**Journal of Food Science and Technology (Iran)**

**Homepage:** www.fsct.modares.ir

**Scientific Research**

# Fabrication of active packaging using eucalyptus and peppermint essential oil by electrospinning technique: study the characterization and antibacterial properties

Zahra Sargazi[1], Mohammad Amin Miri*[2], Mohammadali Najafi[3]

1- M.Sc. student, Department of Food Science and Technology, Faculty of Agriculture, University of Zabol, Zabol, Iran.

2- Department of Food Science and Technology, University of Zabol, Zabol, Iran; Electrospinning Laboratory, University of Zabol, Zabol, Iran

3- Associate Professor, Department of Food Science and Technology, Faculty of Agriculture, University of Zabol, Zabol, Iran

## ABSTRACT

The purpose of this research is to strengthen the antimicrobial properties of active nanofibers containing eucalyptus essential oil by using different concentrations of peppermint essential oil for use as active packaging. Nanofibers containing a mixture of eucalyptus essential oil (10%) and peppermint essential oil (concentrations of 0, 2.5, 5, 10% (v/v)) were produced. SEM and Image-J results showed that the loading of essential oil increased the diameter of electrospun fibers from 200 to 400 nm. SEM images showed that the morphology of electrospun fibers is tubular. XRD was used to study the physical structure of electrospun fibers and XRD diffractograms show that adding essential oil to zein did not change the crystalline structure of zein. TGA thermograms showed that the loading of essential oil increased the thermal stability of electrospun fibers. FTIR spectrum shows the interaction between electrospun fibers and the essential oil. Antibacterial test was done by disc diffusion method and the results showed that the fibrous coating containing essential oil prevented the growth of *staphylococcus aureus* and *escherichia coli*. According to the results of this research, fibers containing a mixture of eucalyptus and peppermint essential oils can be considered as an active packaging for use in packaging different food products such as cheese, meat and some other food products.

## ARTICLE INFO

**Article History:**

Received: 2023/6/20
Accepted: 2023/9/2

**Keywords:**

Mixture of essential oils,
Electrospinning,
Zein,
Antimicrobial properties

DOI :10.22034/FSCT.20.143.91
DOR:20.1001.1.20088787.1402.20.143.7.9

*Corresponding Author E-Mail:
ma.miri@uoz.ac.ir

## 1- Introduction

Biodegradable active packages are currently promising and interesting systems in the food industry to increase the safety and shelf life of food [1]. Electrospun nanofibers are used for food packaging due to several advantages including interconnected structure, larger surface-to-volume ratio, and higher porosity characteristics that allow for the entrapment of more bioactive compounds.Be more attractive than movies for the packageThey have food classification [1, 2].

Zein, a corn protein, is known as a natural and recyclable polymer. Zein is one of the biopolymers that is used to make nanofibers due to its properties such as non-toxicity, low cost, hydrophobicity and compatibility. This biopolymer is chemically stable andFDA It has approved zein as a safe compound for use in food and medicine. This biodegradable polymer can be used to form fibers and capsules by electrospinning [3].

electrospinning It is a simple, flexible and efficient method for making fibers with a diameter of micron to nano. The characteristics of polymer solution and process conditions affect the morphology and diameter of electrospun fibers]4[. Electrospun nanofibers can be prepared by using bioactive compounds such as antioxidant or antibacterial agents or by loading a large number of bioactive components such as essential oils.activated [1, 5, 6]. Eucalyptus essential oil can provide antibacterial, antioxidant and anti-inflammatory activities to electrospun nanofibers due to its presence.Eucalyptol, Seoulinduce [7].

Eucalyptus by nameAcademic*Eucalyptus globulus* It is one of the most famous medicinal plants whose antimicrobial effects and other properties have been of interest since a long time. This plant is a rich source of polyphenols and terpenoids and the main composition of its leaves is eucalyptus or cineole. Eucalyptus is used to treat many diseases such as influenza, tonsillitis, dysentery and skin diseases. The essential oil of this plant has anti-cancer, anti-inflammatory, analgesic, antioxidant, anti-hyperglycemic, anti-malarial, anti-fungal and anti-viral properties.[7]. Also, eucalyptus essential oil has shown antimicrobial activity on a wide range of gram-positive and gram-negative bacteria, such as Staphylococcus aureus, Shigella dysentery, Salmonella paratifi, Escherichia coli, Bacillus cereus, and Candida albicans. But according to the previous study]7[Therefore, nanofibers containing eucalyptus essential oil do not have strong antimicrobial properties for use in food packagingin this studydirection Increasing the efficiency of eucalyptus essential oil, peppermint is also loaded with eucalyptus essential oil in the nanofibers.

Peppermint essential oil widelyO tasterperfumes, medicines and medicinal applications are produced and consumedto be FamousThe most and most usedThe darkest type of mint, peppermint with scientific name*Mentha piperita* L. mayMay it be a hybrid species and from the union between two species. *M. aqatica* L and*M. spicata* L. Obtained]8[ . It has been proven that peppermint essential oil has several important properties such as anti-fungal, anti-viral, anti-bacterial, anti-insect.It is insecticide, larvicide and mosquito repellent, and it is mostly considered as non-toxic compounds for humans and very lethal for pathogens.to be The main active ingredient of peppermint essential oil is menthol, which makes up about 19 to 29 percent of the essential oil.to give]9[.

The purpose of this study is to design a packaging material made of biodegradable and biocompatible natural polymer such as zein, which has antibacterial activity suitable for use in food packaging systems. Therefore, in this research, in order to strengthen the antimicrobial properties of zein nanofibers, peppermint essential oil and eucalyptus essential oil were used. loading in decorative nanofiberscan be After preparing the packageAntimicrobial active packaging, features of active packaging and its antimicrobial effects against*Escherichia coli* And*Staphylococcus aureus* may studybe made

## 2- materials and waysI see

**Preparation of raw materials**

Maize zein (grade Z3625) was purchased from Sigma-Aldrich (Madrid, Spain) and used as soon as received without further purification. Glacial acetic acid with a purity of 99.7% and hexane were obtained from Merck (Germany). Eucalyptus and peppermint essential oil were obtained from Tabib Daru Company. Distilled water was obtained from the laboratory of Zabul University Faculty of Agriculture.

**Preparation of polymer solution:**

Zein polymer solution by dissolving a certain amount of zein powder in acetic acid and stirring using The magnetic stirrer will be prepared at room temperature. Peppermint essential oil with percentages of 10, 5 and 2.5 will be added to the solution containing eucalyptus essential oil (10%) and zein.]6[.

**Electrospinning process:**

From the uniaxial electrospinning method using the device available in the electrospinning laboratory of Zabul University (modelES1000, Fanavaran Nanomagiyas Company, Iran) was used [3].

