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Fabrication of biofilm based on water-soluble polysaccharide extracted from the Eremurus Spectabilis root: investigation of physicochemical, mechanical and antioxidant properties

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ABSTRACT

Bionanocomposite materials provide an opportunity to use new, high-performance, light-weight, and environmentally friendly composite materials that can replace traditional non-biodegradable plastic packaging materials. In the present study A biofilm based on water-soluble polysaccharide extracted from the root of Eremurus Spectabilis species was prepared And the effect of different concentrations of polysaccharide (1, 1.5 and 2%) on the physical and mechanical properties of the film was investigated. The results showed that with increasing polysaccharide concentration, film thickness and water vapor permeability increased, but its solubility decreased. Also, with increasing polysaccharide concentration, the tensile strength of the films increased significantly. The color analysis of the films showed that parameters a and b increased with increasing polysaccharide concentration, but parameter L decreased. The highest transparency and visible light transmission was related to the 1% polysaccharide film. 1% polysaccharide film was chosen as the final film due to its acceptable mechanical properties, The SEM test of the selected film also showed that the polysaccharide film is a solid and compact film without cracks or holes. According to the results of the DSC test, the melting process of the film was carried out in the temperature range of 202.63-280.46°C. The findings of the current research demonstrate that polysaccharides derived from *E. Spectabilis* root possess the capability to create an efficient film or coating suitable for food preservation, as well as serving as an intermediary layer in multilayer film applications.

1- INTRODUCTION

Food packaging acts as a barrier against contaminants and is closely related to food safety due to its ability to protect against some physical, chemical, and biological hazards such as the risk of microorganisms, dust, light, and gases, loss of texture, and nutritional value of the product [1].

Traditionally, many commonly used packaging materials are plastic.are derived from petroleum [2]. According to global statistics, plastic production in 2020 was estimated at about 350 million tons, of which about 40% was consumed by the packaging industry [3].

Therefore, there is an urgent need to search for alternative packaging strategies to petroleum-based plastic materials with the aim of achieving sustainable and biodegradable packaging.

According to many studies conducted by scientists and researchers, biopolymers have been introduced as alternative packaging materials to plastic materials [4].

Biopolymers are defined as long-chain compounds composed of molecular subunits. They are biodegradable and environmentally friendly and are obtained from renewable natural resources from biological systems such as microorganisms, plants, and animals [5].

Biodegradable films are more expensive than conventional plastics due to expensive raw materials and specialized production processes, and are generally more sensitive to environmental conditions and have a shorter shelf life. However, biodegradable films can decompose into harmless components under certain conditions and reduce long-term environmental impacts [6].

According to the chemical structure of a wide range of polymers synthesized by living organisms, they can be classified into the following main groups: 1) polysaccharides, 2) proteins, and 3) polyesters. Also, based on the advances in biotechnology, natural polymers can be obtained by fermentation of microorganisms or in vitro production by enzymatic processes [7].

Studies on finding new sources of polysaccharides are increasing worldwide. These new polysaccharides are aimed at various applications, including packaging (films,[8] Polysaccharides and proteins as biomaterials can create various interactions that affect the functional properties of the film.Biological processes depend on them. This type of filmDue to their hydrophilic nature, films have high permeability to water, as opposed to gas barrier properties [9]. As a general rule, a film that does not have good water barrier properties is usually resistant to gas transmission and vice versa. Gas transmission resistance for filmsPolysaccharides are very attractive. They can therefore be used to coat or package foods that are subject to oxidation. Since most polysaccharides and other hydrophilic compounds are not resistant to moisture penetration (they are very hygroscopic), they may be applied to the surface of the food as a relatively thick film. The purpose of such a coating on the surface of the food is to absorb water and temporarily protect it from further moisture loss. Therefore, the coated product does not lose moisture until the film is dehydrated [10].

The secret with scientific name*Eremurus*A rhizomatous, spring-flowering plant belonging to the Asphodelaceae family.[1]The seeds of this plant produce an oil that is used in traditional medicine to treat atherosclerosis. The leaves of this plant are used as an edible vegetable, and the roots of this plant, which are in the form of claw-shaped glands and contain a large amount of starch, are used as a glue and also to prepare a type of soup or stew [11,12].

The roots and tubers of the plant are rich in carbohydrates, among which sugars are the most abundant. The total amount of sugar obtained varies from 14 to 22%. The extract obtained from the tubers contains cellulose, but the extract and residue are devoid of starch. The extract of the tubers of this plant contains a small amount of reduced sugar, levulose, cellulose, extractives, albuminoids, ash and minerals, but some have reported that its main component is inulin [14,13].

The accumulation of high levels of water-soluble carbohydrates in the roots of the species of S. spp. has been noted in previous studies [15,16]. Also, the structures and properties of water-soluble glucomannans and galactomannans (GlcMan & GalMan) from the roots of several related S. spp. species such

[1]-Asphodelaceae

as*Eremurus spectabilis*and*Eremurus stenophyllus*grown in Iran have been studied [17].

In addition to the type and concentration of plasticizers, the type of biopolymer and its concentration can greatly improve the quality of films in terms of their physical and mechanical properties.

Shahrampour and Razavi (2022)Physicochemical and structural properties of antioxidant packaging film based on 1.5% Eromorus luteus root gumand studied different concentrations of glycerol and sorbitol.]9[Also Baratian-Gorghi et al. (2018)Features of biodegradable film from SrishwithThey investigated a concentration of 1% by weight.]18[.

A review of existing research shows that no specific study has examined the effect of different concentrations of a single type of biopolymer on film properties, and most previous studies have studied the effect of the type and concentration of plasticizer, thereforeThe purpose of this research was to prepare biofilms with different concentrations of water-soluble polysaccharides extracted from the root of the spectabilis species.[2]And to investigate the effect of polysaccharide concentration on the physical and mechanical properties of the film.

