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Biocomposite films prepared with sour cherry kernel and ınvestigation of some properties

Vişne çekirdeği içi ile hazırlanmış biyokompozit filmler ve bazı özelliklerinin incelenmesi

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Biocomposite Films Prepared with Sour Cherry Kernel and Investigation of Some Properties

Highlights

- *Composite films were obtained with acrylated epoxidized soybean oil and cherry kernel*
- *The antibacterial activities of the biocomposites were determined*
- *The surface morphologies of the polymer composite films were characterized by SEM.*
- *Water vapor permeability properties, pH, swelling-solubility-water content were investigated*

Graphical Abstract

The cherry core was made into a composite with AESO after it was powdered at a size of 63 micrometers. Some properties of the films obtained at different ratios were examined.

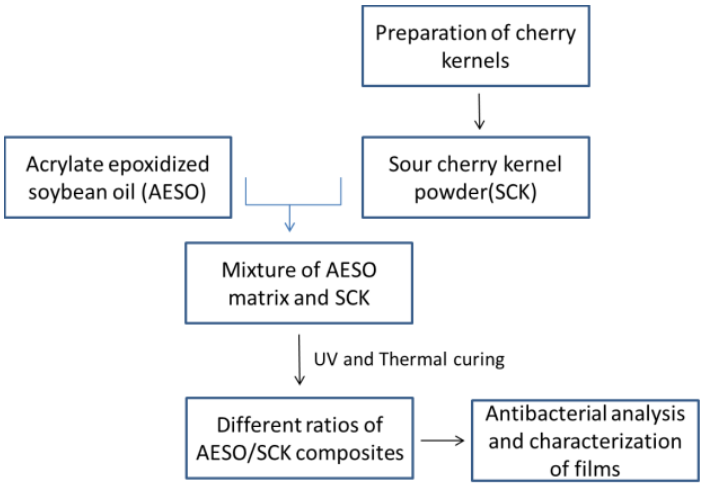

Figure. Flow chart of the study

Aim

Evaluation of natural waste cherry seed, known to have antibacterial properties, as a biocomposite.

Design & Methodology

It was characterized by making a composite of acrylate epoxidized soybean oil, a biobased matrix, with sour cherry kernels.

Originality

According to the literature review, the sour cherry kernel has not been used for the modification of a natural matrix before.

Findings

The swelling ratio of AESO/SCK films was between 0.2433% and 4.6343% by mass, the water solubility ratio was between 0.1103% and 0.7380%, the water content was between 0.660-2.1203%, the pH was between 7.18-7.33 after 72 hours, and the water vapor permeability values was between $1.382x10^{-7}$ *-* $5.025x10^{-10}$ *g.m/(*m^2**Pa*s).*

Conclusion

It was concluded that the sour cherry kernel gives antibacterial properties to the biobased matrix, reduces water vapor permeability, stays in the appropriate pH ranges, and is compatible with the skin.

Declaration of Ethical Standards

Authors declare to comply with all ethical guidelines, including authorship, citation, data reporting, and original research publication.

Biocomposite Films Prepared with Sour Cherry Kernel and Investigation of Some Properties

Araştırma Makalesi / Research Article

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ABSTRACT

The main purpose of this study is to obtain a renewable natural biocomposite film with the sour cherry kernel (SCK), a natural waste. Biobased acrylated epoxidized soybean oil (AESO) resin was used as a composite matrix. The effect of additive ratio on antibacterial activity tests, swelling-solubility-water content, and pH properties of the obtained AESO/SCK composite films were investigated. In addition, the surface morphologies of the film samples were examined by SEM. It has been observed that AESO/SCK films have antibacterial properties. In addition, the swelling ratio of AESO/SCK composite films was found to be between 0.2433% and 4.6343%. The water solubility rate of AESO was determined as 0.1103% by weight. This ratio increased as the SCK ratio increased and reached 0.7380% with a 50% SCK ratio. The water content of AESO/SCK composite films was in the range of 0.660-2.1203%. The pH of all prepared biocomposite films was between 7.18-7.33 after 72 hours, and these values were found to be compatible with skin pH. The water vapor permeability of AESO was measured as $1.382x10^{-07}$ g.m/(m^2*Pa*s) on average. With 50% SCK by weight, this value decreased to $5.025x10^{-10}$ g.m/(m^2*Pa*s).

