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**RESEARCH ARTICLE** / ARAŞTIRMA MAKALESİ

# Investigation of Mechanical Properties of Aloe Vera Gel (AVG)/PVA/PLLA Layered Nanobiocomposites

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**Abstract**

Aloe Vera Gel (AVG) is a product obtained from the leaf portion of the *Barbadensis Miller* plant and known for its wound-healing properties. PVA is a water-soluble, biologically disintegrated polymer. PLLA, the stereoisomer of the biodegradable polylactic acid obtained from corn, is a thermoplastic polymer and has properties such as strength and elasticity. In this study, in the first stage, PLLA polymer was converted into nanoweb form as a carrier layer. In the second stage, two-layer nanobiocomposites were produced by applying aloe vera (AVG)/PVA mixture on the existing PLLA nanoweb on the collector of the electrospinning device. The effects of the AVG addition of AVG/PVA/PLLA nanobiocomposite structures containing 0 %, 5 %, 10 %, and 20 % of AVG were examined by using instrumental methods such as viscosity, conductivity, pH, SEM, tensile strength, stretch %, delicacy, FT-IR, and XRD.As a result, the percentage of crystallization due to the AVG ratio in the mixtures increased and has been found to provide resistance to the structure. This feature will be the source for the formation of biocrheable resistant materials in future medical studies related to AVG.

**Keywords:** PLLA (poly-L-lactic acid), PVA ((Poly(vinyl alcohol), AVG (Aloe Vera Gel), Nanobiocomposite, Electrospinning

## I. INTRODUCTION

Aloe Vera is among ‘’Selected Medicinal Plants’’ by (WHO World Health Organization) and principally this species is called as Aloe Barbadensis Miller. It is an approximately 12-years old plant that has 30-50 cm height and its leaves have 10 cm wideness at its deep parts and that has fine and sparse tubular shaped light yellow flowers at the mid parts that includes a colourless gel at inner parts (parenchyma region) and a plant that grows so many tropical and hot regions like all Mediterranean mainly upper parts of “Nile“ river located in Sudan African Continent and Asia, Bahamas, Central America, Mexico, south part of USA, Southeast Asia and West India [1-2]. Aloe Vera Barbadensis Miller plant has totally 200 components that 75 of these components have a biological activity. Gel part of plant is constituted from 99,5% water and 0,5% solid matter content [3]. The materials like (β (1, 4) acetylated mannose, xylose, mannose, galactose and arabinose, Lupeol (a triterpenoid), cholesterol, campesterol and β-sitosterol) constituted by long chain polysaccharides that are known as glucose and mannose are constituted from 1,4 glycosides bonds, polymers at branched linear structure and acidified glaucoma’s are water soluble [4-5]. AVG (Aloe Vera Gel) is a type of nectar that have different effects like scar treatment [6-7], skin renovation [1], wrinkle correction [8-10], skin damage renovation bound to UV and X-ray [11], antibacterial [12], antimicrobial [6], anti-inflammatory and antiarthritic [13].

PVA (Poly(vinyl alcohol) is a water-soluble and hydrophilic polymer same as AVG and it is the most produced artificial adhesive in the world. It is used in a significant number of commercial products because of its excellent chemical resistance, physical and biodegradable properties. It is used as equalizer for coating material, sizing agent, adhesive, emulsion stabilizer and colloid suspensions in textile and paper industry [14-15]. It is a widely used advantageous polymer due to being a biodegradable polymer constituting degradation products like $H_2O$ and $CO_2$, as well as easy processing feature especially for biomedical applications and drugs and also being a biological adhesive that is not toxic and carcinogenic [15-17].

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Polylactic acid (PLA) has a leading position in bio plastic market with regard to the demand situation and the appropriate production costs. It is aliphatic polyester produced from lactic acid and it also is relatively naturally occurring acid and a food additive. PLA is a thermoplastic material having similar rigidity and transparency to polystyrene and polyester. Different end-use products like flexible and rigid film packages, injection moulds, extrusion coating and textile fibers are produced from PLA polymer. It is a bio-based and biodegradable polymer that is absorbable in the soil under industrial recycling conditions **[18].**

Uslu et al. (2010) added AVG into biopolymers, such as PVA, PVP (Polyvinyl pyrrolidone, PEG (Polyethylene glycol ) etc., to produce nanofibers and they investigated the effects of AVG on pH, surface stretching, viscosity and conductivity of nanofibers by using characterisation techniques. It was observed that the fiber diameter was 200-500nm, homogenous, tandem and linear and it was reported that a crystalline and cross-linked hybrid polymer occurred when 3%wt ratio of Aloe Vera was added **[19]**. In another study, a nanofiber structure was produced by adding HPMC (hydroxypropyl methylcellulose) and AVG (2%, 4% and 6%) into the PVA/PVP/PEG solution with the aims of water retention and wound healing properties, respectively. It was observed that amorphous ratio, $T_m$ (Melting temperature) and $T_g$ (Glass temperature) values and correspondingly thermal stability were increased with increase in AVG ratio inside smooth fine fibers in 100-900 nm diameter. It was also seen that its wound healing and bacteria protection properties increased with increase in number of pores **[20].** Serincay et al. (2013) reported that nanofiber porous structure produced by adding 0.2g ciprofloxacin HCI (Hydrochloric acid) and 0,08 g AVG into PVA/PAA (Polyacrylic acid) solution at different ratios showed an appropriate humidity, oxygen transmittance and thermal stability and it was also bacteria proof that addition of ciprofloxacin HCI and AVG into the solution prevented bacteria passage and ciprofloxacin HCI drug was released in 120 minutes **[21].** Kim et al. solved PLLA polymer in dichloromethane and dimethyl acetamide mixture solution and added $AgNO_3$ (silver nitrate) nano particles at different ratios and produced nanofiber by electro spinning. Produced nanofiber structure contained 0%, 3%, 6% and 9% wt. ratio of $AgNO_3$. The nanofiber structure was investigated under UV spectrophotometer, It was seen that bead formation in the solution was decreased with an increase in number of silver particles that resulted an improved electro spinning process. It was observed that the structure contained 10% PLA and 6% showed the best result, thinner and smoother fiber diameter **[22].** Tomaszewski et al. produced nanofiber and microfiber structures from poly-L-lactic acid (PLLA) by single jet and multi jet electro spinning and then investigated tensile properties. They observed that thickness and quality of fiber was directly proportional to viscosity of solution concentration. Furthermore, it was reported that durability and mechanical properties improved with an increase in crystalline region as seen in their DSC and tensile strength test results **[23]**.

The amount of AVG used in this study is the highest ratio in nanofiber materials up to now which constitutes a foresight for the studies to be conducted in medical field in the future. Fully biodegradation of polymer materials, healing properties of aloe vera gel and positive change in the mechanical properties of the nanobiocomposite material constitute the outline of this study.