2-Materials and methods

2-1- Materials

The roots of E. spectabilis were obtained from Mashhad Plant Sciences Research Institute, and then the air-dried roots were cleaned, ground into powder, and passed through a 70-mesh sieve. Glycerol, sodium chloride, Folin-Ciocalcio reagent[3], 2 and 2 diphenyl-1-picrylhydrazyl[4] , 96% ethanol, methanol, and sodium carbonate were obtained from Merck or Sigma Aldrich.

2-2- Extraction

For extracting polysaccharide extract from syriacus root, prepared 2% w/v concentration of syriacus root powder in distilled water and incubated for 2 hoursThe temperature was 80-90°C and homogenized on a magnetic stirrer. Then the extracted extract was filtered with a linen cloth. In order to further purify the obtained extract, a centrifuge was used at a speed of 8000 rpm for 5 minutes. In the next step, to remove chemical impurities such as color, fat and simple sugars, 96% ethanol was added to the extracted extract in a ratio of 1:1. After 15 minutes of rest and precipitation of polysaccharides, a centrifuge was used at a speed of 7000 rpm for 5 minutes at ambient temperature to separate the polysaccharides. At the end of the extraction process, the obtained polysaccharide was dried using a hot air dryer at a temperature of 45°C for 24 hours, thenFrom that millAfter sieving with a 45 mesh, it was poured into special containers and stored in a cool and dry environment for further tests..

2-3- Film production

To prepare the ESREP film-forming solution, different concentrations of ESREP (1, 1.5, and 2% w/v) were first prepared in distilled water and homogenized on a magnetic stirrer for 24 hours. Then, 30% w/v based on the weight of glycerol polysaccharide was added and placed on a magnetic stirrer for 30 minutes to completely disperse. Finally, 46 ml of the film-forming solution was poured into a 10 cm diameter plastic plate and kept in a desiccator at 45°C for 24 hours. The film was separated from the surface of the plate and, for conditioning, transferred into a desiccator containing a saturated solution of magnesium nitrate (the relative humidity of the interior of the desiccator at 25°C was about 53%) and placed in a desiccator at 25°C for 72 hours. The conditioned film was packaged in zip-lock plastic bags until the tests were performed. The filmHealthy, bubble-free films were selected to measure film properties.

2.4- Film thickness measurement

Film thickness at five random points on the film surface with a digital micrometer (with an accuracy of 0.001).±mm) (Mitutoyo, Tokyo, Japan) measured and then averaged the data± The standard deviation was reported [9].

2.5- Determining film solubility

To determine the solubility of the dried film in water, a 2 x 2 cm2 film was immersed in 50 ml of distilled water for 6 hours at room temperature. The undissolved film was separated with a Whatman filter paper at the end of the time and then dried in an oven at 103°C for 24 hours. The solubility of the film was calculated using the equation 2-1:

$$\text{Film solubility (percentage)} = 100\frac{M1-M2}{M1} \times \quad \text{رابطه 2-1}$$

2-*Spectacular Eremurus* root extracted water soluble polysaccharide (ESREP)

3-Folin-Cicalteus Phenol Reagent

4-2,2-Di-phenyl-1-Picryl-Hydrazyl (DPPH)

Where M_1Initial dry film weight (in grams) and M_2The weight of the dry undissolved film (in grams) is [9].

2-6- Water vapor permeability[5]

The ASTM E96 (1995) method was used to measure water vapor permeability. Glass vials were used for this purpose. The cap of these vials has a 13 mm diameter hole, through which pieces of the film under test are placed. Silica gel was placed inside the vials. The cap of the vial was covered with pieces of film. The vials were weighed with all their contents and placed in a desiccator containing saturated sodium chloride brine. The desiccator was placed in a greenhouse at 25°C and the weight of the vials was measured every 24 hours for ten days. The amount of water vapor transferred from the filmThe weight gain of the vials over time was plotted and after calculating the linear regression, the slope of the resulting line was calculated. The water vapor transmission rate was calculated by dividing the slope of the line for each vial by the total film surface area exposed to water vapor transmission.[6]The water vapor permeability of the film was obtained.was calculated from the following equation.

Relationship 2-2

WVP = (WVTR.X)/ P

where X is the film thickness in millimeters and P is the partial pressure of water vapor at 25°C [19].

2.7- Antioxidant activity

In order to investigate the antioxidant activity of the films, their total phenol content and anti-radical activity against DPPHIt was determined.

2-7-1- DPPH radical scavenging power

To determine the DPPH free radical scavenging power of the film, 2.5 ml of methanolic DPPH solution (0.004%) was added to 500 µl of the film extract in a test tube and the resulting mixture was vigorously stirred. The test tubes were placed in the dark for 30 min. After this period, the absorbance was read at a wavelength of 517 nm. It should be noted that in the control sample, the extract was replaced with 500 µl of methanol. Finally, the percentage of scavenging of DPPH radicals by the film was calculated using the equation 2-3 [20].

=Free radical scavenging power of the film (percentage)

100×Control absorption / (sample absorption - control absorption)

Link 2-3

2-7-2- Total phenolic compounds

The amount of total phenolic compounds was measured by the Folin-Ciocaltio method.Gallic acid was used as a standard to draw the calibration curve.and the results were expressed in mg of gallic acid per gram of extract. Briefly, in this method, 500 µl of the film extract solution was mixed in a test tube with 500 µl of Folin-Ciocaltio reagent. After 5 minutes, 2.5 ml of sodium carbonate solution (7.5% w/v) was added to the contents of the test tube. The absorbance of the samples was read after two hours with a spectrophotometer at a wavelength of 760 nm [21].

