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Production of novel composite bioactive film of whey protein concentrate and Jujube mucilage reinforced by postbiotics of *Bacillus coagulans* IBRC-M 10807

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ABSTRACT

The aim of this study was to produce a new bioactive composite film using whey protein concentrate and jujube mucilage reinforced with postbiotics of *Bacillus coagulans* IBRC-M 10807. For this purpose, four films including whey protein concentrate film (WPC), whey protein concentrate film containing *B. coagulans* postbiotics (WPC+PBs), whey protein concentrate film and jujube mucilage (WPC+MUC), and whey protein concentrate film and jujube mucilage containing *B. coagulans* postbiotics (WPC+PBs+MUC) each in three replicates of production and their physicochemical, antimicrobial, antioxidant and mechanical, were compared in the form of a completely random design and with the analysis of variance method. The results showed that the addition of postbiotics and jujube mucilage caused a significant increase in the moisture and solubility of the films ($P<0.05$). Adding postbiotics causes an inhibitory effect against Staphylococcus aureus and Escherichia coli bacteria ($P<0.05$). The addition of postbiotics and jujube mucilage caused a significant decrease in the *L* index of the produced film samples ($P<0.05$). The results showed that the *a* and *b* indexes increased significantly with the addition of postbiotics and jujube mucilage ($P<0.05$). The results of the present study showed that the produced bioactive biocomposite film has the potential to be used in food packaging.

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1- Introduction

Edible films are among the active biodegradable packages that are considered as one of the basic ways to control physiological, microbial, physical, and chemical changes in food. These films can reduce moisture loss, fat oxidation and color deterioration and act as a carrier in the transfer of antioxidant substances and antimicrobial compounds, leading to the preservation and improvement of the quality of fresh, frozen foods and processed meat products.]1[. Proteins, polysaccharides, lipids or a combination of these are used to prepare biodegradable films.]2[. Mucilages are biopolymers with high molecular weight that are widely used in pharmaceutical, industrial, health and medical fields. Also, these materials are used in food industry as methoxylizer, thickener and stabilizer. The main source of synthesis of these compounds is seeds, but they are also found in fruits, leaves, flowers and other plant organs.]3[. Whey protein concentrate is a substance that is obtained from sufficient separation of non-protein substances from the whey so that the final dried product contains at least 25% protein. Whey protein concentrate may be produced with a wide range of functional properties that can make it attractive. Increase as a food composition. These functional characteristics are defined as chemical-physical characteristics that can affect the behavior of protein in the food system during processing, storage, preparation and consumption.]4[.

Jujube with scientific name*Ziziphus jujuba*Miller fruit is a shrub with a height of about 10 meters, which has wide branches and long or short and curved thorns. The jujube fruit is spherical to slightly elongated and oval, red or dark brown with a sweet taste and an elongated and pointed oval seed and ripens in summer to early autumn. It is used in Iranian traditional medicine as a blood purifier and breast softener and to relieve inflammation and heat. This plant grows in the north of Iran and also grows in the Caucasus, Central Asia, Afghanistan, Pakistan and India.]5[.

Adding probiotics is one of the ways to increase functional properties in edible films and coatings. Probiotics are living microorganisms that, when consumed in sufficient amounts, create health-giving properties for the host.]6[. Considering that the direct use of probiotics in food products has disadvantages, postbiotics can be A suitable alternative for the use of live bacteria and their metabolites]7[. Postbiotics can be called non-living functional components of probiotic cells that are usually produced by living bacteria during the fermentation process or on a laboratory scale with different physical and chemical methods. Postbiotics include inactivated microbial cells, cell components (teichoic acid, muropeptides derived from peptidoglycan, cell surface proteins, and oxopolysaccharide) and cell metabolites (short-chain fatty acids, enzymes, bacteriocins, and organic acids) secreted while the microbial cells are alive or after When they break down, they are released in the environment of the host's intestine, and if they are received in sufficient quantity, they leave the health effects of themselves in the host.]8[. *Bacillus coagulans*[1]It is a gram-positive, facultative anaerobic, non-pathogenic, spore-forming bacterium and is used as a probiotic due to the production of lactic acid and is very important from an industrial point of view.]9[.