**Electron microscope imaging (WHICH):**

Movies by Gold (Sputter Coater- BAL-TEC, SCDOOS ) were covered and their morphology and diameter were imaged using the softwareImage Jwill be reviewed]10[.

**Fourier transform infrared spectroscopy ( FTIR ):**

Chemical analysis in order to investigate the chemical reaction between zein and eucalyptus essential oil and peppermint essential oil uploaded byFTIR spectroscopy will be done]11[ .

**Gravimetric calorimetry[1] (TGA)**

The thermal stability and thermal degradation behavior of nanofibers are investigated with a heating rate of 10 °C/min in a space containing nitrogen and in a temperature range of 25 to 750 °C [12].

**X-ray diffraction (XRD)**

X-ray diffraction (XRD) to check the physical condition of essential oil and peppermint essential oil in electrospun nanofibers. Diffraction patternsXRD through a diffractometerXMD-300 (Unisantis, Germany), using radiationWith Ka (1.54 Å)in range$^{\circ}$2θ=4-40 And the scan step time is 53 seconds [13].

**Encapsulation efficiency**

Mix 10 mg of the resulting nanofibers in 10 ml of ethanol in a closed container for 15 minutes, and then read through a smooth filter and absorbance at 282 nm. The following relations are used to calculate the efficiency and loading rate of essential oil:

Encapsulation efficiency = (amount of eucalyptus essential oil and peppermint essence encapsulated / amount of primary essential oil) x 100

**Antimicrobial properties**

Disc diffusion method to measure the antimicrobial properties of electrospun nanofibers against microbial species including gram positive bacteria*Staphylococcus aureus* and gram negative*Escherichia coli* which was prepared in a lyophilized form from the Scientific and Industrial Research Organization of Iran, was used. Bacterial suspension according to the McFarland half standard (CFU/mL $10^8$×1.5) is prepared at a wavelength of 625 nm. From the bacterial suspension, a sterile swab is used to remove it and put it on the culture medium. of decorative nanofibers

[1]-Thermogravimetric Analyzer

containing a mixture of eucalyptus essential oil (concentration 10%) and peppermint essential oil (concentration0, 2.5, 5 and 10%) were prepared by a sterile punch, and 10 mm diameter disks were prepared next to the flame. DiscThe ones prepared from zein without peppermint essential oil were considered as the control group. Then the discs prepared by sterile forceps were placed on the culture medium and placed in a 37°C incubator. After 24 hours, the size of the diameter of the lack of growth is determined by a caliper [6].

### Statistical design

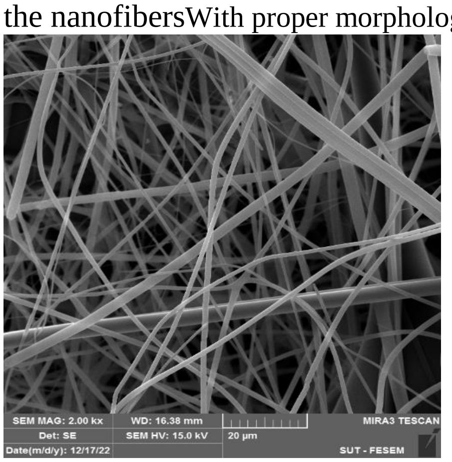
Experiments are done in three replicates. analysis of variance (ANOVA) using softwareSAS version 9/1 and comparing the mean using Duncan's test at the 5% probability level ($p<0.05$) Done. The results of the tests were mentioned as the average of three repetitions along with the standard deviation.

## 3- Results and discussion

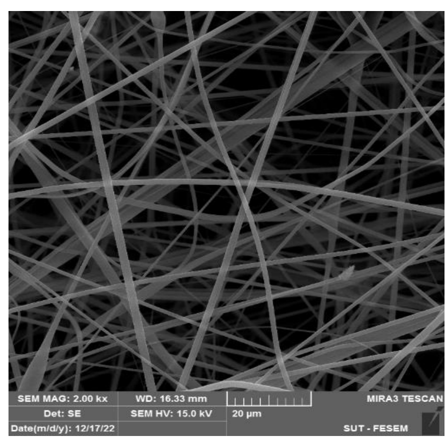
### Morphology of nanofibers

PicturesWHICH The result of peppermint essential oil loading in zein nanofibers is shown in Figure 1.. These images are by softwareImage-J were analyzed and the average fiber diameter was calculated and the results are listed in Table 1.As can be seen in the images, the nanofibersWith proper morphology, without gouache, uniform and uniformare formed Therefore, it can be concluded that the addition of peppermint essential oil does not affect the electrospinning ability of zein solution and the shape of nanofibers. By increasing the essential oil from 0% to 10% in solution, the diameter of zein nanofibersnm 200 tonm 400 increased (Table 1) that MayIts power is attributed to the electrical conductivity of the solution. By increasing the concentration of peppermint essential oil, the electric charge of the solution decreases. In general, by reducing the electric conductivity of the solution, the electric charge density in the fountain resulting from the biopolymer solution for electrospinning is reduced. The lower density of electric charges reduces the tension of the fountain, which in turn increases the diameter of the nanofibers ]14–16[.

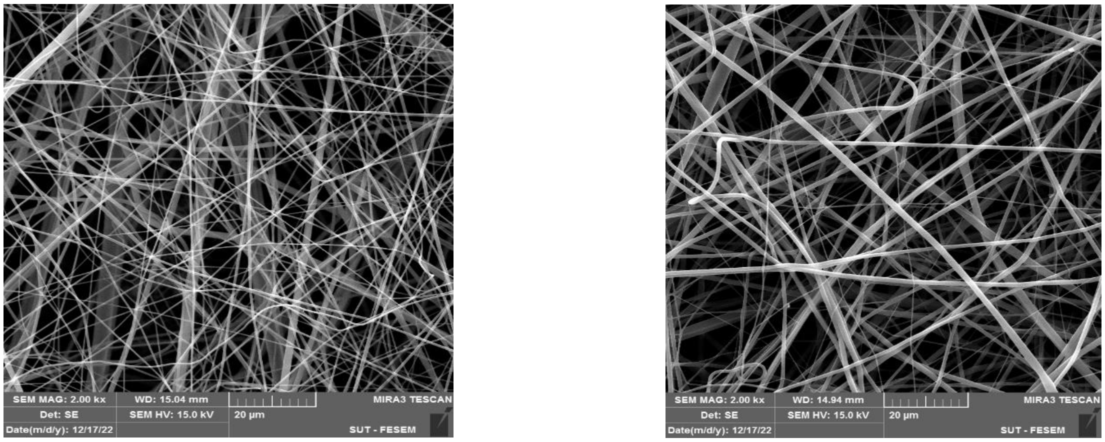
Afshar et al. (2017) reported in a study that by adding peppermint essential oil to chitosan-bovine protein solution, electrical conductivity decreased, which is due to the non-ionic structure of peppermint essential oil. The results of this research are similar to the results of studies [17, 18].