2-8- Optical properties (color, opacity, etc.) UV absorption rate)

To examine the color of the film samples, the sample photos were scanned using a desktop scanner (HP Scanjet300, China). A 3 × 2 cm piece of each image (JPEG format; 400 dpi) was selected using Adobe Photoshop (Adobe Inc., USA). After noise reduction, the pixel parameters were converted to L* and a* parameters using Image J (1.40 g) software [22].

The UV and visible light blocking properties of the film were determined by measuring the percentage light transmission of the film sample (5 cm × 5 cm) at 280 nm (T280) and 660 nm (T660), respectively, using a UV-vis spectrophotometer (DR 5000- HACH LANGE GmbH, USA) [23].

To measure turbidity, the absorbance of the film sample (size 8 mm × 40 mm) was recorded at a wavelength of 600 nm by a UV-vis spectrophotometer. The turbidity of each film was determined by the method of Hasheminya et al. (2019) according to equation 2-4:

Link 2-4 $\frac{A600}{X}$= turbidity

where X is the film thickness (mm) and A600 is the film absorbance at 600 nm [24].

2-9- Tensile properties

The tensile properties of the film were measured using a Texture Analyzer (TA Plus-LLOYD, UK) and in accordance with ASTM D882-09 [25]. A 6 × 1 cm2 sample was cut from the conditioned film and its tensile properties were measured at ambient temperature. After drawing the stress-strain curve, the values of tensile strength, elongation

5-Water vapor permeability (WVP)

6-water vapor transmission rate(WVTR)

at break and tensile modulus were determined. From the load cell[7]200 Newtons were used for the device, the distance between the two jaws was set to 40 mm, and the speed of movement of the upper jaw was set to 40 mm/min.

2-10- Microstructure

Surface microstructure of film samples using scanning electron microscopy[8]Model MIRA3 TESCAN

It was investigated with gold coating and a voltage of 10 kV [26].

2-11- Thermal properties

To measure thermal properties using a differential scanning calorimeter[9](DSC 1(METTLER TOLEDO (Switzerland) was used. This process was carried out from 0 to 350°C at a heating rate of 10°C/min under nitrogen flow. All graphs were analyzed using STAR*E software [27].

2-12- Fourier transform infrared spectroscopy[10]

The presence of functional groups was analyzed by infrared spectroscopy. For analysis, about 10 mg of the sample was pressed with potassium bromide salt and placed in the instrument (AVATAR 370 FT-IR-Thermo Nicolet, USA) and the percentage transmission between wavenumbers 400 and 4000/cm was recorded with a resolution of 4 [28].

2-13- Statistical analysis

The tests were performed in triplicate and the results were averaged.±Standard deviation (SD) was reported. Statistical analysis was performed through simple completely randomized design and one-way analysis of variance (ANOVA) at P<0.05 using SPSS software (version 23).

3-Results and Discussion

3.1- Film thickness

Film thickness is an important factor in determining gas and water permeability, which not only affects the appearance of the food product but also its taste, so the minimum film thickness should be used as much as possible to avoid undesirable changes in the taste of the food. The film thickness with different ESREP concentrations is shown in Table 1. As can be seen, increasing the ESREP concentration significantly increases the film thickness.It was $(0.05)p <$). Film thickness depends on various factors, mainly the solids content of the film-forming solution; generally, higher film solution concentrations result in thicker films. In addition, the nature and composition of the film[29] Therefore, increasing the ESREP concentration results in more dissolved solids in the solution and consequently a thicker film.The effect of increasing the concentration of the base material on increasing the film thicknessThe results observed in this study are consistent with the results of previous studies reported by Saravani Pak et al. (2020) on edible film based on Persian gum, Arham et al. (2016) on edible film of agar, Kokoszka et al. (2010) on edible film based on soy protein isolate andSadeghi-Varkaniet al. (2017) on edible film from balango seed mucilage It corresponds to [30-33].

3.2- Solubility in water

According to Table 1, with increasing ESREP concentration in the film, the solubility decreased significantly (P<0.05). The solubility of the filmThe solubility of the film varied from 26.7% to 44.6%. The increase in film solubilityThe studied films were inversely related to polysaccharide content. This phenomenon may be due to the compaction of the film structure with increasing ESREP concentration, as the penetration of water molecules into the structure of films containing higher ESREP concentrations is less [9]. Previous studies on edible films based on agar (Arham et al., 2016) and Persian gum (Saravani Pak et al., 2020) yielded similar results [30, 31]. FilmHighly soluble compounds can be used in some cases, including film.Bioactive compound-carrying products and ready-to-eat foods with easy film melting during boiling in water are useful. Hence, the filmESREPs with relatively high solubility are suitable for preparing food packaging.

3-3- Water vapor permeability

The inhibitory properties of a polymer film are very important for estimating or predicting the shelf life of the food packaged in it. The effect of three different ESREP concentrations on WVP is shown in Table 1. Differences between WVP of the filmwas significant $(0.05).p <$With increasing ESREP concentration, WVP filmincreased from 0.5 to 1.8. WVP of the filmThe nutritional value of food depends on many factors, including:The strength of the film's structural coherenceThe

7-Load cell
8 -Scanning Electron Microscopy (SEM)
9- Differential Scanning Calorimeter (DSC)
10- Fourier transform infrared spectroscopy (FTIR)

polymer chain mobility, the ratio of hydrophilic to hydrophobic parts in the film [34], the type and amount of plasticizer, the film thickness, the sensitivity to water, and the environmental conditions (temperature and relative humidity) [29].

In purely polysaccharide films, there is no barrier to water vapor penetration due to the absence of hydrophobic compounds such as lipids, and in the absence of these compounds, increasing the polysaccharide concentration increases the moisture absorption capacity of the film due to the hydrophilic nature of polysaccharides [35, 36]. It has been found that the thickness usually has a direct relationship with the WVP of the film.hydrophilic films, i.e., WVP increases with increasing gum concentration and film thickness [29], this could be due to the high presence of hydroxyl groups in the gum, which increases the interaction with water and helps in the transport of water vapor in the film structure, which was consistent with the results obtained in the present study. Also, the results of Haq et al. (2014) showed that the WVP of Cordia gum film increased as a function of film thickness [37].

