0,06	0,25^{c}	0,03	1,11^{a}	0,15	0,18^{c}	0,01
Hexyl Butyrate	0,89^{a}	0,07	0,88^{a}	0,05	0,90^{a}	0,03	0,17^{b}	0,03	0,16^{b}	0,05
Hexyl Acetate	0,92^{a}	0,11	0,92^{a}	0,06	0,80^{a}	0,05	0,87^{a}	0,14	0,94^{a}	0,17
Camphor	5,26^{a}	0,20	5,16^{a}	0,14	4,71^{a}	0,13	4,49^{a}	0,36	4,07^{a}	0,22
Linalool	46,6^{a}	0,05	45,78^{ab}	0,58	45,12^{bc}	0,07	42,80^{d}	0,52	43,90^{cd}	0,23
Linalyl Acetate	31,74^{a}	0,13	31,18^{a}	0,58	30,39^{a}	0,65	27,13^{b}	0,29	27,04^{b}	0,12
Lavandulyl Acetate	1,27^{a}	0,18	1,27^{a}	0,01	1,25^{a}	0,02	1,35^{a}	0,16	1,33^{a}	0,12
Alpha-Terpineol	1,46^{a}	0,09	1,41^{ab}	0,01	1,49^{a}	0,04	1,18^{c}	0,05	1,32^{b}	0,11
Borneol	2,89^{a}	0,02	2,83^{a}	0,07	2,77^{a}	0,65	2,22^{b}	0,08	2,18^{b}	0,10
Neryl Acetate	0,37^{b}	0,02	0,40^{ab}	0,07	0,38^{ab}	0,33	0,80^{a}	0,09	0,76^{ab}	0,06
Geranyl Acetate	0,93^{a}	0,10	0,92^{a}	0.06	0,94^{a}	0,08	1,43^{a}	0,10	1,48^{a}	0,04

$^{a-d}$ Means marked with different letters are statistically different from each other ($p < 0.05$). As a result of the evaluation of the peaks in the chromatograms, values below 0.2% were not taken into account.

In the 2nd, 4th and 6th month analysis results, the major components were respectively: linalool (45.78%), (45.12%), (42.80%); linalyl acetate (31.18%), (30.39%), (27.13%); lavandulyl acetate (1.27%), (1.25%), (1.35%); borneol (2.83%), (2.77%), (2.22%); camphor (5.16%), (4.71%), (4.49%); 1-8 cineole (4.06%), (3.89%), (4.29%); 3- octanone (1.12%), (0.96%), (0.57%); alpha terpineol (1.41%), (1.49%), (1.18%). Its minor components are geranyl acetate (0.92%), (0.94%), (1.43%); limonene (1.01%), (0.89%), (0.28%); cis-linalool oxide (0.47%), (0.25%), (1.11%); hexyl butyrate (0.88%), (0.90%), (0.17%); hexyl acetate (0.92%), (0.80%), (0.87%); neryl acetate (0.49%), (0.38%), (0.80%).

The components detected as a result of GC-MS of the 6th month control group lavender essential oils stored with plastic cover material were linalool (43.90%), linalyl acetate (27.04%), lavandulyl acetate (1.33%), borneol (2.18%), camphor (4.07%), 1-8 cineole (3.44%), 3-octanone (0.46%), alpha terpineol (1.32%). Its minor components are geranyl acetate

(1.48%), limonene (0.45%), cis-linalool oxide (0.18%), hexyl butyrate (0.16%), hexyl acetate (0.94%). It was determined as neryl acetate (0.76%).

About the components of lavender essential oil, Smigielski et al. (2009) were reported the main component values of lavender essential oil were linalool (30.6%), linalyl acetate (14.2%), geraniol (5.3%), β-caryophyllene (4.7%), and acetate (4.4%). They also reported that their minor components were limonene (0.5%), camphor (0.5%), 1,8-cineole (2%), lavandulol (1.6%) and a-terpineol (2.7%). Verma et al. (2009) were performed GC-MS analysis to detect the components of lavender (Lavandula angustifolia Mill.) essential oil. They were found major components of lavender essential oil respectively,linalyl acetate (47.56%), linalool (28.06%), lavandulyl acetate (4.34%), α-terpineol (3.75%), geranyl acetate (1.94%), Also, they were reported caryophyllene oxide (1.38%), 1,8-cineole (1.14%) and other minor components in the lavender essential oil were determined β-caryophyllene (0.93%), borneol (0.85%), epi-α-cadinol (0.70%), nerol (0.59%), terpinen-4-ol (% 0.56), β-myrcene (0.55%), limonene (0.55%) and 1-octen-3-ol (0.53%).

According to ISO Standard 3515:2002, acceptable ranges for the main components of L. angustifolia essential oil were reported linalyl acetate (25.0%-47.0%), linalool (20.0%-40.0%), trans-β- cymene (1.0%-6.0%), cis-β-cymene (1.0%-10.0%), Octanone-3 (0%-2%), 1.8 cineole (0.5%-3.0%), Limonene (0.3%-1.0%), Camphor (0-1.2%), Terpinen-4-ol (0-8.0%), Lavandulol (-3.0%), Lavandulyl acetate (0-8.0%) and α-terpinol (0-2.0%).

When the volatile component ratios of lavender essential oil stored for 6 months with an NPF packaging cover were compared with the studies in the literature, it was determined that the linalool linalyl acetate and 1-8 cineole values of the lavender essential oil in our study were high and the lavandulyl acetate and alpha-terpineol values were low. Accordingly, as a result of comparing the proportions of volatile components in lavender essential oil with ISO Standard 3515:2002, it was determined that the limonene value was low and the other volatile components with a high 1-8 cineole value were suitable after stored for 6 months with coated NPF lid pack. When the essential oil analysis results coated with NPF lid pack samples at the end of 6 months were compared with the results of the 6-month control group lavender essential oil stored in plastic clamshell packaging, the results were found to be close.

4. Conclusıon

In conclusion; According to the results obtained when the physicochemical analysis results performed during the storage process of lavender essential oil covered with NPF cap packaging in our study were examined; It is predicted that the produced biodegradable film will be completely degradable in the soil environment within a period of 18 months. It was determined that NPF provided adequate protection of lavender essential oil in terms of free fatty acidity, peroxide number, essential oil components and color compared to the control group (plastic packaging). It has been determined that there is variability in terms of refractive index and viscosity analysis results. It has been determined as a result of studies that NPF lid packaging can be used instead of plastic lid packaging. It is also recommended to investigate the physico-chemical changes that will occur in lavender essential oil during storage by using the nanoclay-containing polymeric film material produced in further studies as a single piece of packaging material instead of lid packaging.

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