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Study of some qualitative and organoleptic properties of enriched apple leather

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ABSTRACT

The purpose of this research was to enrich apple leather with pomegranate seed oil encapsulated with chitosan-soy isolate protein particles and to further investigate the color, texture and organoleptic properties of apple leather. At first, chitosan-soy protein isolate complex particles were prepared and then they were used to stabilize pomegranate seed oil emulsions (20, 30 and 50% oil). The results of the creaming index showed that the 20 % emulsion had the lowest amount of creaming index after 14 days of storage. Next, the droplet size and viscosity of the 20% emulsion were evaluated. The results showed that the size of the emulsion droplets was about 1 µm and the flow behavior of the emulsion was Newtonian. Then, the effect of pomegranate seed oil emulsion (0.2, 0.5 and 1%) on the color, texture and organoleptic properties of apple leather was investigated. The results of the sensory evaluation showed that the apple leather without emulsion had a lighter color compared to the samples with a higher percentage of emulsion. The overall acceptability of apple leather for the control and the sample with 0.2% emulsion was not significantly different, and therefore it can be said that the use of pomegranate seed oil in apple leather in the form of emulsion up to 0.2% is suitable.

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1. Introduction

Pomegranate is one of the oldest edible fruits with a scientific name*Pink garnet* It has a high concentration of polyphenols compared to other fruits**[1].** Pomegranate seed oil (PSO)[1] It is a yellow oil with a mild smell and high nutritional value**[2].** Chemically, ponicic acid, which is the main fatty acid of pomegranate seed oil, contains 66% of cis double bonds and 33% of trans double bonds.**[2].** The concept of encapsulation is relatively new and is widely used in food and drug delivery systems and their stabilization.**[3].** In the encapsulation process, shells or so-called walls form a membrane around the core material and protect it.**[4].** There are different methods for encapsulation, and emulsion is one of these methods. Emulsions consist of two immiscible phases, the dispersed phase consists of spherical droplets distributed in a continuous phase.**[5].** Emulsions of any type, such as: oil in water or water in oil, or even multiple, when they are stabilized by solid particles in the surfactant position, are called Pickering emulsions. Unlike classical emulsifiers, pickering emulsions use solid particles instead of surfactants. Compatibility with the environment and high stability of these particles have attracted the attention of researchers**[6].** In recent decades, the preparation of Pickering emulsion is increasing due to its many uses in the food and pharmaceutical, cosmetic and health industries. In recent years, several researches have been carried out in the field of pickering emulsion, and the ability of pickering emulsion to increase the oxidation stability of emulsions has been investigated.**[7].**

Chitosan, a linear polysaccharide obtained from the deacetylation of chitin, is the second biopolymer after cellulose and the most abundant in nature. It is derived from the exoskeleton of crustaceans, the cuticle of insects, and the cell wall of some fungi. It is a natural biopolymer with a positive charge. Also, chitosan-based particles are good substitutes as Pickering emulsion stabilizers due to their biodegradable and biocompatible properties.**[5].** The complex between chitosan and other polymers is mainly formed by the electrostatic attraction between positively charged chitosan and negatively charged polymers at acidic pH. The complexation of proteins with anionic polysaccharides such as (soybean protein) not only provides spatial stabilization of proteins, but also improves the stabilization of bioactives enclosed in compounds.

Soybean with scientific name*Glycine max* From the legume family and related to clover, chickpea is rich in protein and has a lot of lysine and low methionine, which is recommended to strengthen methionine in breastfed babies.**[8 and 9].**The purest form of soy protein is soy protein isolate, which is produced from the main fraction of soy protein isolate after removing non-protein components. Soy protein isolate is one of the most important commercial proteins, the use of which is a suitable solution for the production of new products due to its favorable performance characteristics in food systems, easy digestion and high nutritional value, and due to its low cost, it is a better alternative to encapsulating materials and due to its surface hydrophobic nature. , is beneficial and a favorable factor in improving the quality of nutrition of consumers**[10].**