(a)




(b)




(c) (d)

**Figure 1** SEM images of eucalyptus/zein electrospun fibers loaded with 0%, 2.5%, 5%, and 10% peppermint essential oil.

**Table 1** Electrical conductivity and average diameter of eucalyptus/zein electrospun fibersloaded with different concentration of peppermint essential oil*

| Peppermint essential oil content (%) | Morphology | Electrical conductivity (µS/cm) | Average fiber diameter (nm) |
|---|---|---|---|
| 0 | Fibers free of beads | 25.8± 0.032 | $103.7 \pm 19.3^{a}$ |
| 2.5 | Fibers free of beads | 20.64 ± 0.1 | $104.6 \pm 19.3^{a}$ |
| 5 | Fibers free of beads | 18.34± 0.5 | $153.6 \pm 19.3^{b}$ |
| 10 | Fibers free of beads | 15.8± 0.87 | $193.9 \pm 19.3^{c}$ |

*Means bearing different superscripts are significantly different ($p < 0.05$). Results are presented as mean ±SD (n=3).

## Reaction between zein and essential oilI see

spectrumFTIR The zein sample (0%) is shown in Figure 2. Indicative peaks decorated in$cm^{-1}$ 3318 Stretching bandO-H , N-H) And$cm^{-1}$ 2933 (Tension bandC-H) seen. deliveryAmid indicatorsI (Action groupC=O) and AmidII (groupN-H) At$cm^{-1}$ 1658 and $cm^{-1}$ 1536 It was observed [19]. spectrumFTIR Peppermint essential oil is shown in Figure 2, which contains a weak peak in$cm^{-1}$ 3476 (LinksO-H) maybe deliveryHi$cm^{-1}$ 2958 and other couriers in the form of shoulderwere observed next to it and the peak $cm^{-1}$ 1444, respectively belonging toAsymmetric stretch bandsC-H, symmetrical tensile bands–CH and bending stripsC-H maybe deliveryStrong essential oils in$cm^{-1}$ 1752 (stretching bandsC=O) due to the presence of esters such as methyl acetate,$cm^{-1}$ 1675 (tensile stripsC=O) due to the presence of Karun and Polgun,$cm^{-1}$ 1374 (bending strips$CH_3$) ،$cm^{-1}$ 1219 (absorbing stretch bandsC-O-C) was observed [20].

spectrumFTIR Electrospun fibers of zein - peppermint essence in concentrations of 2.5% ،5% ، 10% is shown in Figure 2. Stretch bands groupsO-H From the hydroxylated compounds of peppermint essential oil$cm^{-1}$ 3000 with couriersN-H They are spread out and overlapped. Stretch absorption tapeN-H AndO-H Zain in$cm^{-1}$ 3318, respectively, the concentration of 2.5-10% to the frequencies$cm^{-1}$ 3315, 3328 and

3323 have been replaced in electrospun fibers. Amidi tensile absorption tapeI Atcm$^{-1}$ 1658 In addition to increasing the intensity, to the frequenciescm$^{-1}$ 1657, 1642 and 1655 for zein-essence nanofibers with concentration2.5, 5 and 10 percent have been moved respectively.Stretchable absorption band (peak amideII) Atcm$^{-1}$ 1536 became sharper and respectively for zein-essence nanofibers with concentration2.5, 5 and 10 percent to frequenciescm$^{-1}$ 1536, 1538 and 1538 have been transferred. Changes in the spectrumFTIR Zain shows the interaction between Zain and peppermint essenceto give The above results indicate that peppermint essential oil has been successfully loaded into zein nanofibers [11, 19].

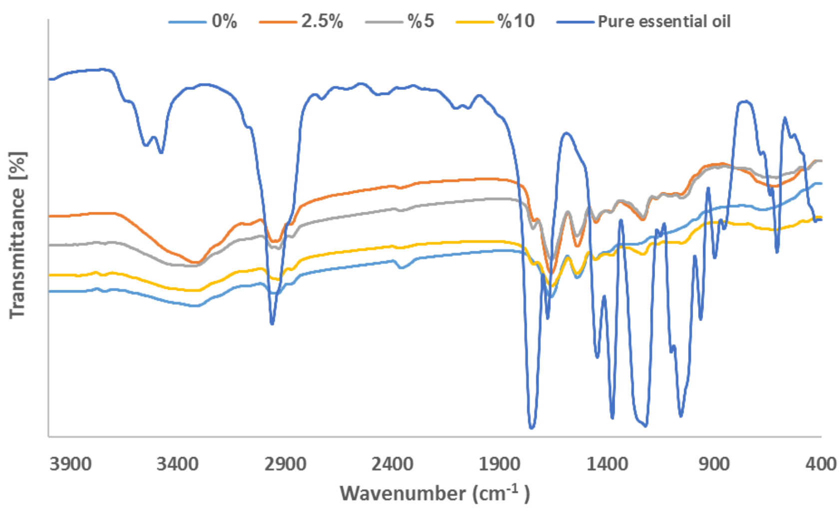



**Figure 2.** FTIR spectra of eucalyptus/zein electrospun fibers loaded with different concentration of peppermint essential oil and pure peppermint essential oil.

**TestXRD**

To check the crystal structure of the examined samples from the testXRD used and the results are shown in Figure 3.

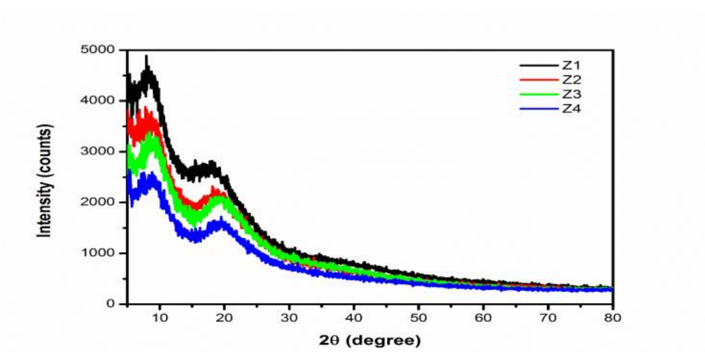



**Figure 3.** X-ray diffraction patterns of eucalyptus/zein electrospun fibers loaded with 0% (Z1), 2.5% (Z2), 5% (Z3), and 10% (Z4) of peppermint essential oil.