In this study, mechanical properties of 2 stratified nanobiocomposite material composed of 2 nanofiber structures; one produced from PVA dissolved in deionised water and contained 5%, 10% or 20% AVG and the other one produced from PLLA dissolved in $CHCl_3$ (chloroform) /DMF(Dimethyl formamide ) / mixture.

## II. MATERIAL AND METHOD

### 2.1. Materials

The stabilized AVG product (whose tolerance was increased with chemical procedures for environment conditions) was purchased from Forever Living Products Company as Aloe Vera Gel (AVG) which was then subjected to filtration procedure by using a socket cartridge (Filter lab 100% Pure Cel. 33X80 MM REF: 1800) and purified from botanical residuals. PLLA polymer was purchased from (85,000-160,000g/mol) Sigma Aldrich Company. PVA (70,000g/mol), $CHCl_3$ (99.0%) which is used to dissolve the polymer, NaCl (Sodium chloride 99. 0%) which is used to increase the conductivity and DMF (98.8%) solvent was purchased from Merck Company. All the chemicals were used as obtained without any further purification.

The whole study was conducted in 3 three parts; (a) solution preparation and its properties, (b) electro spinning process and nanobiocomposite production (c) characterization of produced structures.

### 2.2. Solution Preparation

In this study, to form a nanobiocomposite structure, firstly a nanofiber structure was produced from PLLA (poly-L-lactic) (1g/10 ml (10% wt.) polymer which was dissolved in the $CHCI_3$ (chloroform) 80%: DMF (dimethyl formamide) 20% by using electro spinning method. Two stratified nanobiocomposite structure was produced by forming the second nano fiber structure, which was produced from a solution containing 12% wt. ratio of PVA dissolved in water and stabilised Aloe Vera Gel (95:05, 90:10, 80:20) in different proportions, onto the first one by using the spinning technique.

With the aim of increased conductivity and gravitation of the solution during electro spinning process, 0.2 g NaC1 was added into PLLA (10%wt) solution, and stirred for 24 hours in a magnetic stirrer. The solution was put in the capped glass vials and homogenized by applying 20 kVA power for 10 min in an Everest branded ultrasonic bath.

PVA with a weight ratio of 12% was dissolved in deionised water by being stirred with a magnetic stirrer. Stabilized AVG at different proportions like 95:05, 90:10, and 80:20 was added to prepared PVA solution and 10 ml PVA/AVG solutions mixed by a magnetic stirrer for 24 hours was homogenised in the bath for 10 minutes. pH and (µS/cm) values of the prepared solution was measured with "WTW Cond 3110" branded Manual type conductivity meter and viscosity values of the solution was measured with "Brookfield DV-E" branded viscometer device. Small sample adaptor (for the solutions that are 10 ml and below) s21 number spindle (rotating shaft) was used for viscosity measurement of samples in small quantities and the values were read as cP (centipoise) at 100 rpm and $25^0$C. The measured values are given at (**Table 1**.)

**Table 1.** Polymer Solution Properties Prepared for Electro spinning Process

| Polymer solutions | Blend ratio (%) | Viscosity (cP) | Conductivity (µS/cm) | pH |
|---|---|---|---|---|
| AVG (%100) + $H_2O$ | 100 | 14.8±1.1 | 3.25±1.7 | 5 |
| PVA (%12) + $H_2O$ | 100 | 215±1.8 | 519±2.8 | 5 |
| PLLA (%10) $CHCl_3$/DMF | 100 | 45±2.2 | 1.1±2.0 | 5 |
| PVA (%12) + $H_2O$/AVG (%100) | 95/5 | 58±2.3 | 1020±2.1 | 5 |
| PVA (%12) + $H_2O$/AVG (%100) | 90/10 | 113±1.5 | 1030±1.9 | 5 |
| PVA (%12) + $H_2O$/AVG (%100) | 80/20 | 123±1.2 | 1216±1.7 | 5 |

### 2.3. Electrospinning Process

The electro spinning process was carried out with NS24 laboratory type device of Invenso company that work in accordance with vertical production principle (the needle is below and assembler cylinder is above). Polymer solution drawn into the injector and located on dosing unit was pumped with the help of ml/min adjustable speed injector pump to a gauge with a diameter of 20. The polymer jet taken from the spinneret was directed to 8 cm diameter assembler cylinder, which is 15-30 cm above the spinneret, oscillating from the centre to right and left at 35 d/min rotational speed and electrical field constituted with averagely 30 kV AC alternative current voltage and nano fiber 2 layered composite structures was produced. (Figure 1) Nano composite production was done at 26-30 $^0$C and 30-42% relative humidity (Table 2).

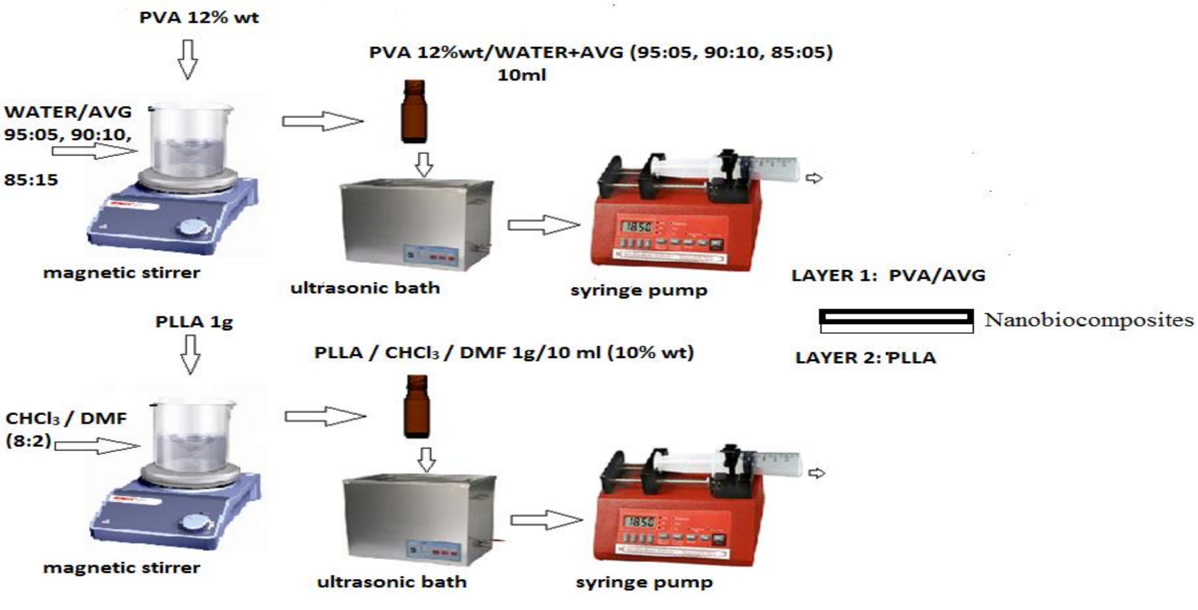

**Figure 1.** Nanobiocomposites Production Chart

**Table 2.** Electro Spinning Production Parameters

| Polymer solutions | NaCI (g) | Production rate (ml/h) | Collector distance (cm) | Temperature ($^0$C) | Relative humidity (%) | AC current (kV) |
|---|---|---|---|---|---|---|
| PVA/AVG | - | 1 | 15 | 26 | 40 | 33 |
| PLLA | 0.2 | 0.30 | 27 | 29 | 32 | 30 |