Therefore, the aim of the current research is to develop a biodegradable composite film of blue cheese protein concentrate and jujube mucilage with the use of postbiotics.*Bacillus coagulans*IBRC-M 10807 as an antimicrobial and antioxidant compound for the first time and determining the characteristics of the production film.

2- Materials and methods

1-2- Materials used

In this research, dried jujube fruit was purchased from Attari located in Urmia city in spring 1401 and after being approved by the Department of Horticultural Sciences of Urmia University, it was transferred to the laboratory of the non-profit Saba University to extract the mucilage. Whey protein concentrate (80%) was obtained from Pegah Company, Tehran, Iran. Glycerol was obtained from Acros Organics, Germany and was used as a softener in all formulations. Other chemicals for the tests, including

1*Bacillus coagulans*

potassium sulfate, calcium sulfate, magnesium sulfate, magnesium chloride, calcium chloride, sodium chloride, sodium carbonate, glucose, and lactose, were obtained from Merck, Germany. Also, yeast extract and peptone water were obtained from Kiolab, Canada.

2-2- Mucilage extraction

In order to extract the mucilage, dry jujubes were washed in the first step and then crushed and soaked in warm water with a temperature of 40 degrees Celsius for 6 hours. Then, the mucilage was separated and placed in a stirrer at a temperature of 50 degrees Celsius for 2.5 hours. A linen cloth was used to pass through the strainer. Finally, the strained mucilage was poured on the foil paper and placed inside the oven with a temperature of 55 degrees Celsius for 24 hours [11].

2-3-postbiotic metabolite production method*Bacillus coagulans*

bacteria*Bacillus coagulans*IBRC-M 10807 in NYSM culture medium[2] The broth was incubated at 37°C for 24 hours, then this culture medium was centrifuged at 4000 rpm for 10 minutes. After removing the supernatant, the remaining materials were filtered through a sterile syringe head filter (mµ40) and freeze-dried and used as postbiotics.]7[.

2-4- Production of jujube mucilage film, whey protein isolate and post-biotic

The film-making solutions were prepared by combining 3% (w/w) whey protein concentrate and 3% (w/w) jujube mucilage (according to Table 1) in 100 mL of distilled water. An aqueous solution containing 5% (w/w) glycerol (based on the weight of the solution) was added as a softener. The prepared suspension was stirred using a magnetic stirrer (model L81, LABINCO, England) at 115 rpm for 30 minutes at a temperature of 70 degrees Celsius and then filtered until large particles were separated. After that, the temperature of the film solutions was decreased to room temperature. Then postbiotics were added to the solution and the solution was homogenized for 25 minutes with a magnetic stirrer. Finally, 45 grams of film solutions were poured on 12 cm plates and dried at 50 degrees Celsius for 24 hours.]12[.

2-5-thickness measurement

The thickness of the produced films was measured using a digital micrometer (model 65 IP, made by Mitutoyo, Japan) at 5 points randomly with an accuracy of 0.01 mm, the average thickness of each film was used in the calculations of mechanical properties and permeability to water vapor [13]. .

6-2- Humidity measurement

To measure the moisture content of the film, first, a film sample measuring 2x2 cm from each film with a certain weight was weighed with a digital scale with an accuracy of 0.001, and then it was placed in a glass plate that had already reached the moisture balance and been weighed. Then it was dried in an oven at 100 degrees Celsius for 24 hours. The samples together with the plate were weighed again after cooling in the desiccator. Finally, the moisture content of the film was obtained from the following equation [14].

$$\textbf{Moisture content} = \frac{M1 - M2}{M1} \times 100$$

Formula 1: M_1The initial weight of the film, M_2 The weight of the sample is after drying.

2-7- Solubility measurement

For this purpose, the film samples were cut to the dimensions of 2x2 cm and placed in an oven with a temperature of 105 degrees Celsius for 24 hours until the sample reaches a constant weight, then the weight of the sample was measured with an accuracy of 0.001 g and as weight The initial dry film was considered. The dried samples were mixed in 50 mL of distilled water at a temperature of 25 degrees Celsius for 6 hours. The solution containing the sample was passed through Whatman No. 1 filter paper and the remaining sample was dried in an oven at a temperature of 105 degrees Celsius until it reached a constant weight and was weighed as the final dry weight. The percentage of solubility of samples in water is obtained from the following equation:

$$WS = \frac{Wi - Wf}{Wi} \times 100$$

Formula 2: W_SThe percentage of solubility in water, W_iWeight of primary dry matter (gram),

2Nutrient Yeast Extract Salt Medium

W_fThe weight of the final dry matter is (grams).]15[.