According to Figure 1, two peaks can be seen in all samples, which are located at angles of about 9 degrees (with a plane distance of about 10 angstroms) and 19.5

degrees (with a plane distance of about 4.5 angstroms) and are related to the zein structure. In other articles, these peaks have been identified for this substance at the same angles [21, 22]. It is believed that the distance between the plates corresponds to the first peak related to the interhelical bundles[2] or is the average distance of neighboring helices and the distance of the second peak planes corresponds to the average distance of α-helical structures in Zein skeleton [23]. According to this figure, the most intense peaks among these samples belong to the pure zein sample, which indicates the greater crystallinity of this material compared to other samples. In fact, due to the non-crystalline (amorphous) structure of the compounds in the essential oil, with the increase in the concentration of these compounds in the nanofibers, the intensity of the peakhas decreased compared to the pure Zein sample. This reduces the intensity of the peakZein has been observed by adding amorphous phases to it in other studies [24, 25]. However, there was no trace of the courierThe results of these compounds indicate that the addition of essential oil to zein did not change the crystalline structure of zein.

**Analysis of test resultsTGA**

In order to check the thermal properties of the examined samples from the testTGA Used and diagramsTGA AndDTGFigure 4 and weight loss values for each step are given in Table 2.

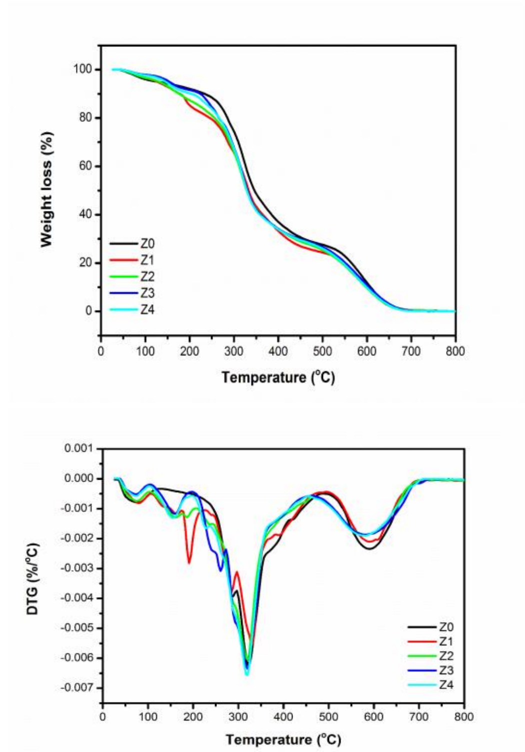


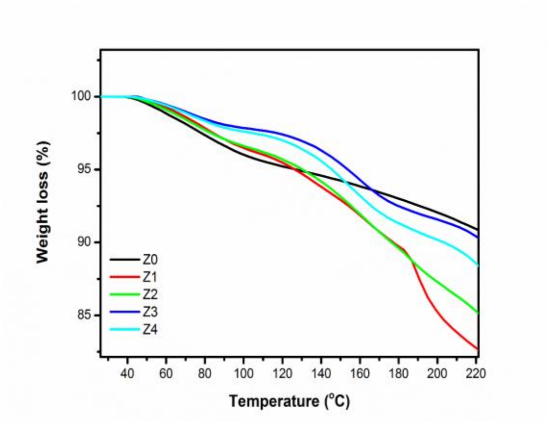

**Figure 4.** TGA (a), and DTG (b) of zein powder (Z0) and eucalyptus/zein electrospun fibers loaded with 0% (Z1), 2.5% (Z2), 5% (Z3), and 10% (v/v) (Z4) of peppermint essential oil.

[2]1- Inter-helix packing

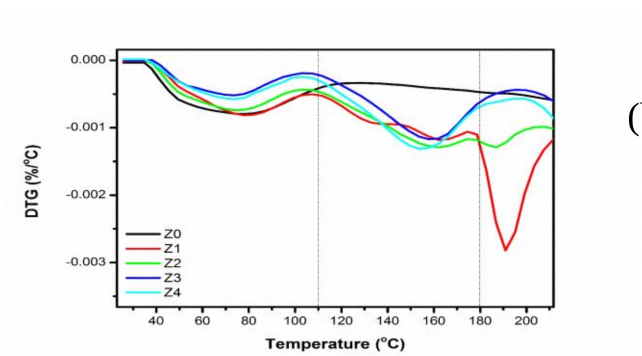
**Table 2** Weight loss values related to each step for the samples

| | First step | | | Second step | | | Third step |
|---|---|---|---|---|---|---|---|
| Sample | 25-110°C | 110-180°C | 180-220°C | 220-270°C | 270-300°C | 300-500°C | 500-800°C |
| Z0 | 4.49 | 2.44 | 2.14 | 5.64 | 11.27 | 46.55 | 27.47 |
| Z1 | 4.05 | 6.09 | 8.07 | 6.86 | 10.53 | 40.08 | 24.32 |
| Z2 | 3.87 | 6.37 | 4.44 | 7.93 | 11.7 | 40.51 | 25.18 |
| Z3 | 2.35 | 5.08 | 2.13 | 11.1 | 11.89 | 41.01 | 26.44 |
| Z4 | 2.27 | 5.91 | 2.82 | 9.45 | 12.53 | 41.26 | 25.7234 |

In order to more closely examine each stage of weight loss, different stages of weight changes are shown separately in thermograms. Figure 5 shows the thermogram for the temperature range of 25 to 220 degrees Celsius.




(a)