### 2.4. Nanofiber Characterization

*2.4.1. Morphological characterization*

In this study, nano fiber structures were first coated with gold and then viewed under JEOL JMS-5910 type scanning electron microscope (SEM) with magnifications of 10000x and 20000x at 20 kV. Statistical analysis of SEM images and measurements obtained from 60 different regions by using image J program via computer and the images were examined with mean and standard deviation methods. (ASTM D 130)

*2.4.2. X-ray Difractometer*

Diffraction angle 2θ of samples was determined by clearance of a specific group planes by using Riguku XRD analyze at X-ray diffraction. Preference orientation along 200 reflection intensity was observed as 30-40 $^o$ according to this value calculated with the help of Bragg equality for all AVG samples (ASTMD4294)

*2.4.3. FT-IR*

Thermo Scientific Nicolet iS50R brand device was used in the study. Nanobiocomposite materials were examined at 4 cm-1 solubility by carrying out 5 different test for per sample between 500 cm$^{-1}$ and 4000 cm$^{-1}$ wavelength. (ASTM D7414)

### 2.5. Mechanical Properties

Test samples were 30x10 mm and in dry condition and they were prepared in the machine and material width direction. Firstly material thickness measurement was carried out with RB Cloth Thickness Tester branded thickness meter from James & Heal Co. Ltd. Tensile strength of nanobiocomposite samples were measured with Instron 4411 branded device under 50 N (Newton) force at 10m/min speed.

Carrying out a test according to tensile strength test standards (according to ASTM D 882-10) applied to film or cheesecloth based fabrics was seen as the most common and most appropriate method in the mechanical property investigations of nanofibers **[25].** Nanobiocomposite structures were cut in the shape of rectangular or dumbbell (standard towing bar) and subjected to disjuncture strength and elongation test at towing bar **[26].** An alternative towing sample was prepared by Huang et al. (2004) for nanofiber cheesecloth based fabrics. The tensile strength of nanocomposite structures which was assembled over the adhesive tape bind on the surface of assembler cylinder was carried out after being cut 30 mm in length, 10 mm and~0,3 mm thickness in width and put into towing device in the shapes of strips [27]. In this study, tensile strength measurement was carried out by taking same method as basis. 0.01 mm thick Aluminium folio, which prevents the fabric being adhered on assembler instead of adhesive tape, was used as carrier.

## III. RESULTS

### 3.1. Morphological Properties

Trace amount of salt (0.2 g) was added to increase the conductivity which was decreased due to AVG addition. Since AVG addition into PVA was carried out homogenously, there was no visible phase separation or any other formation in the SEM images (Figure 2).

The fineness of nanofibers produced from PVA/AVG blend by electro spinning process was decreased with the increase in AVG in the blend. It was thought that the reason for this was the increase of AVG ratio which caused decrease in viscosity and an increase in conductivity of the solution (Table1.)

In the evaluation of the nanofibre thickness, it was seen that the material produced from PVA/AVG blends constituted the finest fibers (Table3). It was assumed that the increase in PVA ratio caused an increase in nanofiber diameter. It was also seen that the increase in PLLA amount in the nanobiocomposite structure caused an increase in nanofiber diameter. The reason for that was semi-crystalline structure of PLLA and amorphous structure of others. Therefore, electro static intensity and polymer concentration had a significant effect on fiber morphology and diameter [24,28-29].

It was thought that decrease of PVA ratio in PVA/AVG blends caused the increase of load density over polymer elongation of jet inside strength field constituted by electrostatic powers and jet showing more elongation and fibers being refined. PVA polymer provided a good adhesive Figure 2.(a) by harmonized with PLLA polymer in Figure 2.(b) and PVA/AVG polymer blend in Figure 2.(c) and Figure 2(d).(Beats occurred due to the change in electrical field which can be seen in SEM image of PVA/AV 80:20 in Figure 2.(e). It was investigated that distribution of nanofiber structure was appropriate for PLLA/PVA mixtures in every direction as seen in Figure 2.(f). It was seen at Figure 2. (g, h, i) that nanobiocomposite structures had homogenous fineness and direction.