Rezaei Taghiabadi et al. (2011) Water vapor permeability of filminvestigated edible films based on tragacanth gum. Similar to the results of this study, the water vapor permeability for the filmThe water vapor permeability of the film based on tragacanth gum was affected by the linear effect of the concentration of tragacanth gum and glycerol. In such a way that the water vapor permeability of the film increased with increasing the concentration of tragacanth gum and glycerol [38]. Also, in the study of Saravani Pak et al. (2020) and Sadeghi-Varkani et al. (2017), similar results were obtained and with increasing the concentration of the base materials, WVP increased [30, 33]. But vice versa in the studySadeghi-Varkaniet al. (2017) found that by increasing the biopolymer content to a certain level (1.2%) at a constant plasticizer concentration, WVP decreased due to more regular chains within the film matrix and better film barrier against water vapor penetration [33].

According to the available results for WVP film[29] It can be said that the WVP of the film prepared from different concentrations of ESREP is approximately 760 times higher than the WVP of the filmSynthetic materials with good barrier properties (polyvinylidene chloride with g/m Pa s^{11-} 10×0.083) and about 1.3 times less than the WVP of the filmSynthetic low barrier (cellophane with g/m Pa s^{10-} 10×41.8). Due to the hydrophilic nature of natural hydrocolloids, the filmEdibles prepared from them cannot act as an effective water vapor barrier.

Table 1. Physical properties of the film (mean ± standard deviation) with different ESREP concentrations

Water vapor permeability (×10^{-10} g $m^{-1}s^{-1}$Well)	Solubility (percentage)	Thickness (mm)	ESREP movie
^{c}1/0± 0/5	^{a}3/0± 6/44	^{c}001/0 ± 04/0	1 percent
^{b}1/0 ± 9/5	^{b}2/0± 5/40	^{b}005 /0 ± 06/0	1.5 percent
^{a}1/0 ± 1/8	^{c}1/0± 7/26	^{a}003/0 ± 09/0	2 percent

Unlike letters in each column indicate significant differences.
Based on Duncan's test (P < 0.05)

3.4- Optical properties (color, turbidity and UV absorption rate)

Film colormay affect the consumer acceptance of a product. In general, desirable properties in edible film coatings and packaging are high transparency and brightness [39, 40].

Film color and transparency parametersThe ESREP parameters are shown in Table 2. With increasing ESREP concentration, the L* parameter decreased and the a* and b* parameters of the film increased (P<0.05).$p <$). Due to the increase in parameter b∗, movieThe produced particles had a yellow appearance, which is related to the original ESREP powder.

Film transparencyare shown in Table 2. The highest turbidity value in the filmThe highest opacity value was obtained for the 1.5% ESREP film and the lowest opacity value was obtained for the 2% ESREP film. Increasing the ESREP content had different effects on the transparency of the film.In fact, the surface morphology of the filmis a determining factor for such changes in opacity, as light reflectance can be affected by the homogeneity of the film matrix at the film-air interface. In other words, higher levels of homogeneity provide lower levels of opacity [41].

Similar to the results of this study, in the researchSaravani Paket al. (2020), increasing the amountSPGDifferent effects on film opacity[30].

The results showed that the filmESREPs compared to filmSynthetics such as low-density polyethylene[11](with 67.5% UV light transmission) and oriented polypropylene[12](with 80% UV transmission) transmits much less UV light [42, 43]. Color parameters and transparency of the filmAcceptable ESREP results and comparable to other filmsIt is hydrocolloid.

Table 2. Color and transparency parameters of films with different ESREP concentrations

Published (nm660)	Turbidity (nm600)	(nm)280	L	b	a	ESREP movie
8/73±2/0[a]	6/2±1/0[b]	2/27±8/1[a]	8/74±2/1[a]	8/25±5/1[b]	2/1±8/0[c]	1 percent
1/65±1/0[b]	7/2±0/0[a]	9/19±5/0[b]	2/66±1/1[b]	5/27±2/2[b]	4/2±0/1[b]	1.5 percent
2/58±2/0[c]	4/2±0/0[c]	9/19±5/0[b]	5/59±8/1[c]	7/37±9/2[a]	8/7±3/1[a]	2 percent

Different letters in each column indicate significant differences based on Duncan's test ($P < 0.05$).