8-2- Measurement of water vapor permeability (WVP[3])

To measure water vapor permeability, special containers with a diameter of 2 cm and a height of 4.5 cm were used. 3 g of calcium sulfate was placed in each container, then the containers were weighed and placed in a drying machine containing a saturated solution of potassium sulfate (97% RH). were placed The weight of the containers was measured every 4 hours for 2 days. The weight increase curve of the containers is drawn over time and after calculating the linear regression, the slope of the resulting line is calculated, the slope of the corresponding line is divided for the entire surface of the film exposed to the water vapor transfer ratio (WVTR) of each container.[4]) Obtained. Water vapor permeability was obtained by dividing by the vapor pressure difference between the two sides of the film. Due to the presence of calcium sulfate in the container, the vapor pressure inside the container was considered zero. The vapor pressure outside the film was also obtained with the relative humidity coefficient inside the drying device (97%) and the vapor pressure of pure water at a temperature of 25 degrees Celsius.]13[.

$$\mathbf{WVP} = \frac{S \times L}{\Delta P \times A \times 3600}$$

Formula 3: In this regard, water vapor permeability, WVP ($g.mm.m^{-2}.d^{-1}.kPa^{-1}$), S slope (g/h), A level (m^2), L is the thickness (m), PΔ is the slope of partial water vapor pressure on both sides of the film (Pa) and 3600 is a fixed number to convert hours to seconds.

2-9- Measurement of antioxidant activity of films

Antioxidant activity in films produced using DPPH[5] And it was done based on the color removal of methanolic DPPH solution as a reagent. Briefly, 25 mg of film samples were mixed in 4 mL of distilled water and stirred for 2 min. Then the resulting mixture was centrifuged for 15 min at 4000 rpm and 2 mL of the extract extracted from the film was combined with 0.2 mL of DPPH methanolic solution (1 mm) and 2 min was mixed well by a vortex at 3000 rpm and the samples were kept for one hour in It was kept in a dark place and at ambient temperature. Finally, the absorbance of the samples was read at 517 nm with an ultraviolet-visible spectrophotometer. The percentage of DPPH free radical inhibitory activity was calculated with the following equation [16].

$$\textbf{DPPH free radicals scavenging } (\%) = \frac{A_{Control} - A_{Sample}}{A_{Control}} \times 100$$

Formula 4: $A_{Control}$ Absorption of control solution and A_{Sample} Absorption is the sample solution.

2-10- Measuring the antimicrobial effect

First, circular plates with a diameter of 6 cm were prepared from the produced films and sterilized using ultraviolet light for 2 minutes under a microbial hood. Then, the agar disk diffusion method was used to check the antimicrobial property of the film against*Staphylococcus aureus*PTCC 1431 and*Escherichia coli*PTCC 1763 was used. For this purpose, a suspension of 10 CFU/mL[6]1x of the activated bacteria was spread separately on the surface of the Mullerhinton agar culture medium, and then circular films were placed on the plate and incubated for 24 hours at 37 degrees Celsius, and finally the diameters of the halos of non-growth were measured.]17[.

2-11-Measurement of color indicators

A scanner (HP G3110, China) was used to determine the color of film samples according to the method of Ghasemizad et al. (2022). Color parameters of brightness (L), a (yellow-blue) and b (red-green). Was determined. Measurements were done with three repetitions of each film [18].

2-12-Measurement of mechanical properties

To measure the mechanical properties of the optimally produced film, the Bongshin texture measuring device model DBBP-20 made in Korea with a capacity of 20 Kgf and with R.O. (Reverse pressure) 0.3 mv/v was used. For this purpose, samples were cut from each optimal film sample using the dumbbell-shaped mold of

3water vapor permeability
4Water Vapor Transmission Rate
5 2,2-diphenyl-1-picrylhydrazyl

the device and placed in the device to measure its tensile strength.]19[.

$$\frac{\Delta L}{L_0} = \frac{\sqrt{D^2 + L_0^2} - L_0}{L_0}$$

Formula 5: In this regard D displacement of the sample and L_0 L_0The length of the primary film layer is related to the measurement radius.