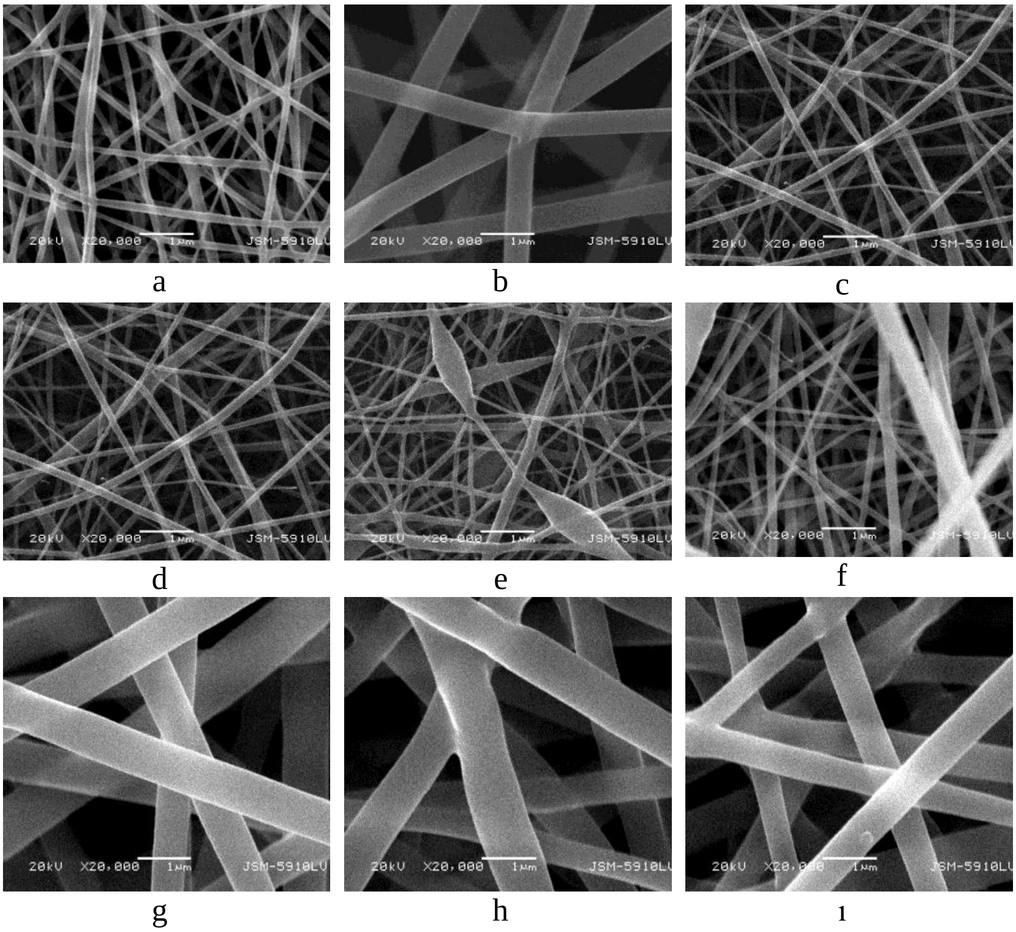

**Figure 2.** SEM images of produced nano fiber and nano composite materials (a) PVA 100%, (b) PLLA100%, (c) PVA/AVG 95:5% (d) PVA/AVG90:10%, (e) PVA/AVG 80:20%, (f) PLLA/PVA 100%, (g) PLLA PVA/AVG 95:5%, (h) PLLA PVA/AVG 90:10% (ı) PLLA PVA/AVG 80:20%

**Table 3** Mixture ratios and fineness of nanofiber

| Polymer solutions | Blend ratio (%) | Nanofiber fineness (nm) |
|---|---|---|
| PVA (%12) | 100% | 167±55 |
| PVA (%12)/AVG | %95/5 | 129±47 |
| PVA (%12)/AVG | %90/10 | 96±50 |
| PVA (%12)/AVG | %80/20 | 83±28 |
| PLLA (%10) | 100% | 534±187 |

### 3.2. Mechanical Properties

Strength values of PVA/AVG blends for machine direction and machine width direction are given in Figure 3. A decrease in strength values was seen as AVG ratio was increased in the blends, in spite of that, the lowest values were recorded in both directions of 100% PVA structures. The best result at strength values according to machine direction was at PVA/AVG (95/5%). Decreases in strength values were seen at elongation values, machine width and material direction. But the best value was (90/10 %) against the decreases at elongation values at material width direction.

In Figure 3, the tensile strength values of nanobiocomposite structures produced by adding PLLA polymer into PVA/AVG blend. Decreases in tensile strength values were seen with the addition of AVG to nanobiocomposite structure. When tensile strength results were taken into account in the direction of material width, the highest tensile strength value was PLLA/PVA/AVG (95:5) nanobiocomposite structure.

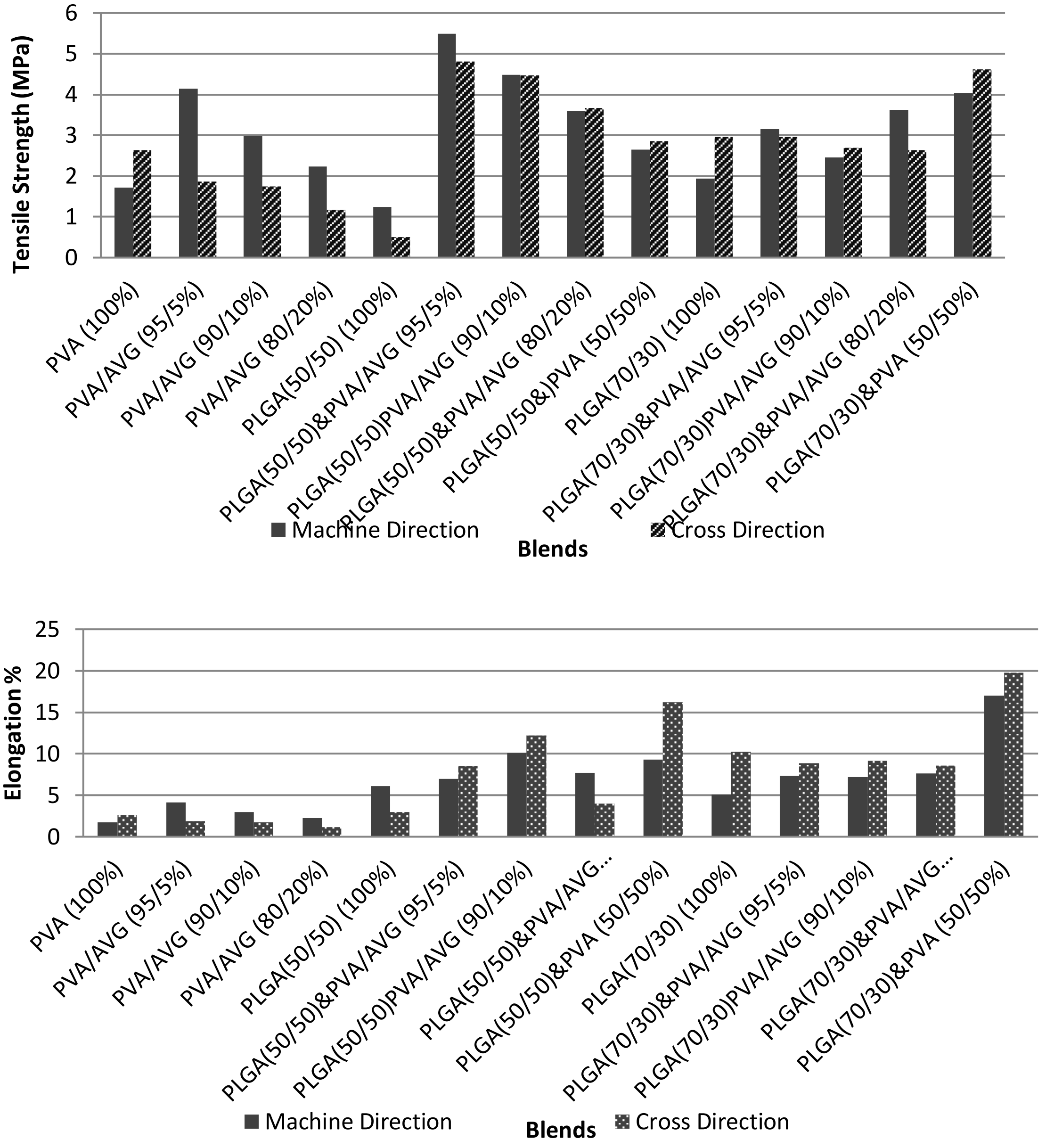

**Figure 3.** Strength and % Elongation Values of nanobiocomposites.

When tensile strength properties were evaluated by taking material width and machine direction into consideration, optimum strength value was recorded in composite structures containing 5% of AVG in the blend. When % elongation values were taken into account, it was expected that PVA would have the highest elongation values **[30]**. When % elongation values were taken into consideration, an increase was observed in elongation values with an increase in AVG amount. While a stable increase in tensile strength in the machine direction, the deformation in the machine direction was decreased. When elongation values of nano fiber structure produced by using PLLA polymer were compared with elongation values of PVA/AVG, it was seen that they provided 5% elongation values which is the optimum value in the machine direction. In bio composite structures, it was observed that the elongation ratio was increased in material width direction. It was thought conceived that the reason was the increase of AVG amount added in stratified bionanocomposites materials produced from PLLA polymer caused to have better elasticity of semi crystalline rigid structure of PLLA.