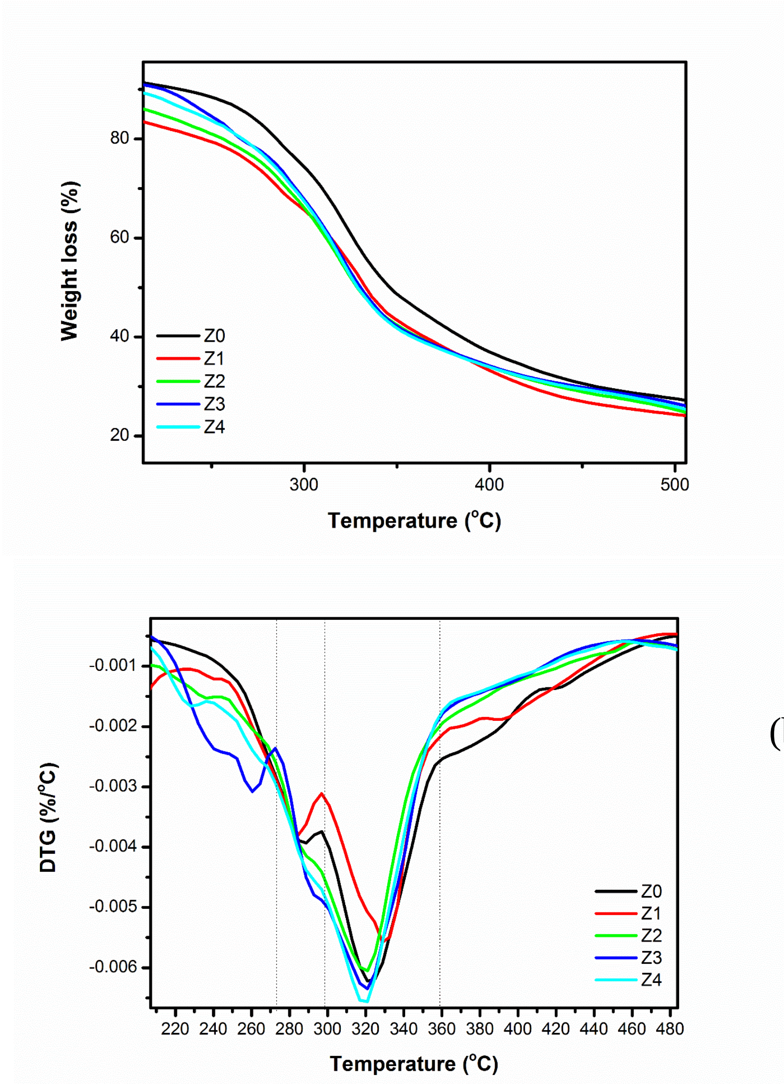

(b)

**Figure 5.** TGA (a), and DTG (b) of zein powder (Z0) and eucalyptus/zein electrospun fibers loaded with 0% (Z1), 2.5% (Z2), 5% (Z3), and 10% (v/v) (Z4) of peppermint essential oil, in the range of 25-225 °C.

According to Figure 5 (a, b), the first stage of weight loss in the temperature range of 25 to 220 °C for all samples is related to the evaporation of surface absorption water, structural water and other solvents.available in the samplesbe [26, 27]. According to this figure, at this stage, three different endothermic peaks can be seen in different areas. The first peak in the temperature range of 25 to 110 degrees Celsius is related to surface absorption water that requires heat for evaporation.It is less productive. According to Table 2, the highest surface water absorption was related to the powdered zein sample, followed by pure electrospun zein, with the addition of essential oil concentration in the structure, the amount of surface water absorption decreased. In fact, it seems that in the samples containing essential oil, the compounds in this essential oil were replaced by water molecules in the structure of the material, and therefore there was less water in these samples. In the part after this stage and in the range of 110 to 180 degrees Celsius, the powder sample has a very small weight loss, but more weight loss is observed in the electrospun samples, especially the samples containing essential oils. This step can be related to water molecules that are hydrogen bonded with the surface [28] and therefore need a higher temperature than surface adsorbed water for evaporation. According to Table 2, it is clear that the amount of this water has increased with the increase in the concentration of essential oil, which is due to the presence of polar compounds in the compounds of this substance, which have formed hydrogen bonds with water. In the third region (temperature range 180 to 220 °C) from this stage only in the sampleZ1and to a lesser extent samplesZ2Endothermic peak in the diagramDTGIt can be seen that this case can be related to the solvent used in the electrospinning stage, such as glycerol (with an evaporation temperature of 198 °C) [29] that with the increase in the concentration of the essential oil, this solvent remains less in the structure of the material and therefore the peak related to It is weakened.

The next stage of weight loss in the range of 220 to 500 degrees Celsius also leads to the thermal decomposition of stable amino acids.

Low thermal and primary protein structure is zein [30]. Also, the compounds in the essential oil are destroyed in this temperature range [31]. In this stage of weight loss, three different ranges can be seen, the amount of weight loss in each range is reported in Table 2, and the thermograms related to this stage are shown in Figure 6.




(b)

**Figure 6.** TGA (a), and DTG (b) of zein powder (Z0) and eucalyptus/zein electrospun fibers loaded with 0% (Z1), 2.5% (Z2), 5% (Z3), and 10% (v/v) (Z4) of peppermint essential oil, in the range of 220-500 °C.

According to Figure 6 and Table 2, an endothermic peak can be seen in the temperature range of 220 to 270 °C in samples containing essential oil, which is related to the removal of hydroxyl groups in essential oil compounds [32]. From Table 2, it is clear that with the increase in the concentration of essential oil to the sampleZ3The amount of this weight loss is also increased and then in the sampleZ4Some of this weight loss has been reduced. The reason for more hydroxyl groups in the sampleZ3compared to the sampleZ4It is unclear and needs further investigation. In the temperature range of 270 to 300 degrees Celsius, other functional groups have been removed in the composition of the essential oil, including carboxylic compounds [33]. According to

Table 2, it can be seen here that the increase in the concentration of essential oil compounds in the structure increases the mass reduction in this thermal range, which is a reason for the more compounds containing these functional groups in the composites with more essential oil. In the next stage of weight loss, in addition to the thermal decomposition of amino acids with low thermal stability and the primary protein structure of zein, compounds with higher thermal stability in the essential oil such as the carbohydrate skeleton of this substance are also decomposed, which increases the weight loss in samples containing Essential oil is higher in this temperature range.

The final stage of weight loss, which is characterized by an endothermic peak in the temperature range of 500 to 800 °C, is also related to the thermal decomposition of amino acids with high thermal stability such as glycine [30]. This stage of weight loss is also shown with greater magnification in the thermograms of Figure 7.