2-13-Statistical analysis

In the current research, the production of film samples is done according to the table below. All the tests, except the device tests, will be done in three repetitions and a completely random design based on one-way analysis of variance will be used. Minitab version 20 software will be used to perform analysis of variance at the 95% probability level and check the statistical difference between the means.

Table 1 Bioactive composite film samples based on whey protein concentrate

	Sample	WPC (%)	Mucilage (%)	Postbiotics (%)
1	WPC	3	0	0
2	WPC+PBs	3	0	30
3	WPC+MUC	3	3	0
4	WPC+MUC+PBs	3	3	30

1: Whey Protein Concentrate
2: Whey Protein Concentrate film containing *B. coagulans*Postbiotics
3: Whey Protein Concentrate film and jujube Mucilage
4: Whey Protein Concentrate film and jujube Mucilage containing *B. coagulans*Postbiotics

3. Results and Discussion

3-1-thickness of films

The thickness of the films used for food packaging is one of the important parameters because it affects other characteristics of the films. It has been reported that by reducing the thickness of the films used in packaging, the permeability to different gases increases and the mechanical resistance decreases. The thickness of an edible or biodegradable film depends on its production method and drying conditions.]20[. Shape1 The results show the thickness of bioactive films produced. The results show that by adding jujube mucilage to films based on milk protein concentrate, the thickness of the films increases significantly (P<0.05). In general, the thickness of the films depends on the soluble solid materials used in its preparation. Therefore, the reason for this increase in thickness can be due to the increase in dry matter content]21[.

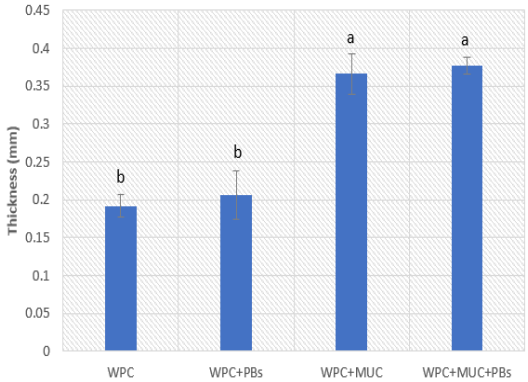

Fig 1 Thickness of produced bioactive films
Different Latin letters indicate significant differences between treatments (p<0.05).

Also, another possible reason for this increase in thickness can be due to the increase in humidity of the films. Because mucilages are hydrophilic in nature and cause swelling in the film structure and cause an increase in thickness. Nisar Et al][22] also obtained similar results, so that the thickness of the produced protein-based films increased with the increase in pectin concentration. Also, the results of the present study with the results of Singh et al]23[also matches. It is worth mentioning that the amount of postbiotics used in the production of bioactive films did not increase significantly in thickness (P<0.05).

3-2- Humidity of films

Moisture content is one of the important features of biodegradable and edible films, because it indicates their effectiveness in protecting food with high water activity or frozen materials.]24[. The humidity level is a characteristic that indicates the space occupied by the moleculeThe type, concentration and hydrophobicity and hydrophilicity indicators of biopolymers and bioactive compounds affect the moisture content of the film, as a result, hydrophilic compounds increase the moisture content of biodegradable and edible films and hydrophobic compounds decrease it.]25[. Figure 2 shows the results of measuring the humidity of the produced bioactive films. The results showed that the addition of postbiotics and jujube mucilage caused a significant increase in the moisture content of the films (P<0.05). The bioactive biocomposite film based on milk protein concentrate containing postbiotics and jujube mucilage had the highest moisture content and the film produced from milk protein concentrate had the lowest moisture content. The reason for the increase in moisture content is due to the presence of hydrophilic compounds such as carbohydrates and proin in jujube mucilage and exopolysaccharides and bacteriocins in postbiotics, which causes swelling in the polymer matrix and thus leads to an increase in moisture. Sani et al]26[Produced a nanocomposite film of potato starch and apple skin pectin containing Shirazi thyme essential oil capsules and zirconium oxide nanoparticles and reported that the addition of essential oil capsules increased the moisture content of the film samples due to the hydrophilic nature of the compounds in the capsule wall. This result with the research that Sani et al]27[did match. He concluded that with a decrease in the percentage of hydrogel in the nanocomposite, the amount of moisture decreased and with an increase in the percentage of hydrogel, the amount of moisture increased. The results of this research are consistent with the results of Karmi Moghadam et al. [28].