### 3.3. FT-IR

FT-IR spectrum of PVA nano fiber is seen in Figure 5. Stretching bands belonging to –OH groups that made a strong intermolecular and intermolecular hydrogen bond at PVA molecule gave wide and severe bands at 3334 cm$^{-1}$. Two severe peaks at 2947 cm-$^{1}$ and 2933 cm$^{-1}$ were characteristic bands belonging to respectively asymmetric and symmetric C-H stretching. The band belonging to stretching intensities of C=O groups was 1735 cm$^{-1}$. C=O bands were carbonyl functional group belonging to acetate groups remaining after preparation of PVA with hydrolyse of oxidation or polyvinyl acetate during manufacture. Absorption bands at 1435 cm$^{-1}$ and 1255 cm$^{-1}$ were resulted from $CH_2$ leaning vibrations and $CH_2$ shaking movement, respectively. They were absorption bands belonging to C-H and OH deflections at 1333 cm$^{-1}$. It was noted that the band at 1093 cm$^{-1}$ belonged to C-C and C-O-C stretching vibrations. In the literature, it was reported that $CH_2$ deflection vibrations for PVA was resulted from 1417 cm$^{-1}$ and 1270 cm$^{-1}$` $CH_2$ shaking movement and 1417 cm$^{-1}$ band belonged to C-C and C-O-C stretching vibrations [20].

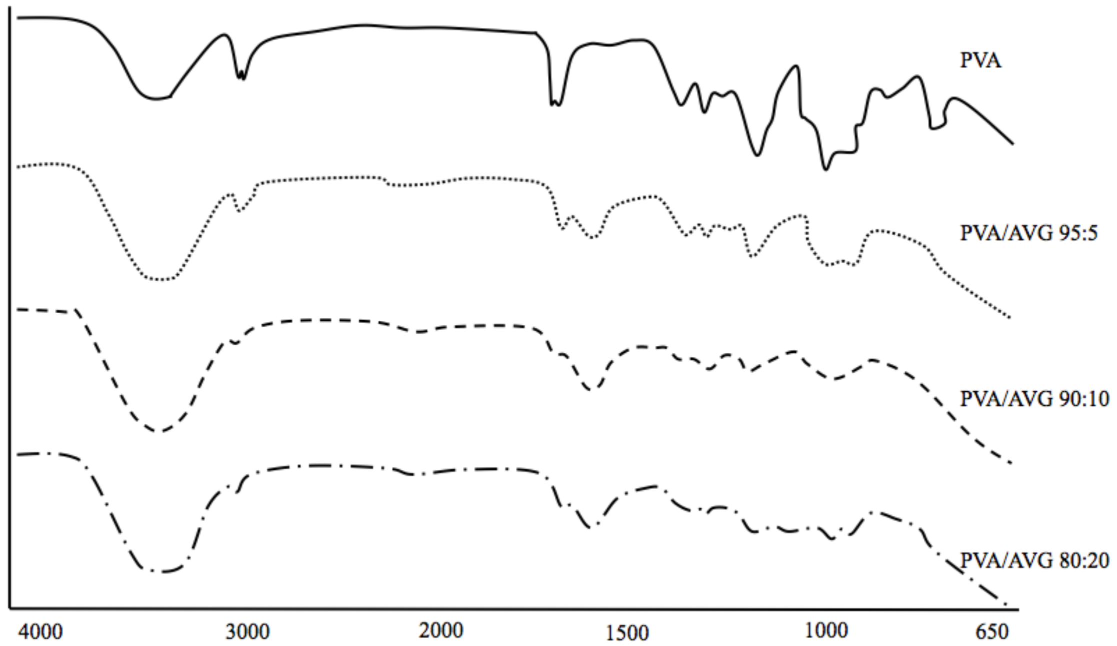

**Figure 5.** FT-IR Analyze Graphic of PVA/AVG Nanofibers and Nanobiocomposites Structure

Characteristic absorption band showing existence of C=O groups at ester groups over characteristic bands of PLLA chains belonging to PLLA fibers was seen at 1749 cm$^{-1}$ (Figure 6). The peak at 1082cm-1 shows stretching band of C-O, while peaks at 1382cm-1 and 2946 cm-1 shows the scissoring (sagging) of -CH- stretching and vibration bands of –CH-, respectively [37]. It was seen in the literature that stretching vibrations of C-H groups for PLLA gave similar values in FTIR analyzes [31]. Characteristic absorption band showed that existence of C=O groups was respectively seen at 1751cm$^{-1}$ (95:05), 1749 cm$^{-1}$ (90:10),1639 cm$^{-1}$ (80:20) for PLLA/PVA/ AVG nanobiocomposite structure. Furthermore, scissoring (sagging) of –CH- groups was seen at 1382 cm$^{-1}$`, 1382 cm$^{-1}$, 1378 cm$^{-1}$, stretching of C-O groups was seen at 1086cm$^{-1}$`, 1084 cm$^{-1}$de, 1089 cm$^{-1}$ and stretching vibration bands of –CH- groups was seen at 2946 cm$^{-1}$, 2996 cm$^{-1}$ and 2948 cm$^{-1}$. Stretching vibrations of –OH groups of PVA nanofibers in PLLA/PVA nanobiocomposites structure gave wide and severe bands at 3325cm$^{-1}$. The peak at 2943 cm$^{-1}$ was the characteristic band of asymmetric C-H. It was thought that wide and mid-severe N-H (amine and amide) at 3300 cm$^{-1}$ was from the texture of AVG sap and PVA bio polymer. In previous studies, phenolic powerful and severe stretching's of OH groups were seen in phenolic, flavonoid, and antracinon available in AVG extract [32] that was seen at 3300 cm$^{-1}$in this study (Figure 6).