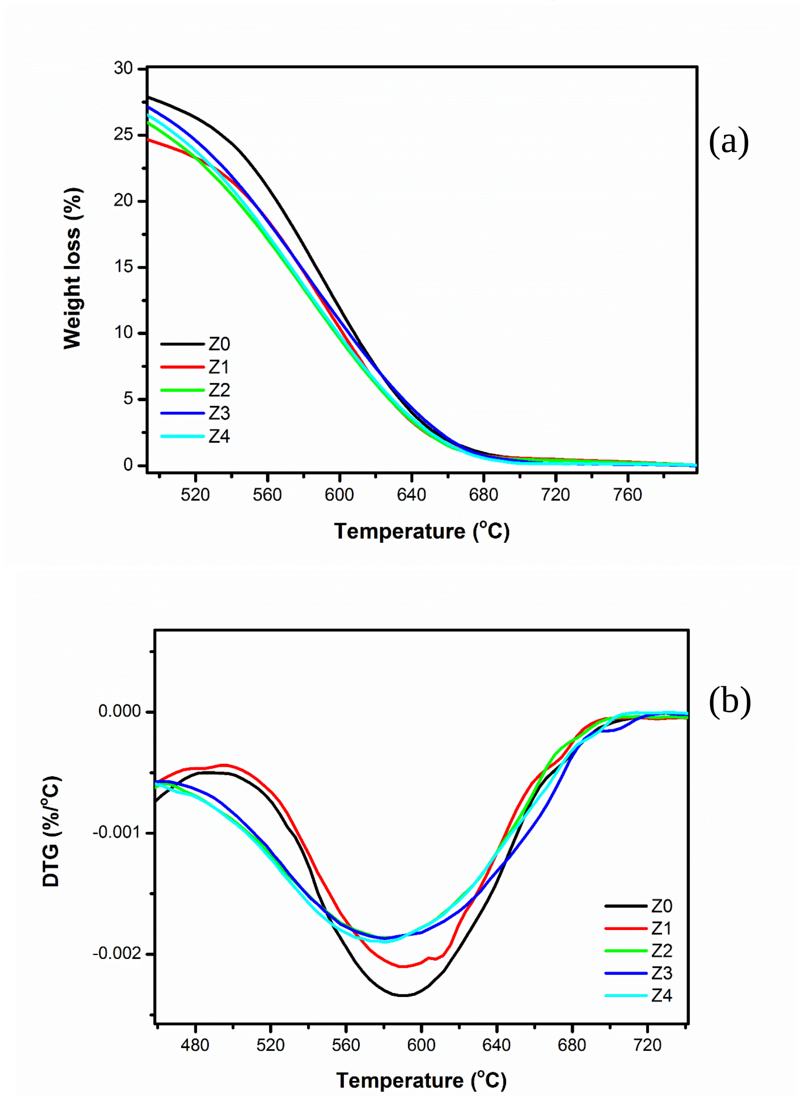



**Figure 7.** TGA (a), and DTG (b) of zein powder (Z0) and eucalyptus/zein electrospun fibers loaded with 0% (Z1), 2.5% (Z2), 5% (Z3), and 10% (v/v) (Z4) of peppermint essential oil, in the range of 500-750 °C

According to Figure 7 and Table 2, it is clear that weight loss in this temperature range in samples without essential oil compounds (samplesZ0AndZ1) was more than the samples containing these compounds, which is due to the complete decomposition of the essential oil compounds in the thermal range of less than 500 degrees Celsius, and therefore the only remaining compounds are amino acids with high thermal stability in the zein structure. In addition to the figure (a7) It is also clear that at the temperature of 800 degrees Celsius, all compounds in all samples were thermally decomposed and almost no compounds remained as ash, and the remaining weight in all samples was close to zero.

**Encapsulation efficiency**

Determining efficiency is one of the important parameters in encapsulation technology, which is the efficiency of nanofibers in trapping essential oils. In this work, the encapsulation efficiency of peppermint essential oil in zein nanofibers was approximately 97% for all levels of encapsulated essential oil. The results of this research are in accordance with the research results of Neo et al. (2013), Yelmaiz et al.be Neo et al. (2013) reported 100% encapsulation efficiency of gallic acid in electrospun zein fibers. Ghaempour and Mortazavi (2014) encapsulated peppermint essential oil in sodium alginate nanoparticles by electrospraying and reported an efficiency of 96%. Yelmaiz et al. (2019) reported an efficiency of 98% for the encapsulation of peppermint essence.

**Antimicrobial properties**

The antimicrobial activity of electrospun fibers plays an important role in their food applications. The results of the previous realization (Rahtinia et al., 1401) showed that nanofibers containing eucalyptus essential oil do not have strong antimicrobial activity. For this reason, in order to strengthen its antimicrobial activity, peppermint essential oil was loaded in different concentrations in nanofibers containing 10% eucalyptus essential oil (which has the most antimicrobial properties). Thus, the antimicrobial activity of fluffy peppermint essential oil loaded in zein nanofibers containing eucalyptus essential oil inequal to*S. aureus*(ATCC 29737), *E. coli*(ATCC 25922), It was evaluated by the disc diffusion method. The diameter of the growth halo was shown in Table 3. The results show that nanofibers loaded with peppermint essential oil and eucalyptus essential oil have strong antimicrobial activity against Gram-positive bacteria (*S. aureus*(and Gram-negative bacteria)*E. coli*) have. By increasing the concentration of peppermint essential oil, the diameter of the halo of non-growth of bacteria also increases. Zein nanofibers with concentrations of 0, 2.5, 5 and 10% of peppermint essential oil in the microbial test against bacteria*Staphylococcus aureus* 13, 16, 18 and 20 mm respectivelyThe diameter of the halo is lack of growth. Also, against bacteria*Escherichia coli* respectively, it has 14, 15.5, 17.6, and 19.5 mm in diameter of the halo of non-growth. Another study conducted by Dabagh Moghadam et al. (2019) shows that zein nanofibers loaded with 3% Shirazi thyme essential oil against*Staphylococcus aureus* With the diameter of the growth halo of 2.25 mm, they show antibacterial activity [27].

The results of this research showed that with increasing the concentration of peppermint essential oil from 2.5 to 10%, the diameter of the growth halo increased (Table 3). The results show the strengthening effect of the two mentioned essential oils on each other's antimicrobial properties. The antimicrobial activity of peppermint essential oil is probably attributed to the high amount of menthol (42%) and menthone (18%). In general, the mechanism of essential oils against microorganisms can be due to the destruction of the cell wall, reaction with membrane proteins, destruction of the cytoplasmic membrane, increase of cell permeability, leakage of cell contents [28, 29, 30]. According to the results related to antibacterial activity against*Staphylococcus aureus* And*Escherichia coli*Can used the loaded nanofibers decorated with eucalyptus and peppermint essential oils as active packaging in a wide range of food products, including for packaging dairy and meat products, because these bacteria are highly prevalent in these products.

**Table 3** Average diameter of bacteria inhibition zone for eucalyptus/zein electrospun fibers loaded with different concentrations of peppermint essential oil. *

| Peppermint essential oil content (%) | Diameter of inhibition zone (mm) | |
|---|---|---|
| | ***S. aureus*** | ***E. coli*** |
| **0** | 13.0±0.0$^{d}$ | 14.0±0.0$^{d}$ |
| **2.5** | 16.0±0.0$^{c}$ | 15.5±0.0$^{c}$ |
| **5** | 18 ± 0.8$^{b}$ | 17.6 ± 0.6$^{b}$ |
| **10** | 20 ± 1.6$^{a}$ | 19.5±0.3$^{a}$ |

* Means bearing different superscripts are significantly different ($p < 0.05$). Results are presented as mean ±SD (n=3).