Keywords: Antibacterial activity, biocomposite film, sour cherry.

Vişne Çekirdeği İçi ile Hazırlanmış Biyokompozit Filmler ve Bazı Özelliklerinin İncelenmesi

ÖZ

Bu çalışmanın temel amacı, doğal bir atık olan vişne çekirdeği içi (VSK) ile yenilenebilir doğal bir biyokompozit film elde etmektir. Matris olarak akrilatlanmış epoksitlenmiş soya yağı(AESO) kullanılmıştır. Elde edilen AESO/SCK kompozit filmlerin antibakteriyel aktivite testleri, şişme-çözünürlük-su içeriği ve pH özelliklerine katkı maddesi oranının etkisi incelenmiştir. Ayrıca film numunelerinin SEM ile yüzey morfolojileri incelenmiştir. AESO/SCK filmlerinin antibakteriyel özelliğe sahip olduğu gözlenmiştir. Ayrıca, AESO/SCK kompozit filmlerin şişme oranı %0.2433 ile %4.6343 arasında bulunmuştur. AESO'nun suda çözünürlük oranı kütlece %0.1103 olarak tespit edilmiştir. Bu oran SCK oranı arttıkça artmış ve %50 SCK oranı ile %0.7380'e ulaşmıştır. AESO/SCK kompozit filmlerinin su içeriği %0.660-2.1203 aralığında değer almıştır. Hazırlanan tüm biyokompozit filmlerin, pH'ı 72 saat sonunda 7.18-7.33 aralığında olup bu değerlerin cilt pH'ı ile uyumlu olduğu görülmüştür. AESO'nun su buharı geçirgenliği ortalama $1.382x10^{-07}$ g.m/(m^2*Pa*s) olarak ölçülmüştür. Kütlece %50 SCK oranı ile bu değer $5.025x10^{-10}$ g.m/(m^2*Pa*s)'ne düşmüştür.

Anahtar Kelimeler: Antibakteriyel aktivite, biyokompozit film, vişne çekirdeği içi.

1. INTRODUCTION

Today, due to the exhaustion of fossil fuel stocks and the increase in plastic waste, there is an urgent demand for replacement or even replacement of oil-based polymers with renewable natural biopolymers, which causes unsustainable environmental problems [1], [2].

Epoxidized soybean oil (ESO) derived from soybean oil is a low-cost epoxy compound and increases the biological content of the composite in which it is involved. Using ESO in a polymer composite structure can improve some physical and mechanical (impact strength, elongation at break) properties of the composite [3], [4], [5]. In addition, good water resistance can be obtained even with a very thin ESO layer, depending on the crosslinking density [6]. In a study by Tanrattanakul and Saithai (2009), it was noted that acrylated epoxidized soybean oil (AESO) showed higher mechanical properties than ESO [7]. Further, thermal stability [3], [5], [8]-[11], and corrosion resistance [3]; it has been reported that it gains flame retardant properties [9], and finally increases the adhesion property of the structure [11].

Biocomposites can be prepared from plant, animal, and mineral-based organic fillers except for the matrix—for example, coconut, nut, walnut, etc. Plant shells, which are many wastes, are natural plant-derived filling materials that are frequently used compared to traditional glass fiber because they have biodegradability, cost-effectiveness, low density, good durability, and modulus of elasticity [12]. Evaluating the waste products released in areas such as the food industry is among the issues that have increased in importance in recent years. A high rate of waste is released during both the production and