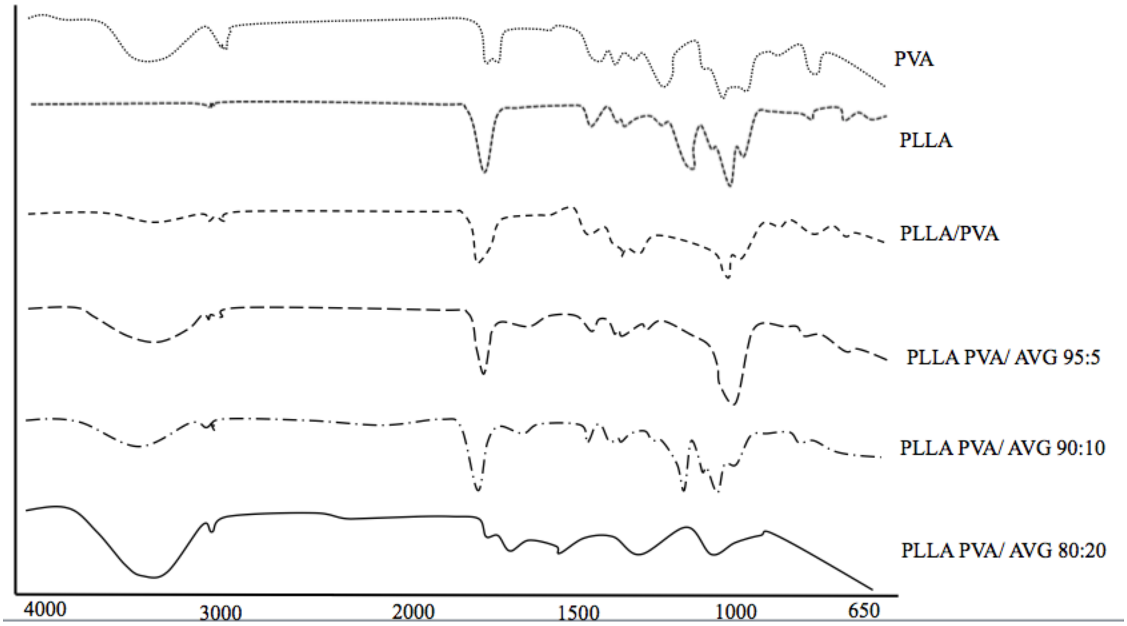

**Figure 6.** FT-IR analyze Graphic of PLLA/PVA/AVG Nanofiber and Nanobiocomposites Structure.

### 3.4. XRD analyze

Diffraction angle of samples was detected by the distinctness between 2θ a specific group planes by using Riguku XRD branded device at X-ray diffraction analyze. It was observed that preference orientation along 200 reflection intensity planes was 30-40° according to the value calculated with the help of Bragg equality for all AVG samples. Diffraction way of peak shifted to left and showed an amorphous structure [33].

It is seen that PVA wide peak was 20° centred. 2θ = 19° is totally lost (Figure 7). It is possible to define maximum 2θ of PLLA fibers approximately at 15° [34].

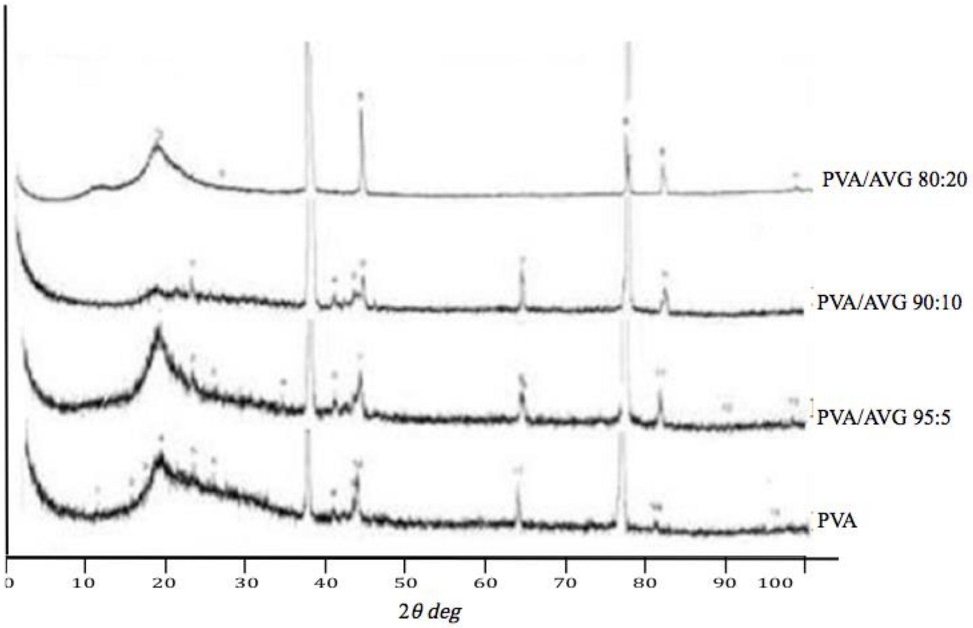

**Figure 7.** XRD analyze of 100% PVA Nanofiber and PVA/AVG Mixture Nanofibers

The maximum 2θ of PLLA was approximately 15° in literature that can be seen in Figure 8. In the literature, peaks for PLLA polymer were defined at 10°-25° in XRD analysis. It is assumed that a 2θ approximately 150° wide peak was constituted as a result of coincide of PLLA/PVA peaks. Figure 7., 8. The values in the literature coincide with the data determined [34-35].

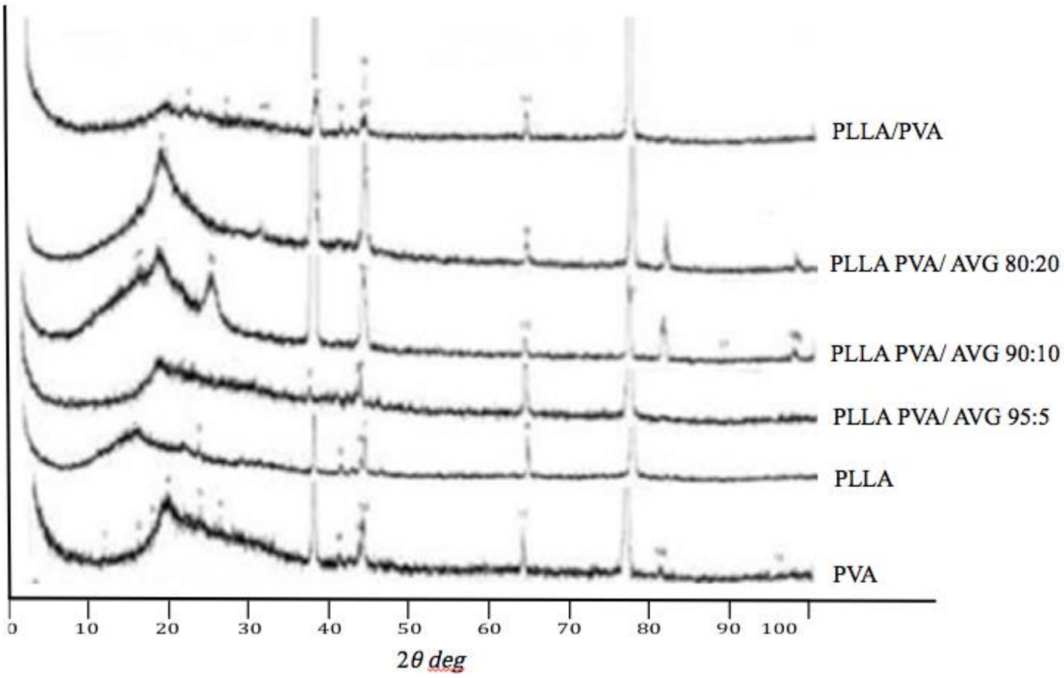

**Figure 8.** XRD analyze of 100% PLLA Nanofiber nanobiocomposites Structure Constituted with PVA/AVG

It was observed that PVA, PVA/AVG nanofibers constituted the only wide and severe peaks on 2θ =~20 ° at x-ray diffractometers of nanofiber and nanobiocomposite structure. Calculation of these peak fields revealed out that PVA polymer had 23,7% crystallinity An increase in the crystallinity was observed with an increase in AVG amount in the blend (Table 4). Crystallinity was calculated according to the equation given below (1).

$$Crl\,\% = \frac{x1-x2}{x2} \times 100 \tag{1}$$

$Crl$ % : Crystallinity %
$X_1$ : Maximum peak value
$X_2$ : Minimum peak value [36].