## 4- Resultget

In this study, a mixture of eucalyptus and peppermint essential oils was encapsulated in electrospun fibers for the first time. Zein protein was used as matrix. The results showed that essential oil loading has no effect on the morphology of electrospun fibers of zein. As expected, the diameter of electrospun fibers increased with the increase of essential oil concentration. PicturesWHICH, tube morphologyE shows the electrospun fibers.ResultsXRD showsadding essential oil to the ornament has not changed the physical structure of the ornament. ThermogramTGA showed that essential oil increases the thermal stability of fibers. spectrumFTIR It showed that there is an interaction between essential oils and cosmetics, spectrumFTIR showed that cumin essential oil affects the secondary structure of zein. High encapsulation efficiency for all sampleswas obtained. The results of the antimicrobial test showed that the fibers containing the essential oil have antibacterial activity against Gram-positive and Gram-negative bacteria. The results show the strengthening effect of the two mentioned essential oils on each other's antimicrobial properties. According to the results of this work, fibers containing a mixture of eucalyptus essential oil and peppermint can be considered as an active packaging.

## 5- Appreciation

Authors from Zabul University for financial support (IR-UOZ-GR-4249) They are grateful for the implementation of this project.

## 6- Resources

[1] Aman Mohammadi M, Ramezani S, Hosseini H, et al (2021) Electrospun

Antibacterial and Antioxidant Zein/Polylactic Acid/Hydroxypropyl Methylcellulose Nanofibers as an Active Food Packaging System. Food Bioprocess Technol. 14:1529–1541

[2] Jiang S, Chen Y, Duan G, et al (2018) Electrospun nanofiber reinforced composites: a review. Polym Chem 9:2685–2720. https://doi.org/10.1039/C8PY00378E

[3] Ghasemi M, Miri MA, Najafi MA, et al (2022) Encapsulation of Cumin essential oil in zein electrospun fibers: Characterization and antibacterial effect. J Food Meas Charact. https://doi.org/10.1007/s11694-021-01268-z

[4] Miri MA, Ghorani B, Miri HR (2019) Electroencapsulation: Fundamentals and applications in food industry. JFST 16:1–21

[5] Antunes MD, da Silva Dannenberg G, Fiorentini ÂM, et al (2017) Antimicrobial electrospun ultrafine fibers from zein containing eucalyptus essential oil/cyclodextrin inclusion complex. Int J Biol Macromol 104:874–882. https://doi.org/10.1016/j.ijbiomac.2017.06.095

[6] Hosseini F, Miri MA, Najafi M, et al (2021) Encapsulation of rosemary essential oil in zein by electrospinning technique. J Food Sci 64:1750–3841.15876. https://doi.org/10.1111/1750-3841.15876

[7] Rahmatinia N, Aran M, Miri MA, Ramezan D (2022) Electrospun zein nanofibers as a nanocarrier of Eucalyptus essential oil: Characterization, and antimicrobial properties. Food Sci Technol 18:81–91. https://doi.org/10.52547/fsct.18.121.7

[8] Beyki M, Zhaveh S, Khalili ST, et al (2014) Encapsulation of Mentha piperita essential oils in chitosan-cinnamic acid nanogel with enhanced antimicrobial activity against Aspergillus flavus. Ind. Crops Prod. 54:310–319

[9] Tabatabaei Yazdi F, Alizadeh Behbahani B, Vasiee AR, et al (2018) Evaluation antioxidant activity, phytochemical constituents and antimicrobial of Mentha Piperita essential oil on some infectious and poisonous microorganisms. Food Sci Technol [Persian] 15:67–76

[10] Aghaei Z, Ghorani B, Emadzadeh B, et al (2020) Protein-based halochromic electrospun nanosensor for monitoring trout fish freshness. Food Control 111:107065. https://doi.org/10.1016/j.foodcont.2019.107065

[11] Iranmanesh S, Aran M, Miri MA, Pirnia M (2022) Preparation and Characterization of Zein Electrospun Fibers for Nano Encapsulation of Ajowan (Trachyspermum copticum L.) Essential Oil. J Essent Oil-Bearing Plants 25:219–233. https://doi.org/10.1080/0972060X.2022.2068970

[12] Rezaei M, Aran M, Amani AM, et al (2021) Use of electrospun chitosan nanofibers as nanocarriers of

Artemisia sieberi extract: Evaluation of properties and antimicrobial effects. J Food Sci Technol 18:323–334. https://doi.org/10.29252/fsct.18.03.27

[13] Yao ZC, Chang MW, Ahmad Z, Li JS (2016) Encapsulation of rose hip seed oil into fibrous zein films for ambient and on demand food preservation via coaxial electrospinning. J. Food Eng. 191:115–123

[14] Ramakrishna S, Fujihara K, Teo WE, et al (2005) An introduction to electrospinning and nanofibers

[15] Tan SH, Inai R, Kotaki M, Ramakrishna S (2005) Systematic parameter study for ultra-fine fiber fabrication via electrospinning process. Polymer (Guildf). 46:6128–6134

[16] Nayak R, Padhye R, Kyratzis IL, et al (2013) Effect of viscosity and electrical conductivity on the morphology and fiber diameter in melt electrospinning of polypropylene. Text Res J 83:606–617. https://doi.org/10.1177/0040517512458347

[17] Ardekani NT, Khorram M, Zomorodian K, et al (2019) Evaluation of electrospun poly (vinyl alcohol)-based nanofiber mats incorporated with Zataria multiflora essential oil as potential wound dressing. Int J Biol Macromol 125:743–750. https://doi.org/10.1016/j.ijbiomac.2018.12.085

[18] Teilaghi S, Movaffagh J, Bayat Z (2020) Preparation as Well as Evaluation of the Nanofiber Membrane Loaded with Nigella sativa Extract Using the Electrospinning Method. J Polym Environ 28:1614–1625. https://doi.org/10.1007/s10924-020-01700-3

[19] Bumedi F, Aran M, Miri MA, Seyedabadi E (2023) Preparation and characterization of zein electrospun fibers loaded with savory essential oil for fruit preservation. Ind Crop Prod 203:. https://doi.org/https://doi.org/10.1016/j.indcrop.2023.117121 Received

[20] Yilmaztekin M, Lević S, Kalušević A, et al (2019) Characterisation of peppermint ( Mentha piperita L.) essential oil encapsulates. J Microencapsul 36:109–119. https://doi.org/10.1080/02652048.2019.1607596

[21] Ullah S, Hashmi M, Khan MQ, et al (2019) Silver sulfadiazine loaded zein nanofiber mats as a novel wound dressing. RSC Adv 9:268–277. https://doi.org/10.1039/C8RA09082C

[22] Yang SB, Rabbani MM, Ji BC, Han D (2016) Optimum Conditions for the Fabrication of Zein / Ag Composite Nanoparticles from Ethanol / H 2 O Co-Solvents Using Electrospinning. Nanomaterials 6:1–11. https://doi.org/10.3390/nano6120230