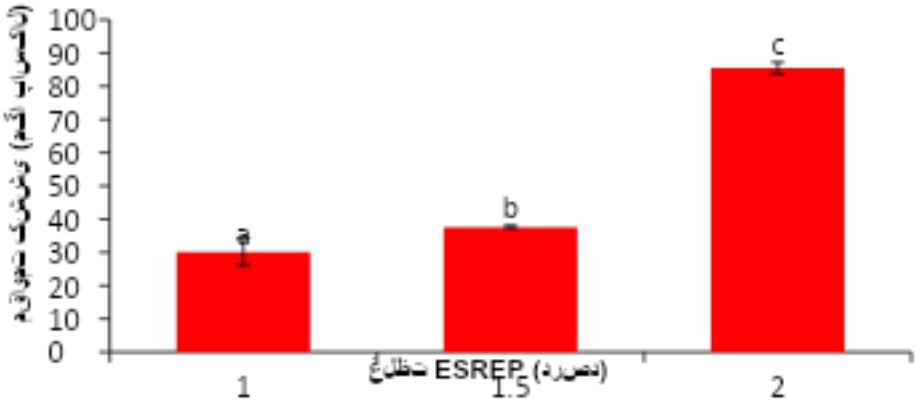
5.3- Tensile properties

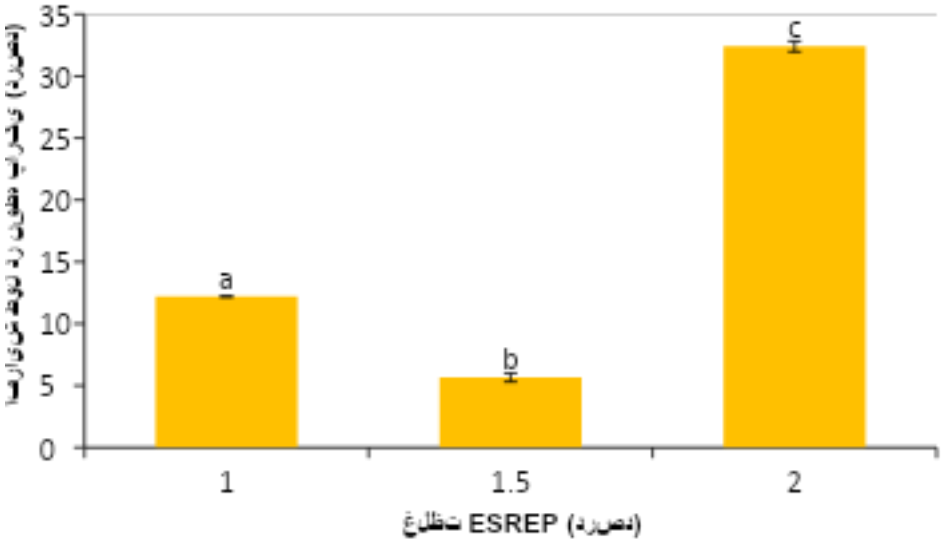
Tensile properties of edible/degradable films by measuring three common parameters: Tensile strength[13], elongation at break[14]and elastic modulus[15]or Young's modulus[16]The effect of adding ESREP concentration on the tensile properties of the filmare shown in Figure 1. According to the results, there is a significant difference in terms of tensile strength and elongation at break between the films.were observed $(0.05)p <$The results showed that tensile strength and Young's modulus increased significantly with increasing ESREP concentration ($P<0.05$).$p <$The highest tensile strength and the highest elongation at break were for the film with a concentration of 2% ESREP, so that by increasing the ESREP concentration from 1% to 2%, the tensile strength increased from 30.15 MPa to 85.4 MPa and the elongation at break increased from 12.2% to 32.4%.IncreaseThe ESREP content leads to increased molecular interaction between polymer chains and ultimately the filmIn other words, the more compact the structure and the smaller the distance between the biopolymer chains, the higher the tensile strength [29]. Increasing the TS value due to the effect of increasing the concentration of the base materials also has an effect on the film structure.Agar-based [31], balango seed mucilage [33], and protein and starch [44-47] have been reported.

Elongation at break is a key mechanical property that indicates the flexibility and ductility of a film. In polysaccharide-based films, this property often shows a nonlinear trend—first decreasing, then increasing—when certain variables (such as polysaccharide content, plasticizer concentration, or crosslinking agent) are changed. This phenomenon is due to the complex interactions between film components and their influence on the film microstructure [48, 49]. Furthermore, the increase in EB value with increasing biopolymer concentration is consistent with the research of Arham et al. (2016) and Murdinah et al. (2007) [31, 50].

According to the results of the tensile properties of ESREP film, it can be concluded that ESREP film is strong, flexible and has a high elastic modulus. The main factors that lead to the difference in the tensile properties of the filmThe film composition, the type of plasticizer, and the method of film preparation may be the factors [50].Those whose TS is in the range of 10-100 MPa and whose elongation at break is greater than 10% can be considered as film components.[33], in addition, dried gums are usually used at low concentrations (about 1% w/v) to avoid problems caused by high viscosity of gum solutions in different stages of film formation (mixing, degassing and casting) [29]. Therefore, according to the results obtained, 1% ESREP film can be selected as an optimal film with acceptable physical and mechanical properties.

11- LOW-density polyethylene (LDPE)
12- Oriented polypropylene (OPP)
13- Tensile strength (TS)
14- Elongation at break (EB)
15- Elastic modulus (EM)
16- Young's modulus (YM)


100
90
80
70
60
50
40
30
20
10
0
a
b
c
1
1.5
2
ESREP تظاهر (دصرد)


35
30
25
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a
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1
1.5
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ESREP تظاهر (دصرد)

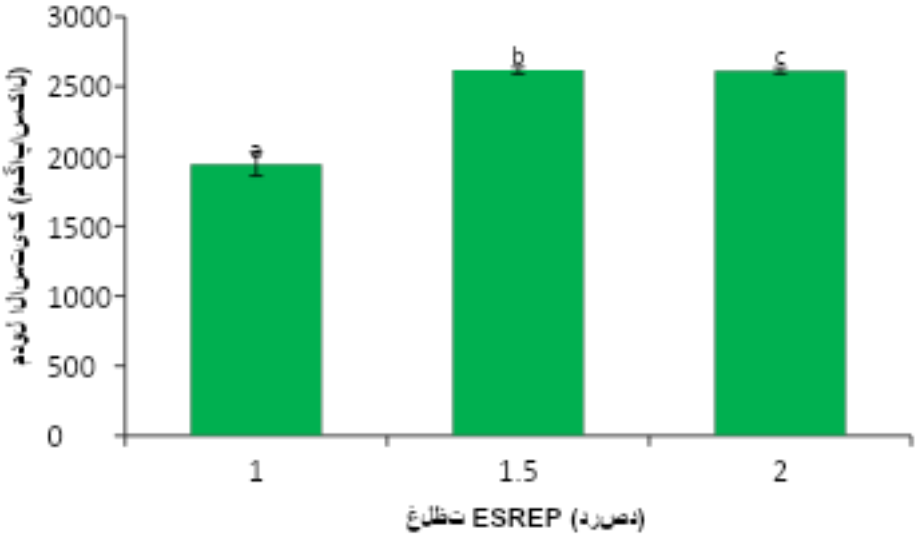

3000
2500
2000
1500
1000
500
0
a
b
c
1
1.5
2
ESREP تظاهر (دصرد)