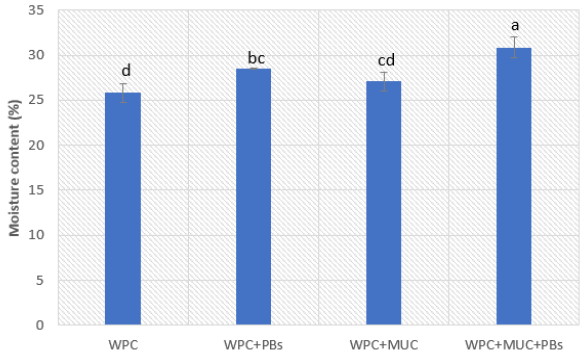

Fig 2 Moisture content of produced bioactive films
Different Latin letters indicate significant differences between treatments (p<0.05).

3-3- Solubility in water of films

Figure 3 shows the solubility of the produced films. As can be seen, the addition of postbiotics and jujube mucilage has caused a significant increase in the solubility of bioactive biocomposite films (P<0.05). The results showed that the bioactive biocomposite film based on milk protein concentrate containing postbiotics and jujube mucilage has the highest solubility and the film produced from milk protein concentrate has the lowest solubility. Addition of hydrophilic compounds increases the solubility of biodegradable and edible films. Sani et al]27reported that the reason for the high solubility of the resulting films in water is due to the hydrophilic nature of the hydrogel macromolecule, which is consistent with the results of this study.

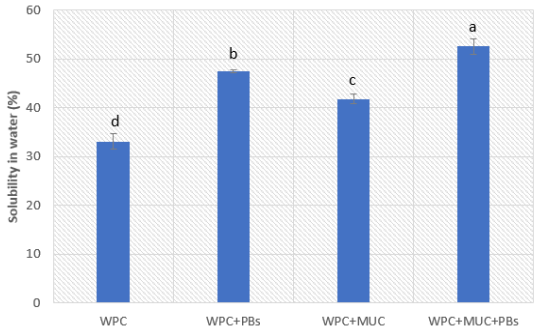

Fig 3 Solubility in water of produced bioactive films
Different Latin letters indicate significant differences between treatments (p<0.05).

3-4-Permeability to water vapor

Water vapor permeability is a simple method of measuring the amount of penetration and passage of moisture into a material. The transfer of water vapor from films depends on the two

factors of solubility and permeability of water molecules in the film matrix]29[. Permeability to water vapor[6](WVP) is one of the important parameters of biodegradable films. The permeability of the film to water vapor is influenced by several factors such as the mobility of polymer chains, the interaction between functional groups of polymers, the integrity of the film structure, the ratio of hydrophilic to hydrophobic groups, and the ratio of crystalline to amorphous regions.]30-33[. Because one of the most important applications of food packaging is to minimize the transfer of moisture between the food and the surrounding atmosphere, therefore the permeability of the packaging material to water vapor should be minimal.]34[. This parameter was investigated in order to investigate the combined effect of glycerol, sorbitol and black seed oil on the barrier properties of the tested film. As seen in Figure 4, the effect of adding postbiotics increases WVP (P<0.05). While the addition of jujube mucilage decreases WVP (P<0.05). These results with the results of Jabraeili et al]35[Correspond. In this study, the permeability to water vapor increased with the increase in the hydrogel concentration, which was attributed to the high presence of hydroxyl groups in the hydrogel, which increases the interaction with water and facilitates the transfer of water vapor in the film structure. Based on studies]36[Higuchi and Aguiar, the permeability of films to water vapor is dependent on the number of polar groups of the polymer, which causes the attraction of water molecules towards the polar groups and thus facilitates the transfer of water. As the proportion of hydrophobic compounds increases, this factor will increase. Casein films are completely soluble in water, while they have a high non-polar amino acid content (35-45% of the total amino acid) and can be prepared at a temperature above 20 degrees Celsius. The presence of the structure, arrangement and composition of casein amino acids, the possibility of creating hydrogen bonds, electrostatic bonds and hydrophobic forces are effective in the formation of edible films made from casein.]37[. Casein films are clear and transparent and show a very high barrier to oxygen; But their permeability to water vapor is high]38[. Generally, due to the high number of hydrophilic groups in the polymer chains of edible carbohydrate and protein films, they have little resistance to water vapor.]39[.