[23] Oliviero, M., Di Maio, E., & Iannace, S. (2010). Effect of molecular structure on film blowing ability of thermoplastic zein. Journal ofApplied Polymer Science, 115,(1), pp. 277–

[29] Meyer N, Rivera LR, Ellis T, et al (2018) Bioactive and Antibacterial Coatings Based on Zein/Bioactive Glass Composites by Electrophoretic Deposition. Coatings 8

[30] De Figueredo GP, De Carvalho AFM, De Araújo Medeiros RLB, et al (2017) Synthesis of MgAl2O4 by Gelatin Method: Effect of Temperature and Time of Calcination in Crystalline Structure. Mater Res 20:254–259. https://doi.org/10.1590/1980-5373-MR-2017-0105

[31] Akbarzadeh S, Ramezanzadeh M, Ramezanzadeh B, Bahlakeh G (2020) A green assisted route for the fabrication of a high-efficiency self-healing anti-corrosion coating through graphene oxide nanoplatform reduction by Tamarindus indiaca extract. J Hazard Mater 390:122147. https://doi.org/10.1016/j.jhazmat.2020.122147

[32] Javidparvar AA, Naderi R, Ramezanzadeh B (2020) L-cysteine reduced/functionalized graphene oxide application as a smart/control release nanocarrier of sustainable cerium ions for epoxy coating anti-corrosion properties improvement. J Hazard Mater 389:122135. https://doi.org/10.1016/J.JHAZMAT.2020.122135

[33] Aliyev E, Filiz V, Khan MM, et al (2019) Structural Characterization of Graphene Oxide: Surface Functional Groups and Fractionated Oxidative Debris. Nanomaterials 9:1180. https://doi.org/10.3390/nano9081180

287. https://doi.org/10. 1002/app.31116

[24] Feng Y, Lee Y (2017) Microfluidic fabrication of hollow protein microcapsules for rate-controlled release. RSC Adv. 7:49455–49462

[25] Xu Q, Bai Z, Ma J, et al (2021) Effect of different drying methods on zein-based microcapsules loaded with Artemisia argyis essence obtained by anti-solvent precipitation. J Appl Polym Sci 138:50921. https://doi.org/https://doi.org/10.1002/app.50921

[26] Roshanghias A, Sodeifian G, Javidparvar AA, Tarashi S (2022) Construction of a novel polytetrafluoroethylene-based sealant paste: The effect of polyvinyl butyral (PVB) and nano-alumina on the sealing performance and construction formulations. Results Eng 14:100460. https://doi.org/10.1016/J.RINENG.2022.100460

[27] Javidparvar AA, Naderi R, Ramezanzadeh B (2019) Epoxy-polyamide nanocomposite coating with graphene oxide as cerium nanocontainer generating effective dual active/barrier corrosion protection. Compos Part B Eng 172:. https://doi.org/10.1016/j.compositesb.2019.05.055

[28] Ferreira-Villadiego J, García-Echeverri J, Vidal M V, et al (2018) Chemical Modification and Characterization of Starch Derived from Plantain (Musa paradisiaca) Peel Waste, as a Source of Biodegradable Material. In: CHEMICAL ENGINEERING TRANSACTIONS

مجله علوم و صنایع غذایی ایران

سایت مجله: www.fsct.modares.ac.ir

مقاله علمی_پژوهشی

# ساخت بسته بندی فعال با استفاده از اسانس اکالیپتوس و اسانس نعنا فلفلی به روش الکتروریسی: بررسی ویژگی‌ها و خاصیت ضد باکتریایی

زهرا سرگزی[۱]، محمد امین میری*[۲]، محمد علی نجفی[۳]

۱- دانشجوی کارشناسی ارشد علوم و صنایع غذایی، دانشکده کشاورزی، دانشگاه زابل، ایران.

۲- استادیار، گروه علوم و صنایع غذایی، دانشکده کشاورزی، دانشگاه زابل، ایران؛ آزمایشگاه الکتروریسی، دانشگاه زابل، زابل، ایران.

۳- دانشیار، گروه علوم و صنایع غذایی، دانشکده کشاورزی، دانشگاه زابل، ایران.

**اطلاعات مقاله**

**تاریخ های مقاله :**

**تاریخ دریافت: ۱۴۰۲/۳/۳۰**

**تاریخ پذیرش: ۱۴۰۲/۶/۱۱**

**کلمات کلیدی:**

مخلوط اسانس‌ها ،

الکتروریسی،

زئین،

خاصیت ضد میکروبی

**DOI: 10.22034/FSCT.20.143. 91**

**DOR:20.1001.1.20088787.1402.20.143.7.9**

* مسئول مکاتبات:

ma.miri@uoz.ac.ir

**چکیده**

هدف از انجام این تحقیق، تقویت خاصیت ضد میکروبی نانوالیاف فعال حاوی اسانس اکالیپتوس با استفاده از غلظت های مختلف اسانس نعناع فلفلی برای استفاده به عنوان بسته‌بندی فعال می‌باشد. نانوالیاف حاوی مخلوط اسانس اکالیپتوس (۱۰ درصد) و اسانس نعناع فلفلی ( غلظت‌های ۰، ۲،۵، ۵، ۱۰ درصد (حجمی/حجمی)) تولید شد. نتایج SEM و Image-J نشان داد که بارگذاری اسانس، قطر الیاف الکتروریسی شده را از ۲۰۰ به ۴۰۰ نانومتر افزایش داد. تصاویر SEM نشان داد که مورفولوژی الیاف الکتروریسی شده به شکل لوله‌ای است. XRD برای مطالعه ساختار فیزیکی الیاف الکتروریسی شده به کار گرفته شد و دیفراکتوگرام‌های XRD نشان می‌دهد که افزودن اسانس به زئین، منجر به تغییر ساختار کریستالی زئین نشده است. ترموگرام‌های TGA نشان داد که بارگذاری اسانس باعث افزایش پایداری حرارتی الیاف الکتروریسی شده، گردید. طیف FTIR برهمکنش بین الیاف الکتروریسی شده و اسانس را نشان می دهد. آزمایش ضد میکروبی به روش انتشار دیسک انجام شد و نتایج نشان داد که پوشش فیبری حاوی اسانس از رشد *استافیلوکوکوس اورئوس و اشریشیا کلی* جلوگیری نموده. با توجه به نتایج این تحقیق، الیاف حاوی مخلوط اسانس‌های اکالیپتوس و نعناع فلفلی را می توان به عنوان یک بسته بندی فعال برای استفاده در بسته‌بندی مواد غذایی مختلف مانند پنیر، گوشت و برخی محصولات غذایی دیگر در نظر گرفت.