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consumption of foods. [13]. Some wastes of the food industry are evaluated as animal feed or thrown directly into nature, causing the degradation of various nutrients. Especially since the waste of food industries can contain high amounts of microbial toxic substances, it causes pollution in nature. Based on the reports of the National Agricultural Statistics Service, 99% of the cherry produced in the world is consumed as processed products in the form of fruit juice, jam, or canned food [14]. During these productions from sour cherry, sour cherry seeds emerge as waste material [15]. Kernels are used as a chemical raw material and energy source. The sour cherry seed consists of 46.6% carbohydrates, 29.3% protein, 17.0% lipids, 3.9% moisture, and 3.1% ash [16]. Its component contains essential amino acids such as glutamic acid, aspartic acid, phenylalanine, proline, glycine, lysine, serine, and alanine [17]. It also contains γ-sitosterol, β-tocopherol, anthocyanidin, and hydroxycinnamic acid. Among them, anthocyanins, represented by cyanidin glycosides, are the main phenolic substances of the cherry kernel and give it antibacterial and antioxidant properties [18]-[28]. Hosseini et al. (2020) showed that the antioxidant capacity of the sour cherry kernel is very close to the well-known antioxidants ascorbic acid and BHA (Butylated hydroxyanisole) [29].

In this study, it was aimed to add the sour cherry kernel (SCK), a natural waste, which is added to the obtained biocomposite films in specific proportions, to the biobased matrix as a filling material while at the same time gaining antibacterial properties. Thus, it is aimed to be a material that is entirely renewable and antibacterial, does not create harmful solid waste, and is expected not to harm the environment while soluble.

2. MATERIAL AND METHOD

In the study, acrylated epoxidized soybean oil (AESO) (density: 1.04 g/cm^3; viscosity: 18,000–32,000 cps) was obtained from Sigma-Aldrich as the matrix (Figure 1). Cherry Kernel (SCK) is obtained from the sour cherry fruit supplied from the local market in season. Microorganism strains used in the study were obtained from Selcuk University, Faculty of Science, Department of Biotechnology. Two types of agents were used as curing agents. The first is the UV curing agent: Irgacure 184 is a radical photoinitiator (Figure 2) from Sigma-Aldrich. The second is IPOX EH 2041(TAD 305-335 mg KOH/g, viscosity (25°C): 125-225 MPa.s; density (25°C): 1.04 g/cm^3) a polyamine type curing agent from Sar Chemical Co. (Turkey) was purchased (Figure 2). 2,4,6-tris-(dimethylaminomethyl)phenol ($C_{15}H_{27}N_3O$-density (25˚C): 0.969 g/cm^3) was used as accelerator.

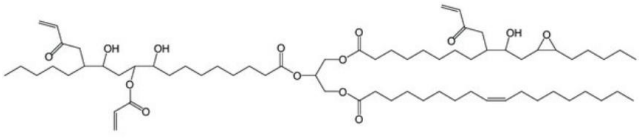

Figure 1. Acrylate epoxidized soybean oil (AESO)

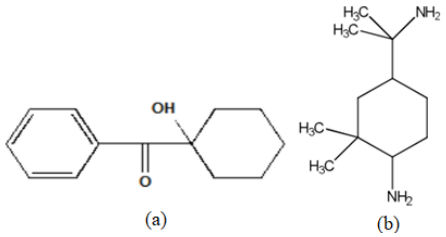

Figure 2. UV curing agent: Irgacure 184 (a), Polyamine type curing agent: Cycloaliphatic polyamine (b)

2.1 Preparation of Cherry Kernel Filler

First, the kernel (SCK) of the purchased sour cherry fruit was separated. It was then dried and milled. Finally, it was sieved at the last 63-micron size to reach the desired fineness. The process steps are shown in Figure 3.

Figure 3. Preparation stages of sour cherry pits

2.2 Preparation of Biocomposite Films

In preparing the films, SCK was added at a ratio of 10%, 20%, 30%, 40%, and 50% by weight of the total matrix relative to the resin. The most appropriate SCK ratio was determined as a result of the antibacterial analysis.