**Table 4.** XRD analyze results of nano fiber and nanobiocomposite structure

| Nanofiber /Nanobiocomposites | Blend ratio % | Reflection intensity 2θ (°) | Crystalinity Crl (%) |
|---|---|---|---|
| PVA | 100 | 20 | 23.7 |
| PLLA | 100 | 17 | 52.1 |
| PVA/AVG | 95:05 | 20 | 16 |
| PVA/AVG | 90:10 | 20 | 17.9 |
| PVA/AVG | 80:20 | 20 | 18.2 |
| PLLA/PVA | 100+100 | 19 | 43.6 |
| PLLA/PVA/AVG | 100+95:05 | 20 | 20.5 |
| PLLA/PVA/AVG | 100+90:10 | 19 | 21.5 |
| PLLA/PVA/AVG | 100+80:20 | 20 | 23 |

Reflection intensity of nanobiocomposites and nanofiber ranges between 2θ=19° - 20° structures produced from PLLA polymer. Crystallization percentage of PVA/AVG blends increased depending on AVG ratio. Even though PLLA/PVA/AVG layered nanobiocomposite structure showed lower crystallinity as compared to 100% PLLA polymer, an increase in crystallinity was still observed with the increase of AVG percentage (Table 4). The reason is that PLLA polymer has a semi crystallized structure and PVA/AVG blends is in accordant with each other and constitutes an accordant structure.

## IV. CONCLUSION

In this study, firstly, PLA carrier polymer nanofiber floor, which is the biodegradable feature, was created by using PVA/ AVG mixture nanofibers and the electrospinning method by using a two-layer nanobiocomposite structure. Then, to characterize the samples, strength, % elongation measurement, sem, contact angle, FT-IR, DSC, and XRD analyses were applied to the nanofiber and nanocomposite structures. Observation made on viscosity and conductivity values shows that viscosity decreased, but conductivity increased due to the amount of AVG increase depending on the amount of polymer found in the solution and molecular weight. Again, the increase in the amount of PLLA in nanofiber has increased nanolyphic thickness. Considering the standard deviation values, the PVA/PLLA mixture shows that nanobiocomposite structure provides the best machine direction and strength values in the direction of material width. As the amount of AVG added to the structure of nano biocompositis increased, there was a decrease in strength. When the DSC thermograms are examined, PLLA polymer is semi-crystalline, and other polymers and aloe vera gel (AVG) used in the study were determined by peaks obtained from amorphous structure. DSC thermograms show that in nanobiocomposite structures obtained from PLLA polymer, TG and TM values decrease and heat stability increases. This is considered to be caused by the cross-bond made by PVA polymer and AVG. In PLLA/ PVA/ AVG Nanobiocomposites structures, the characteristic absorption band that shows the presence of c = those groups, the scissors of the -ch- groups, the stress of c-O groups, the stress vibration bands of the -ch-groups, the AVG plant extract and the structure of the PVA biopolymer It is seen that it is similar to two characteristic groups. In the light of all data obtained in XRD analysis, PLLA polymer's semi-crystalline structure and AVG and PVA molecular structure are considered to be amorphous materials. It is seen that the reflection intensity value in the diffractograms obtained contains a wide and severe peak specific to the structure of amorphous materials and constitutes close peak values.

As a result, it has been observed that AVG participation has positive contributions to the thermal properties of nanobiocomposite structures. It is considered that different solvents and additional additives are used to improve strength properties. The fact that the biopolymers and AVG used in the study have a completely biological disintegration feature indicates that it is an environmentally non-toxic substance. In addition, the presence of AVG plant extract in nanobiocomposites obtained constitutes a prediction for studies in the future medical field.

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## REFERENCES

**[1]** Reynolds,T., (2004) “Aloes: The genus Aloe” book CRC Press chapter :8,7 USA

**[2]** WHO, (1999) “ Monographs on selected medicinal plants” Volume 1 World Health Organization, ISBN 92 4 154517 8,Geneva

**[3]** Saeed M.A., Ahmad I., Yaqub U., Akbar S., Waheed A., Saleem A, (2004) “Aloe Vera: A Plant Of Vital Signifinaces” Science Vision Vol.9 No.1-2

**[4]** Ahlawat,K.S, Khatkar,B.S., (2011) “Processing, food applications and safety of aloevera products: a review” J Food Sci Technology Vol. 48 (5) :525–533

**[5]** Lee J.K., Lee M.K.,Yun Y.P., (2001) “Acemennan purified from Aloe vera induced phenotypic and functional maturation of immature dendritic cells” Int Immunopharmacol jul;1 (7) :1275-85,

**[6]** Bassetti A.,SaIa S., (2005) “THE GREAT ALOE BOOK History, botany, composition, and pharmacological aspects of this legendary plant.” Zuccari Pty Ltd Via Maccani, 34 - 38100 Trento USA 31

**[7]** Jing Yin, Lan Xu, (2020) Batch preparation of electrospun polycaprolactone/chitosan/aloe vera blended nanofiber membranes for novel wound dressing,International Journal of Biological Macromolecules,Volume 160, 2020, Pages352-363, ISSN0141-8130,

**[8]** Surjushe, A., Vasani, R. and Saple, D. G. (2008) “Aloe vera: A short review”. Indian Journal of Dermatology 53:163-166.

**[9]** Solaberrieta, Ignacio, Alfonso Jiménez, Ilaria Cacciotti, and Maria C. Garrigós (2020). "Encapsulation of Bioactive Compounds from Aloe Vera Agrowastes in Electrospun Poly(Ethylene Oxide) Nanofibers" Polymers 12, no. 6: 1323. https://doi.org/10.3390/polym12061323

**[10]** Davis, R. H., Parker, W. I. and Samson, R. T., (1991) “Isolation of a stimulatory system in an aloe extract” J. American Podiatric Medical Assoc. 81:473-478.