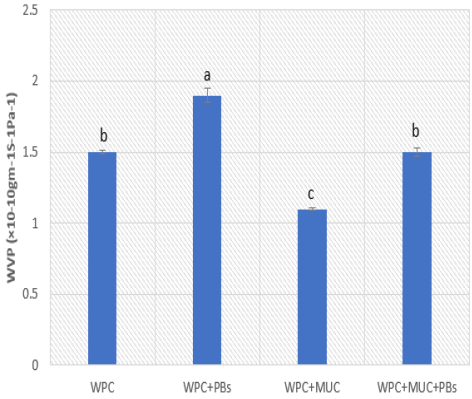

Fig 4 Water vapor permeability of produced bioactive films

Different Latin letters indicate significant differences between treatments (p<0.05).

5-3-Antioxidant activity of films

The antimicrobial effect of biodegradable films is shown in Table 2. The results showed that the addition of postbiotics has an inhibitory effect against bacteria*Staphylococcus aureus*And*Escherichia coli* becomes (P>0.05). The reason for this is the existence of various compounds with antimicrobial properties in postbiotics. Aguilar-Toalá et al]8[He relates the antimicrobial effects of postbiotics due to the presence of metabolites with antibacterial properties such as bacteriocin. Smaoui et al]40[They reported that the postBiotic can multiply aerobic and even facultative anaerobic bacteria such as*Escherichia coli* to delay It is worth mentioning the halo diameter of non-growth of bioactive films containing postbiotics against bacteria*Staphylococcus aureus* And*Escherichia coli* There is no significant difference (P<0.05). Yordshahi et al]7[They stated that the use of postbiotics in the bioactive edible film caused a significant decrease in the bacterial population*Listeria monocytogenes*compared to the witness sample. It is worth mentioning that the addition of jujube mucilage has an inhibitory effect against bacteria*Staphylococcus aureus*And*Escherichia coli* No (P < 0.05).

6. Water vapor permeability

Table 2 The inhibitory effect of produced films on the growth of *S. aureus* and *E. coli*

Samples		Zone of inhibition (mm)	
		E.coli	*S.aureus*
S1	WPC	0.0±0.0	0.0±0.0
S2	WPC+PBs	13.5±0.5^{Ab}	15.6±0.4^{Aa}
S3	WPC+MUC	0.0±0.0	0.0±0.0
S4	WPC+MUC+PBs	13.8±0.5^{Ab}	16.1±0.8^{Aa}

Different Latin letters indicate significant differences between treatments (p<0.05).

6-3- Antioxidant properties of films

Measuring the inhibition of DPPH free radicals is one of the conventional methods for measuring antioxidant activity]41[. Figure 6 shows the amount of antioxidant activity in the produced film samples. The addition of postbiotics and jujube mucilage caused a significant increase in the amount of antioxidant activity of the produced films (P<0.05). The highest amount of antioxidant activity was found in the biocomposite bioactive film of milk protein concentrate containing postbiotics and jujube mucilage, and the milk protein concentrate film had no antioxidant activity. The reason for the increase in antioxidant activity with the addition of postbiotics and jujube mucilage can be attributed to the bioactive compounds present in them. . Amiri et al]42[And]11[reported antioxidant activity for mucilage of marshmallow root and fenugreek seed.

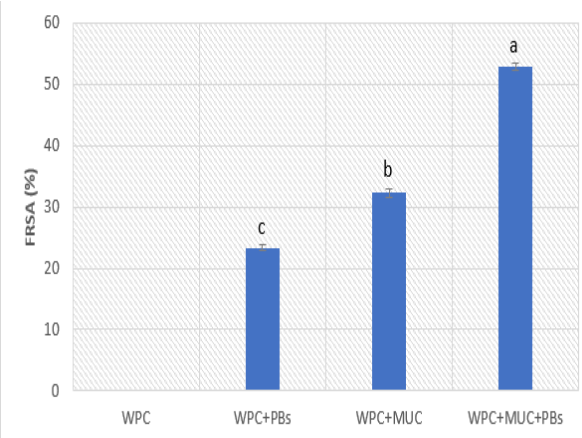

Fig 6 Antioxidant activity of produced bioactive films

Different Latin letters indicate significant differences between treatments (p<0.05).