AESO and calculated SCK were mixed in a magnetic stirrer for 15 minutes at 200 rpm and 25°C after being taken into the beaker. By adding 4 wt% Irgacure [30], and 30 wt% IPOX, it was mixed with the glass baguette in a way that does not form foam. It was kept in an ultrasonic bath for 15 minutes to remove the bubbles. The samples were placed on teflon surface material cut 10x10x0.5 cm by gel pouring method and in petri dishes for microbiological analysis. performed. Curing was completed in a drying oven at 100°C for 24 hours (Figure 4). The most appropriate SCK ratio was determined as a result of the antibacterial analysis.

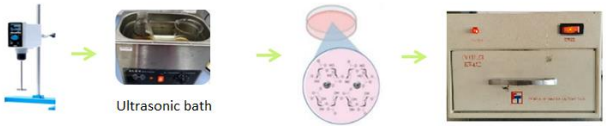

Figure 4. Biocomposite film production steps

2.3 Bacteriological Analysis

It has been tested using the agar diffusion method described in AATCC TM 147-1998. Antibacterial activity was evaluated against three types of Gram-negative (*Escherichia coli DH5a, P. aeruginosa, Klebsiella pneumoniae*) bacteria and three types of Gram-positive (*S. aureus, S. aureus MRSA* and *E. faecalis*) bacteria. The 0.9 cm diameter sample was

gently placed on an agar surface sterilized under UV light for 10 minutes on each side and previously inoculated with a test bacteria. After 24 hours of incubation at 37°C, the diameters of the sample or along the boundaries of the antagonistic zone were measured.

2.4 Scanning electron microscope (SEM) images

Using the Philips XL30 SFEG SEM device, images of our AESO samples were taken and their surface morphologies were examined.

2.5 Solubility-Swelling-Water Content Tests

Discs with a diameter of 1.5 cm were prepared for solubility-swelling-water content tests. The initial weights of the film samples were weighed (W_1) and kept in an oven at 70°C for one day (W_2). The wet weights of the samples were taken after 24 hours in 20 ml of distilled water (W_3). Finally, it was kept in an oven at 70°C for one day, and its final weight was taken (W_4). The solubility-swelling-water contents of the films were determined by using the following formulas.

$$\% \text{ Water content} = (W_1-W_2)/(W_1)x100$$

$$\% \text{ Swelling} = (W_3-W_2)/(W_2)x100$$

$$\% \text{ Solubility} = (W_2-W_4)/(W_2)x100$$

Swelling, solubility, and water content analyses for each film composition were repeated at least three times, and the values found were statistically analyzed.

2.6 Water Vapor Permeability Test

To determine the water vapor permeability values of the film samples, the dryer method was applied according to ASTM E96. The sample was cut into a circular shape with a surface area of $2.5x10^{-4}$ m^2 and placed on a cylindrical glass filled with dried silica gel providing 1±1% relative humidity. The samples were then completely covered with glass with parafilm and placed in a desiccator filled with saturated NaCl solution to reach a relative humidity of 75±1%, and weight changes were recorded at one-hour intervals. The water vapor permeability (WVP) of the film samples was calculated as follows.

$$WVP = w/t*L/\Delta P/A$$

w/t =Regression coefficient obtained from the plot of masses against time at steady state

A= film area (m^2)

L= average film thickness (m)

ΔP= partial water vapor pressure difference (Pa) between both sides of the film

2.7 pH Tests

pH measurement of 25x25 mm cut film samples was carried out by keeping them in 20 mL 0.9% NaCl for 72 hours. The pH values taken at 24-hour intervals are tabulated.

2.8 Statistical Analysis

Data were analyzed using one-way ANOVA in the MINITAB® release 16.0 program, and the mean analytical values obtained were compared for significant differences using the Tukey multiple range test at $p<0.05$.

3. RESEARCH RESULTS AND DISCUSSION

3.1 Bacteriological Analysis

The antibacterial activity properties of AESO/SCK biocomposite films were evaluated against three Gram-negative (*Escherichia coli* DH5a, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*) bacteria and three Gram-positive (*S. aureus*, *S. aureus* MRSA and *E. faecalis*) bacteria. The zone images formed by the cherry core (SCK) in the AESO polymer composite film are given in Figure 5. The inhibition diameters measured accordingly are shown in Table 1.