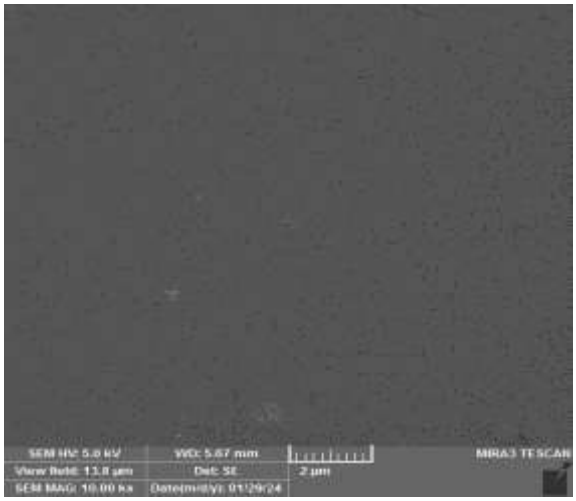
Figure 1. Tensile properties of the filmESREP: tensile strength (a), elongation at break (b) and elastic modulus (c). Error bars indicate standard deviation (SD). Different letters on each column indicate significant differences (P < 0.05) based on Duncan's range test.

3.2- Optimal ESREP film properties

3-2-1- Microstructure

Micrographs taken from the surface or cross-section of the film are useful for elucidating film characteristics such as WVP, mechanical properties, opacity, and density. SEM is used as a method to evaluate the integrity of the film structure, the layering of the structure, the presence of pores and cracks, surface smoothness, and to determine the film thickness. When the film matrix is uniform and compact, without cracks or voids, it is an indication of structural integrity and, consequently, its mechanical properties are desirable [51].

Analysis of the SEM results of the ESREP film (Figure 2) showed that the optimal ESREP film is formed by a dense structure and has a completely uniform and homogeneous surface morphology.



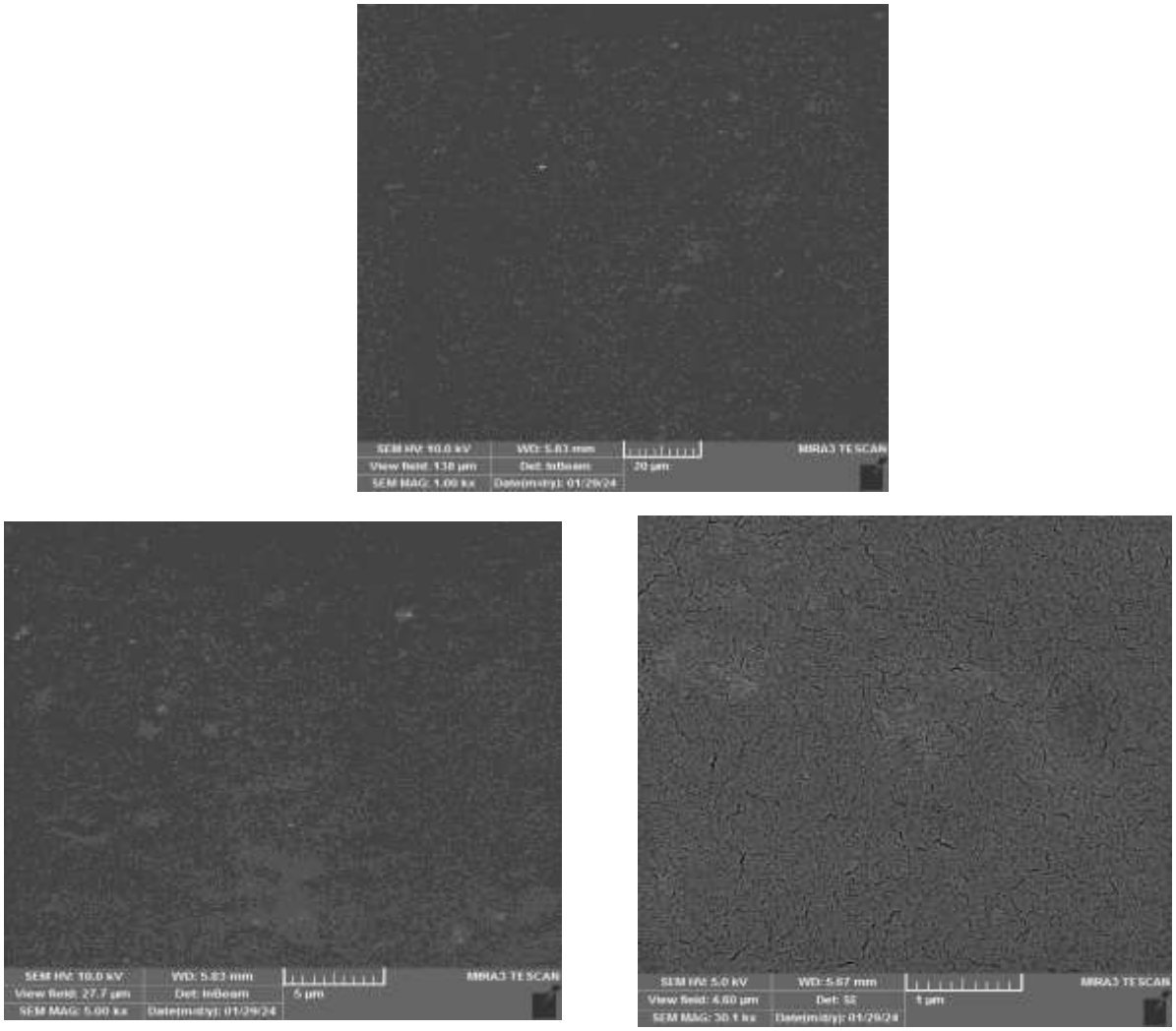


Figure 2.Electron microscopic images of 1% ESREP film at different magnifications