3-7 Color parameters of films

Color characteristics are one of the important factors of biodegradable and edible films and it depends on the type of compounds used in their production]43[. Figure 7 shows the color parameters L, a and b of the produced films. As can be seen, the addition of postbiotics and jujube mucilage caused a significant decrease in the L index of the produced film samples (P<0.05).

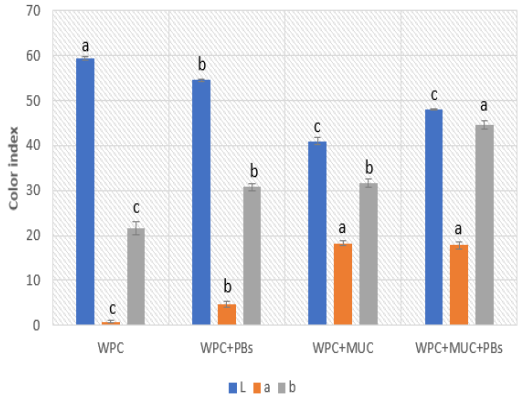

Fig 7 Color parameters of produced bioactive films

Different Latin letters indicate significant differences between treatments (p<0.05).

The results showed that indices a and b increased significantly with the addition of postbiotics and jujube mucilage (P<0.05). The reason for this is due to the dark color of postbiotics and jujube mucilage. Vegetable compounds usually reduce the brightness of the film due to having high intensity colorsare bioactive. Pelissari et al]44[reported the similar results of this research and showed that adding banana flour to the structure of edible films caused an increase in the redness of the produced films. These changes in the color of the bioactive biocomposite films produced are probably due to the presence of high phenolic compounds in jujube mucilage and the color of the culture medium containing postbiotics, which reduced the transparency and increased the yellowness of the films.

3-8 - Mechanical properties of films

The mechanical properties of the films show the resistance of the polymer produced for food

packaging and storage from damages during transportation. The tensile test is one of the most common tests to evaluate the mechanical properties of edible films; Although sometimes other tests such as piercing test are also used. Tensile strength and tensile strength at the breaking point are two important characteristics of packaging materials. In fact, during the tensile test, the final tolerable stress of the film is measured. Examining different mechanical properties of films is important from the point of view of the need of edible polymers to have good strength and elasticity and also to be free from defects such as holes and small fractures. Tensile strength (TS) and elasticity to breaking point (EB) are useful indicators in predicting the ability of edible films to maintain integrity when used as food packaging, which are the key indicators of strength and flexibility of films. In general, the mechanical properties of edible films are influenced by several factors, including interactions

Among the components of the film, there are temperature, physical and chemical conditions]43[. Stretchability up to breaking point is defined as the maximum elongation of the film before tearing, and tensile strength or tensile strength represents the maximum tensile stress that the film can withstand.]45[. Table 3 shows the mechanical properties of the produced films. The results showed that there was no significant difference in the tensile strength of the prepared films (P<0.05). The highest amount of tensile strength was observed for the sample of concentrated film of milk proteins and jujube mucilage, which can be due to the interaction between protein and polysaccharide compounds. The lowest amount of tensile strength was observed in the samples containing postbiotics, because the presence of postbiotics caused structural compaction and decreased tensile strength of the film samples. It has been reported that the addition of antimicrobial compounds to different polymers changes the mechanical properties of the film due to changes in the molecular level.produced from these polymers. These changes are due to the destruction of the film matrix in most cases, the degree of reduction of the film's resistance to stretching. According to the results, the elongation parameters at the breaking point decreased and increased with the addition of jujube mucilage and postbiotics, respectively. Also, Young's modulus increased and decreased with the addition of jujube mucilage and postbotics respectively. In general, with the decrease in tensile strength, the increase in length increases. Similar results by Kavoosi et al]25[has been presented, so that with increasing thymol percentage in gelatin-based films, the tensile strength and Young's modulus of the films decreased. Hosseini Et al]20[showed that with increasing percentage of oregano essential oil in the filmBased on gelatin and chitosan, the tensile strength and Young's modulus of the films decreased.