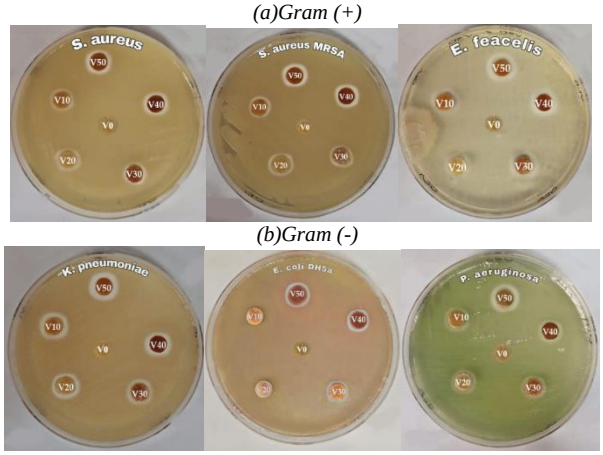

Figure 5. AESO/SCK zone images: (a) Gram-positive, (b) Gram-negative bacteria

Table 1. AESO/SCK inhibition diameter variation*

SCK (% by weight)	Inhibition diameter (mm)					
	S.aureus MRSA Gram(+)	*E.faecalis* Gram (+)	*S.aureus* Gram (+)	*K.pneumoniae* Gram(-)	*E.coli DH5a* Gram (-)	*P.aeruginosa* Gram (-)
0	x	x	x	x	x	x
10	11.183 ±1.125^{C}	10.566 ±0.603^{B}	10.676±0.781^{B}	11.626 ±0.701^{C}	0.000±0.000^{C}	12.200±1.480^{B}
20	12.567 ±0.850 ^{BC}	12.300 ±0.624^{AB}	11.167 ± 0.862^{AB}	12.500 ±0.964^{BC}	0.000±0.000^{C}	14.301 ±0.920^{AB}
30	13.500±0.500 ^{BC}	12.843 ± 1.618^{AB}	11.308 ± 0.713 ^{AB}	12.931 ±1.491^{ABC}	10.500 ± 0.500^{B}	15.145 ±0.608^{AB}
40	14.211 ±0.908 ^{AB}	12.921 ± 1.485^{AB}	12.477 ±1.004 ^{AB}	15.261 ±0.800^{AB}	15.267 ± 2.040^{A}	15.595 ± 0.929^{A}
50	16.297±1.407 ^{A}	14.261 ± 0.852^{A}	13.330 ±0.799 ^{A}	16.047 ± 1.824^{A}	16.333 ±1.710^{A}	16.630 ±1.875^{A}

**Different letters in the same column represent the statistical difference between samples ($p<0.05$).*

From Table 1, it is seen that there are no zones of inhibition in the control films without SCK. Statistically, the diameter of inhibition from gram-positive *S. aureus MRSA* bacteria and the SCK ratio did not increase

significantly from 10% to 30% but increased significantly in 40%, and the increase from 40% to 50% was statistically significant. It was not found to be significant ($p<0.05$). The same behavior was also shown against gram-positive *E. faecalis* and *S. aureus* bacteria with smaller zone diameters. *K. pneumoniae* and *P. aeruginosa* bacteria from Gram-negative bacteria provided a significant increase in the inhibition diameter with 40% SCK of the composite ($p<0.05$). On the other hand, *E. coli* bacteria did not show any antibacterial effect up to 30% SCK in AESO. The increase in the diameter of inhibition from 40% to 50% SCK was found to be insignificant. As a result, the highest inhibition diameter was obtained with *P. aeruginosa* bacteria, with an average of 16.630 mm at 50% SCK ($p<0.05$). Antimicrobial activity in the tested samples depends on the presence of phenolic acids and tannins, the amount of unsaturated free fatty acids, and the polyphenol content of the oils [27], [31]. The total amount of phenolic substances in sour cherry seeds is 538 mg gallic acid/kg on average. The main phenolics in the cherry kernel are anthocyanins represented by cyanidin glycosides [18], [19]. In addition, sour cherry seed oil contains approximately 80% unsaturated fatty acids, which are linoleic and oleic acids [18]. It is the phenolic substances that contribute the most to the antibacterial property and are the secondary metabolites secreted during the normal development of the plant. Phenolic compounds perform their antimicrobial activities by disrupting the structure of the cytoplasmic membrane in the bacterial cell and by preventing ion movements in the active transport process. Thus, they suppress the outflow of protons (H^+) and coagulate the cell contents. This has an inhibitory effect on fungi, bacteria, and viruses [32].