3-2-2- Thermal properties

Table 3 shows the results of thermal analysis of the film prepared from ESREP with a concentration of 1%.The thermogram of the film (Fig. 3) showed an initial endotherm peak in the range of 66.16–152.65°C. This peak corresponds to the surface desorption of moisture bound to the hydrophilic groups of the sample [52].Melting, an endothermic phenomenon, occurs in the crystalline parts of polymers. Melting occurs when the polymer chains break out of their crystalline structures and become a disordered liquid.]53[. The second thermal profile in the sample of this study was again recorded as an endotherm peak in the temperature range of 202.63-280.46°C, which could be related to the film melting process.

In addition to two endotherm peaks in the DSC curve of the prepared film, an exotherm peak at a temperature of about 303°C is observed, which is probably related to the depolymerization and decomposition of the polymer chain [54].

Table 3. Thermal parameters of 1% ESREP film

Third courier	Second courier	First Courier	Temperature (degrees Celsius)
303	63/202	16/66	Starting point
---	32/252	47/109	Pack
---	46/280	65/152	End point
---	75/883-	40/1289-	Enthalpy (millijoules)

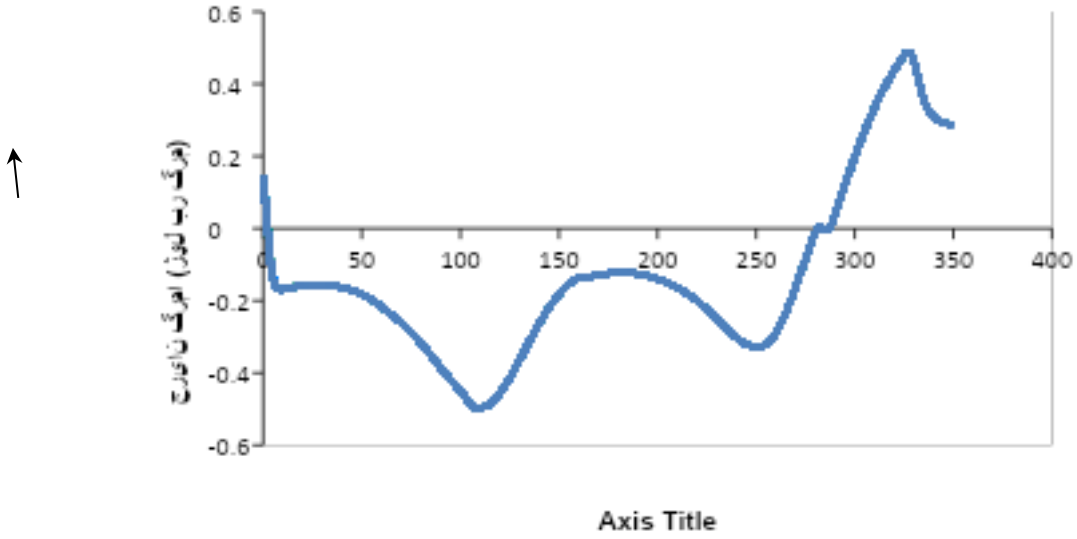


Figure 3. DSC thermogramFilm prepared from ESREP at a concentration of 1 percent

3.2.3. Fourier Transform Infrared Spectroscopy

Fourier transform infrared spectroscopy is commonly used in polysaccharides to investigate the type of glycosidic bonds, type of monosaccharides, and functional groups.

The FTIR spectrum for the film with 1% ESREP concentration is shown in Figure 4. As can be seen in this figure, in the range of 3590-2950, which is characteristic of O-H stretching vibrations, there is an absorption peak with wave number 3431/24, which is related to the free, intra- and intermolecular stretching vibrations of hydroxyl functional groups. This band is related to the moisture content of the film, the presence of glycerol or hydroxyl groups of the sugar ring. In the range of 3000-2800, which is characteristic of C-H stretching vibrations; there are absorption peaks with wave numbers 2879 and 2932. This absorption band is indicative of the presence of sugars and glycerol. This region is also a standard of amorphous regions. The absorption band at 1735.30 cm can be related to the stretching vibration of the C=O acidaronic bond [8]. The peaks observed in the region of 1500-1200 cm are attributed to the vibration of the bending bands of the C-H groups and the bending bands of the alcoholic O-H groups. The region between 950 and 1150 cm is related to the vibrations of the C-O and C-O-C glycosidic and C-O-H bonds [39].

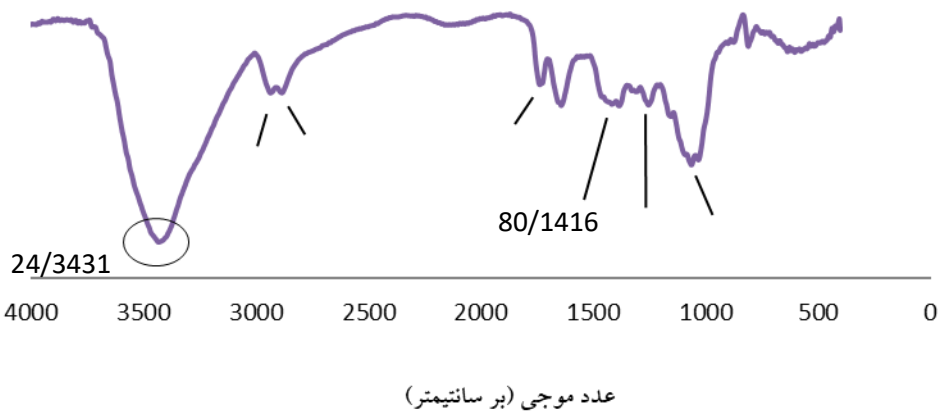


Figure 4. FTIR spectrum of 1% ESREP film

3-2-4- Antioxidant activity

The antioxidant capacity of packaging can play a role in preserving freshness and extending the shelf life of foods.