**[11]** Alven,S.;Khwaza,V.; Oyedeji, O.O.; Aderibigbe, B.A. (2021) Polymer-Based Scaffolds Loaded with Aloe vera Extract for the Treatment of Wounds. Pharmaceutics 21, 13, 961. https://doi.org/10.3390/ pharmaceutics13070961

**[12]** Christaki E.V., Florou-Paneri P., (2010) Aloe vera: A plant for many uses, Journal of Food, Agriculture & Environment 8 (2) : 245-249,

**[13]** Barbosa R, Villarreal A, Rodriguez C, De Leon H, Gilkerson R, Lozano K. (2021) Aloe Vera extract-based composite nanofibers for wound dressing applications. Mater Sci Eng C Mater Biol Appl.2021. doi: 10.1016/j.msec.2021.112061.

**[14]** Bootdee K., Nithitanakul M.,(2021) Poly(d,l-lactide-co-glycolide) nanospheres within composite poly(vinyl alcohol)/aloe vera electrospun nanofiber as a novel wound dressing for controlled release of drug, International Journal of Polymeric Materials and Polymeric Biomaterials, 70:4, 223-230, DOI: 10.1080/00914037.2019.1706512

**[15]** Cai W., Gupta,B.,R., (2002) “Hydrogels”, Kirk-Othmer Encyclopedia of Chemical Technology Wiley, New York, NY Online

**[16]** Hikmawati, D., Maharani, N. P., & Putra, A. P. (2020). The Effect of Ultraviolet Exposure on Physical Properties of Electrospun Nanofiber Membrane Based on Polyvinyl Alcohol and Aloe vera. In Key Engineering Materials ( 860, 244-250). Trans Tech Publications Ltd

**[17]** Pala, N., Aral, N., & Nergıs, B. (2022). Emulsion electrospinning of pva nanofibers containing hypericum perforatum oil. Tekstil ve Mühendis, 29(128), 267-271.

**[18]** H. Tsuji, Y. Ikada, (1996) "Crystallization from the melt of poly (lactide) s with different optical purities and their blends" Macromol. Chem. Phys. 197, 3483–3499.

**[19]** Uslu İ., KeskinS., Gül A., KarabulutT.C., AksuM.L., (2010), "Preparation and Properties of Electrospun Poly (vinyl alcohol) Blended Hybrid Polymer with Aloe vera and HPMC as Wound Dressing" Hacettepe J. Biol. & Chem., 38 (1) 19-25

**[20]** Uslu İ., Aytimur A., (2011) "Production and Characterization of Poly (vinyl alcohol)/Poly (vinylpyrrolidone) Iodine/Poly (ethylene glycol) Electrospun Fibers with (Hydroxypropyl) methyl Cellulose and Aloe Vera as Promising Material for Wound Dressing", Journal of Applied Polymer Science, 124 – 4 3520-3524

**[21]** Serinçay H., Özkan S., Yılmaz N., Koçyiğit S., Uslu İ.,Gürcan S.,Arısoy M., (2013), "PVA/PAA-Based Antibacterial Wound Dressing Material with Aloe Vera", Polymer-Plastics Technology and Engineering, 52: 1308–1315.

**[22]** Kim E.S., Kim S.H., and Lee C. H.,(2010), "Electrospinning of Polylactide Fibers Containing Silver Nanoparticles", Macromolecular Research, 18(3), 215-221

**[23]** Tomaszewski W., Duda A., Szadkowski M., Libiszowski J.,Ciechanska D., (2008), "Poly(L-lactide) Nano- and Microfibers by Electrospinning: Influence of Poly(L-lactide) Molecular Weight", Macromol. Symp. 272, 70–74

**[24]** Li WJ, Laurencin CT, Caterson EJ, Tuan RS, Ko FK. (2002) "Electrospun nanofibrous structure: A novel scaffold for tissue engineering". J. Biomed. Mater. Res. 60, 613–621

**[25]** Andrady A.L., (2008) "Science and Tecnology of Polymer Nanofibers", A John Wiley Sons Inc., ISBN 978-0-471-79059-4

**[26]** Ding, B., J. H. Kim, Y. Miyazaki, and S. M. Shiratori (2004) . "Electrospun nanofibrous membranes coated quartz crystal microbalance as gas sensor for NH3 detection." Sensors and Actuators B: Chemical 101 (3) :373–380.

**[27]** Huang, Z. M., Y. Z. Zhang, S. Ramakrishna, and C. T. Lim (2004) . "Electrospinning and mechanical characterization of gelatin nanofibers." Polymer 45 (15) : 5361–5368.

**[28]** Pala Avcı, N., Aral Yılmaz, N., & Nergis, F. B. (2024). The Effect Of Polymer Concentration On Coaxial Electrospinning Of Pvp/Pcl Core-Sheath Nanofibers. Politeknik Dergisi, 27(5), 1781-1787.

**[29]** Avcı, N. P., Yılmaz, N. A., & Nergis, F. B. (2024). The effect of essential oil on fiber morphology and surface properties in coaxial nanofibers. Uludağ Üniversitesi Mühendislik Fakültesi Dergisi, 29(1), 125-138.

**[30]** Peresin,M.S., Habibi, Y., Vesterinen,H.A., Rojas,O.J. PawlakJ.J, SeppaJ.V., (2010) "Effect of Moisture on Electrospun Nanofiber Composites of Poly (vinyl alcohol) and Cellulose Nanocrystals", Biomacromolecules,11, 2471–2477

**[31]** Clarisse Ribeiro C., SencadasV., Costa C.M., Luís J., Ribelles G.,and Mendez S.L., (2011), "Tailoring the morphology and crystallinity of poly (L-lactide acid) electrospun membranes" Sci. Technol. Adv. Mater. 12 , 9

**[32]** Ray A., GuptaS.D., Ghosh S., (2013), "Evaluation of anti-oxidative activity and UV absorption potential ofthe extracts of Aloe vera L. gel from different growth periods of plants", Industrial Crops and Products. 49, 712– 719

**[33]** Gunalan S.,Sivaraj R., Venckatesh R., (2012) "Aloe barbadensis Miller mediated green synthesis of mono-disperse copper oxide nanoparticles:Optical properties", Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 97,1140–1144

**[34]** Paragkumar N1, EdithD, Six J.L, (2006) "Surface characteristics of PLA and PLGA films", Applied Surface Science 253 2758–2764

**[35]** Cao D.,Wu Y.P.., Fu Z.F., Tian Y., LiC.J., Gao C.Y., (2011) "Cell adhesive and growth behavior on electrospun nanofibrous scaffolds by designed multifunctional composites", Colloids and Surfaces B: Biointerfaces 84 26–34

**[36]** Guimarães J.L., Frollini E., Silva C.G., Wypych F., Satyanarayana K.G., (2009), "Characterization of banana, sugarcane bagasse and sponge gourd fibers of Brazil", Industrial Crops and Products 30, 407–415

**[37]** Agirgan M., Taskin V., (2020): Nonwoven Production from Waste Rice Straw by Using Enzymatic Method, Journal of Natural Fibers, DOI:10.1080/15440478.2018.1546637