3.2 Scanning Electron Microscope (SEM) Images

Surface morphologies of AESO/SCK polymer composite films were characterized by SEM.

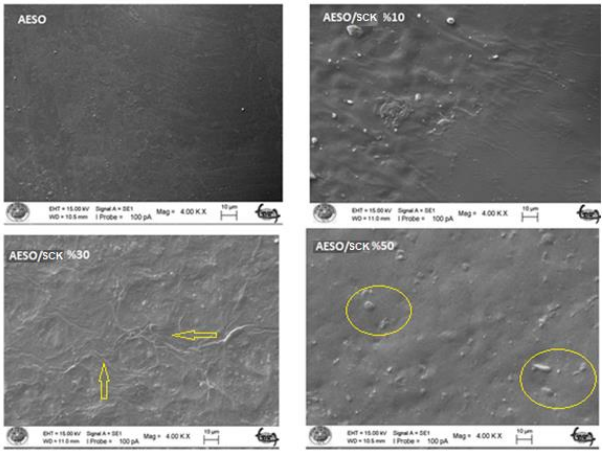

Figure 6. SEM images of AESO and AESO/SCK polymer films (4.00 KX magnification)

Looking at Figure 6, it can be seen that the surface of AESO is generally smooth. The surface of 10% SCK-reinforced AESO composite film has ripples and some SCK grains. On the other hand, it is seen that the surface of the 30% SCK-added composite film is rougher and more granular. In the film containing 50% SCK, agglomeration of SCK particles was observed.

3.3 Solubility-Swelling-Water Content Tests

Solubility-swelling-water content tests determined the behaviors of AESO/SCK polymer composite films in water. The data obtained from the test are given in Table 2.

Table 2. AESO/SCK swelling ratio*

SCK (% by weight)	Swelling ratio (%)
0	0.2433 ± 0.0093^{F}
10	1.2860 ± 0.0115^{E}
20	1.6317 ± 0.1063^{D}
30	2.1070 ± 0.0911^{C}
40	3.2740 ± 0.1159^{B}
50	4.6343 ± 0.0667^{A}

**Different letters in the same column represent the statistical difference between samples ($p<0.05$).*

Table 2 shows a statistically significant increase in swelling with an increase of 20% or more in the SCK ratio in the film structure ($p<0.05$). Due to the polarity of water molecules, they will bind to polar groups in the film structure [33]. In general, the polarity order of functional groups is carboxyl>amide>hydroxyl>ketone, aldehyde>amine>ester>ether>alkene>alkane. AESO has groups such as hydroxyl and ester. Apart from polarity, the second important point affecting water absorption is the free volume of the film structure [34], [35]. As curing increases, the dry, free volume decreases, and water absorption decreases. On the other hand, as the amount of SCK added to the AESO structure increased, the hydrophilic property of the polymer film increased slightly. Therefore the water-holding property of the polymer film increased with the increase of the hydroxyl groups possessed by the SCK, causing swelling [36], [37].

Table 3. AESO/SCK water solubility ratio*

SCK (% by weight)	Water solubility ratio (%)
0	0.11033 ± 0.0101^{D}
10	0.12067 ± 0.010^{D}
20	0.25767 ± 0.0160^{C}
30	0.58200 ± 0.0958^{B}
40	0.59567 ± 0.0297^{B}
50	0.73800 ± 0.1249^{A}

**Different letters in the same column represent the statistical difference between samples ($p<0.05$).*

As seen in Table 3, AESO has low water solubility. However, experimentally, it is seen that the water solubility of biocomposite films increases slightly from 10% to 50% with the addition of SCK. Statistically, the increase in solubility of 10% SCK was insignificant, while the increase in water solubility of polymer

composite films containing 20% and 50% SCK was significant.