Table 3 The results of the mechanical properties of the produced films

Samples		Tensile strength (Mpa)	Elongation at break (%)	Elastic modulus (Mpa)
S1	WPC	11.1±0.8^{b}	30.2±5.1^{b}	1.6±0.2^{b}
S2	WPC+PBs	3.9±0.6^{d}	49.5±3.3^{a}	0.9±0.1^{c}
S3	WPC+MUC	70.0±0.1^{a}	16.6±2.4^{c}	2.6±0.2^{a}
S4	WPC+MUC+PBs	6.5±0.2^{c}	46.0±2.5^{a}	1.0±0.2^{c}

Different Latin letters indicate significant differences between treatments (p<0.05).

4 - Conclusion

The results of the present study indicated that it is possible to produce a biocomposite film based on milk protein concentrate with jujube mucilage. Also postbiotics*Bacillus coagulans*As a new antimicrobial compound, it can be used in bioactive films. The results showed that the addition of jujube mucilage to films based on milk protein concentrate significantly increased the thickness of the films, but the addition of

postbiotics to the production of bioactive films did not significantly increase the thickness. The bioactive biocomposite film based on milk protein concentrate containing postbiotics and jujube mucilage had the highest moisture content and the film produced from milk protein concentrate had the lowest moisture content. The addition of postbiotics and jujube mucilage caused a significant increase in the solubility of bioactive biocomposite films. The addition of postbiotics increased the WVP, while the addition of jujube mucilage decreased the WVP. The addition of postbiotics and jujube mucilage caused a significant increase in the amount of antioxidant activity of the produced films. The results showed that the addition of jujube mucilase and postbiotics improved the mechanical properties of the prepared films. In general, this research showed the possibility of using jujube mucilage and postbiotics in the production of bioactive biocomposite.

5- Resources

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مقاله علمی_پژوهشی

تولیدفیلم کامپوزیتی زیست فعال نوین کنسانتره پروتئین‌های آب پنیر و موسیلاژ عناب تقویت شده با پُست بیوتیک های *باسیلوس کوآگولانس* IBRC-M 10807

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چکیده

هدف از این پژوهش تولید فیلم کامپوزیتی زیست فعال نوینبا استفاده از کنسانتره پروتئین آب پنیر و موسیلاژ عناب تقویت شده با پست‌بیوتیک*باسیلوس کوآگولانس* IBRC-M 10807بود. برای این منظور چهار فیلم شامل فیلم کنسانتره پروتئین آب‌پنیر (WPC)، فیلم کنسانتره پروتئین آب‌پنیرحاوی پست‌بیوتیک*باسیلوس کوآگولانس* (WPC+PBs)،فیلم کنسانتره پروتئین آب‌پنیرو موسیلاژ عناب (MUC+WPC) و فیلم کنسانتره پروتئین آب‌پنیرو موسیلاژ عناب حاوی پست‌بیوتیک*باسیلوس کوآگولانس*(MUC+WPC+PBs) هرکدام در سه تکرار تولید و ویژگی‌های فیزیکوشیمیایی، ضدمیکروبی، ضداکسایشی و مکانیکی در قالب طرح کاملا تصادفی و با روش تجزیه و تحلیل واریانس مورد مقایسه قرار گرفت. نتایج نشان داد که افزودن پست‌بیوتیک‌ها و موسیلاژ عناب موجب افزایش معنی‌داری دررطوبت، حلالیت فیلم‌ها شد (P<۰/۰۵). افزودن پست‌بیوتیک‌ها باعث اثر بازدارندگی در برابر باکتری‌های *استافیلوکوکوس اورئوس و اشریشیا کولی* می‌گردد (P<۰/۰۵). افزودن پست‌بیوتیک‌ها و موسیلاژ عناب سبب کاهش معنی‌دار در شاخص L نمونه‌های فیلم‌های تولید شده گردید (P<۰/۰۵). نتایج نشان داد شاخص‌های a وb با افزودن پست‌بیوتیک‌ها و موسیلاژ عناب به طور معنی‌داری افزایش یافت (P<۰/۰۵). نتایج پژوهش حاضر نشان داد که فیلم بیوکامپوزیتی زیست فعال تولید شده پتانسیل استفاده در بسته بندی مواد غذایی را دارد.