Phenolic compound content of 1% film sample ESREP 90/2±135.06 (milligrams of gallic acid per 100 grams of extract powder) and DPPH free radical scavenging power, 0.60±was 25.56%. Soni et al. (2018) showed that the antioxidant activity of 75.25 wt% and 100.0 wt% chitosan/TEMPO cellulose nanofibers (CNFs) films towards DPPH radical scavenging was 1.2 and 2.8 (mg Trolox activity/g sample), respectively. Hence, the study concluded that the antioxidant activity was linearly related to the chitosan concentration [55].

Polysaccharide film based on mucilage of seeds in the study of Jouki et al. (2013) and Uromorus film with different concentrations of glycerol (30-50%) in the study of Shahrampour and Razavi (2022) showed 18.39 and 25.71-16.98% DPPH radical scavenging power, respectively [56, 9].

Karaman et al. (2011) investigated the content of phenolic compounds, antioxidant, antimicrobial, and antiradical activities of ethanolic, methanolic, and aqueous extracts of Arbutus spectabilis from Antalya region. Thirty-four volatile compounds were identified in Arbutus spectabilis. The major phenolic compounds of Arbutus spectabilis were carvone.[17]and carvacrol[18]The highest amount of phenolic compounds was in methanolic extracts at 0.48.±31.92 mg of gallic acid equivalents were observed per gram of dry extract. The ethanol extract showed the highest anti-radical activity. The strongest antioxidant property was determined in the methanol extract [57].

4- Conclusion

In this researchFeatureHi Physical MechanicalBiofilm based on water-soluble polysaccharide extracted from the root of the species of Seris spectabilis was investigated. The results showed that the tensile strength and Young's modulus increased significantly with increasing ESREP concentration, but to avoid problems caused by the high viscosity of gum solutions in different stages of film formation, 1% ESREP was selected as an optimal film with acceptable physical and mechanical properties. SEM, DSC, FTIR and antioxidant activity tests were performed on the selected film. The results of this study showed that the polysaccharide film is a suitable option for combining with other films.Synthetic transparent films for film productionMultilayer films are suitable for food packaging applications because they increase the biodegradability of the film.The aforementioned will be.

Conflict of interest

The authors declare that they have no known financial conflicts of interest or personal relationships that could be considered to influence the research reported in this article.

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Authors' Contributions

Zahra Hosseinpour: Research, writing (first draft), formal analysis. Razieh Nezamdash: Validation, project management, conceptualization, writing (review and editing), supervision, data management. Mohammad Reza Abdollahi Moghadam: Writing (review and editing), supervision, data management. Mahboobeh Sarabi Jamab: Writing (review and editing), supervision, data management.

Data access

No data was used in the research described in this article.

Artificial Intelligence Statement

Artificial intelligence has not been used.

5-Resources

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18 -Carvacrol

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ساخت بیوفیلم بر پایه پلی‌ساکاریدمحلول در آب استخراج شده از ریشه سریش گونه اسپکتابیلیس: بررسی ویژگی های فیزیکوشیمیایی، مکانیکی و آنتی اکسیدانی

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چکیده

مواد بیونانو کامپوزیت فرصتی را برای استفاده از مواد کامپوزیتی جدید، با کارایی بالا، وزن سبک و سازگار با محیط زیست ایجاد می کنند و می‌توانند جایگزین مواد بسته‌بندی پلاستیکی غیرقابل تجزیه زیستی سنتی شوند. درپژوهش حاضر یک بیوفیلم بر پایه پلی ساکارید محلول در آب استخراج شده از ریشه سریش گونه اسپکتابیلیس تهیه شد و تاثیر غلظت های مختلف پلی ساکارید (۱، ۱/۵ و ۲ درصد) بر ویژگی های فیزیکی مکانیکی فیلم بررسی شد. نتایج نشان داد با افزایش غلظت پلی ساکارید، ضخامت و نفوذپذیری بخار آب فیلم افزایش اما حلالیت آن کاهش پیدا کرد. همچنین با افزایش غلظت پلی ساکارید مقاومت کششی فیلم‌ها به طور معنی داری افزایش پیدا کرد.آنالیز رنگ فیلم‌ها نشان داد پارامترa و b با افزایش غلظت پلی ساکارید افزایش اما پارامتر L کاهش پیدا کرد. بیشترین شفافیت و انتقال نور مرئی هم مربوط به فیلم ۱ درصد پلی ساکارید بود.فیلم ۱ درصد پلی ساکارید به علت نشان دادن خواص مکانیکی قابل قبول به عنوان فیلم نهایی انتخاب شد که آزمون SEM فیلم منتخب نیز نشان داد فیلم پلی ساکارید فیلم یکپارچه و فشرده، بدون ترک و حفره می‌باشد. طبق نتایج آزمون DSC فرآیند ذوب فیلم در محدوده دمایی ۲۸۰/٤٦-۲۰۲/٦۳ درجه سانتی‌گراد بود. نتایج پژوهش حاضر بیانگر قابلیت پلی ساکارید ریشه سریش برای تهیه فیلم یا پوشش کارامد برای نگهداری مواد غذایی و یا به عنوان لایه میانی در فیلم های چند لایه می باشد.