The solubility values of the films differ depending on the nature and concentration of the additives added and the hydrophilic and hydrophobic indices of these additives. As the hydrophilic property increases, the solubility is expected to increase [38]. In this case, the hydrophilic property can increase slightly as the SCK ratio increases in the composite film structure.

Table 4. AESO/SCK water content ratio*

SCK by weight (%)	Water content (%)
0	0.6600 ± 0.0181^{D}
10	0.6697 ± 0.0147^{D}
20	0.8637 ± 0.0920^{C}
30	1.8740 ± 0.0521^{B}
40	1.9700 ± 0.0240^{B}
50	2.1203 ± 0.0170^{A}

**Different letters in the same column represent the statistical difference between samples (p<0.05).*

As seen from the findings in Table 4, SCK added to AESO films slightly increased the affinity for water molecules. In general, it is seen that the water content of the composite structure increases with the increase of the SCK ratio from 10% to 50%. Statistically, the water content of the polymer composite film containing 20% and 50% SCK was significant ($p<0.05$). In comparison, the water content increased until the 20% SCK addition was found to be insignificant.

The composite film's protein structure, amino acid composition, and surface polarity are the most critical factors affecting the water-holding capacity [39]. Glutamine, proline, serine, unionized aspartic acid, unionized glutamic acid, tyrosine, threonine, arginine, and lysine among amino acids possessed by the protein with an average weight of 29% in SCK are polar in the structure, aspartic acid(-), glutamic acid(-), ionized tyrosine(-), ionized arginine(+), histidine(+), ionized lysine(+) in the ionic structure; alanine, glycine, phenylalanine, valine, isoleucine, leucine, and methionine are apolar [40]. Water molecules can bind to charge-bearing groups (ion-dipole interaction), peptide bonds, amide groups of glutamine, hydroxyl groups of serine, tyrosin, and tyrosine (dipole-dipole interaction), and apolar amino acids [40]. The literature has reported that the water absorption capacity of the SCK is 130% on average [15]. As a result, as the protein content increases with the increase in the ratio of SCK in the composite film structure, the water content is expected to increase to a certain extent.

3.4 pH Tests

The pH values of AESO/SCK polymer composite film samples kept in salt water for 72 hours are given in Table 5.

Table 5. pH values of AESO/SCK polymer composite films*

SCK (% by weight)	pH			
	0 hour	24 hour	48 hour	72 hour
0	$7.33\pm0.147^{A,a}$	$7.29\pm0.036^{A,a}$	$7.29\pm0.02^{A,a}$	$7.23\pm0.03^{A,a}$
10	$7.33\pm0.145^{A,a}$	$7.29\pm0.06^{A,a}$	$7.25\pm0.025^{A,a}$	$7.21\pm0.026^{AB,a}$
30	$7.33\pm0.135^{A,a}$	$7.28\pm0.071^{A,a}$	$7.25\pm0.01^{A,a}$	$7.20\pm0.017^{AB,a}$
50	$7.33\pm0.137^{A,a}$	$7.27\pm0.015^{A,ab}$	$7.25\pm0.02^{A,ab}$	$7.18\pm0.044^{B,b}$

*$^{A-B}$*Capital letters in the same column show the differences between samples, a- Small letters in the same row show the differences between the times (p<0.05).*

Statistical pH values of AESO/SCK polymer composite films were evaluated in terms of two different parameters: differences between samples and differences between times. The effect of adding SCK at different rates to the polymer composite films on the pH values of the samples was determined at 0, 24, 48, and 72 hours and is given in Table 5. When we examined the data in the table in terms of differences between the times, considering the standard deviations, the pH value of the composite films decreased from 7.33 to 7.23 after 72 hours with the first pH measurement in the control samples without SCK. This increase in acidity was found to be statistically insignificant ($p<0.05$). The acidity increases after the 72nd hour of the film containing 10% SCK, whose pH decreased from 7.33 to 7.21, which was statistically insignificant. The same behavior was observed at 30% WCI. However, the increase in acidity at the 72nd hour at 50% SCK was found to be statistically significant ($p<0.05$).

When we examine the data in Table 5 in terms of differences between samples, a slight decrease was detected in the pH value as the SCK ratio in the structure increased in the samples containing 0% to 50% SCK in the first pH measurements (0. hour), this decrease was not statistically significant. At the end of 72 hours, no statistically significant difference was observed when each pH value was compared for all composite films ($p<0.05$). The average pH of the oil, which contains 17% by weight in the cherry kernel, is 5.45 [27]. As the SCK ratio increases in the AESO polymer structure, a slight decrease in the pH value can be attributed to this.

It is an important feature that the pH values of a material are compatible with the skin pH value, and this range is given as pH 5.25-7.9 in the literature [41]. The pH of all prepared biocomposite films is between 7.18-7.33 after 72 hours, and these values are compatible with skin pH.

3.5 Water Vapor Permeability Test

One of the critical factors determining the usage potential of polymer composite films is the water vapor permeability capacity. Mainly if these films will be used as packaging materials in the food industry, the primary purpose is to prevent or reduce the moisture transfer between the food and the surrounding atmosphere [42].

Water vapor permeability values of AESO/SCK composite films are given in Table 6. Since AESO polymer is lipid-based, it is resistant to water vapor permeability by forming a hydrophobic structure [43], and its water vapor permeability was measured as $1.382x10^{-07}$ g.m/(m^2*Pa*s). According to Table 6, although the decrease in the values was statistically insignificant, the water vapor permeability decreased to an average of $2.512\ x10^{-10}$ with the addition of 10% SCK, and the decrease continued, albeit at a low rate, with the addition of more SCK. This is because SCK closes a small number of pores in the AESO structure that allow water vapor permeability.

Table 6. AESO/SCK water vapor permeability*

SCK (% by weight)	WVP [g.m/(m^2*Pa*s)]
0	$1.382\pm0.124x10^{-7\ A}$
10	$2.512\pm0.001x10^{-10\ A}$
20	$2.010\pm0.710x10^{-10\ A}$
30	$3.770\pm1.760x10^{-10\ A}$
40	$3.780\pm1.770x10^{-10\ A}$
50	$5.025\pm0.001x10^{-10\ A}$

**Different letters in the same column represent the statistical difference between samples ($p<0.05$).*

4. CONCLUSION

In this study, biocomposite films with antibacterial properties were obtained with AESO, a renewable natural polymer, and sour cherry kernel (SCK), which is also a natural waste. A certain increase was observed in the zone diameters for the examined bacterial species as the amount of SCK in the biocomposite films increased. The behavior of AESO/SCK biocomposite films in water was determined by solubility-swelling-water content. Compared to AESO, there was a slight decrease in these properties of AESO/SCK biocomposite films, depending on the ratio. The pH of all prepared biocomposite films was found to be between 7.18-7.33 after 72 hours, and it was concluded that these values were compatible with skin pH. The water vapor permeability of AESO was measured as $1.382x10^{-07}$g.m/(m^2*Pa*s) on average. The water vapor permeability decreased to $5.025x10^{-10}$g.m/(m^2*Pa*s) with a 50% SCK rate. As a result, it is suggested that the produced biocomposite films can be used in the existing areas of AESO, as well as in food packaging or medical industries, supported by additional tests.

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DECLARATION OF ETHICAL STANDARDS

Authors declare to comply with all ethical guidelines, including authorship, citation, data reporting, and original research publication.

AUTHORS' CONTRIBUTIONS

Ulku SOYDAL: Original draft- article writing-examination and evaluation of results, project management, supervision.

Muhammed Melih BUL: Research, analysis, resources.

Murat YILDIRIM: Resources, evaluation of results.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

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