One of the largest global trade among garden fruits and cold and temperate regions is apple, apple is a good source of vitamin C, fiber and rich in phenolic compounds such as chlorogenic acid, procyanidin B.[2] And it is quercetin, this fruit has a lot of antioxidant properties and reduces the risk of prostate, liver and lung cancer. From a long time ago, drying and preparation of lavash are among the practical and useful methods in the long-term preservation of agricultural products, especially fruits. Lavashk is a thin sheet or flexible strip made of fruit puree or fruit juice concentrate, and in some cases, it is strengthened by adding thickeners such as starch, gelatin, gum, and cellulose derivatives.**[11].** Javaria et al. (2021) in a research produced nutrient-rich fruit lavash for consumers, and in this study, the mixture of apple and peach fruit lavash was preferred by experts in terms of sensory evaluation of color and taste.**[12].** In a study, Torres et al. (2015) prepared apple juice without adding preservatives, and the results showed that the samples were microbiologically stable for up to 6 months of storage.**[13].** Therefore, according

[1]. Pomegranate seed oil

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to the mentioned materials and also by checking the sources, no research was found regarding the different properties of apple lavash enriched with pomegranate seed oil. Therefore, the purpose of this research is to study some qualitative and sensory properties of apple lavash enriched with pomegranate seed oil coated with chitosan-soy protein isolate emulsion.

2- Materials and methods

The materials used include: chitosan with a deacetylation degree of 75-85% (Sigma Aldrich, USA), soy protein isolate 90% (Shandong Yuwang Ecological Food Industry Company, China), ethanol alcohol 96% (Zakaria Jahrom Company, Iran), acetic acid (Merck company, Germany), pomegranate seed oil from Kamjad Shahroud company and Majen Shahroud apple fruit with Golden Delicious cultivar.[2] Was.

2-1- Tests before preparation of emulsion

2-1-1- Preparation of wall material solution (chitosan-soy protein isolate)

The solution of 0.5% by weight and volume of chitosan and the solution of 0.05% by weight and volume of soy protein isolate with a ratio of 1:10 were prepared separately. First, 0.5 g of chitosan was dissolved in 100 ml of aqueous acetic acid (1% v/v) and the resulting solution was placed in an ultrasonic bath for 20 minutes. Then the prepared chitosan solution was placed on a magnetic stirrer at 500 rpm, and then the soy protein isolate solution was dissolved in 20 ml of 70% alcohol for 5 minutes at 30 degrees Celsius, and then the soy protein isolate was sonicated. The probe was added to the chitosan solution**[5].**

2-1-2- Solvent evaporation with a condenser under vacuum and preparation of Pickering emulsions

The ethanol solvent of the resulting dispersions was removed using a rotary evaporator under vacuum. Evaporation was done until the volume was reduced to half of the initial volume. After evaporation of ethanol, pomegranate seed oil was added with the ratio of 1:10 seed to wall for encapsulation and preparation of emulsion and 0.5% oil emulsion was formed. Then it was stirred with a high speed stirrer at 11000 rpm to form an emulsion for 5 minutes. In the continuation of the initial emulsion, in order to reduce the particles, it was subjected to ultrasonic probe conditions with a power of 65%, which is the treatment T1 (control), T2 (0.2% emulsion), T3 (0.5% emulsion) and T4 (1% emulsion).. The total test time was 5 minutes, 5 seconds on, 5 seconds off.

2-1-3- Scanning electron microscope (SEM)[3]

Morphology and particle size of chitosan-soy protein isolate was investigated using scanning electron microscope images. For this purpose, a drop of freshly diluted sample was poured on the slide and dried and measured by SEM.**[14].**

2-1-4- Determining the size of particles

The size of the emulsion particles was determined using DLS, ZEN 3600 (Dynamic Light Scattering, England). Particle size was determined for both types of emulsions after sonication. The Span index shows the range of the particle size distribution diagram. The narrower the chart, the smaller the Span number. Particle size distribution was calculated using equation (1):

$$\text{Span} = \frac{D(\%90)-D(\%10)}{D(\%50)}\text{Span} = \frac{D(\%90)-D(\%10)}{D(\%50)}$$

where D is the diameter of which the volume of particles smaller than that constitutes 10, 50 and 90% of the total volume of particles in the system, respectively**[15].**

2-2- Tests after emulsion preparation

2-2-1- Calculation of creaminess index

The creaminess index of the prepared Pickering emulsion was evaluated according to the method of Chong et al. (2016). In this way, 10 ml of emulsions containing 20, 30 and 50% pomegranate seed oil were poured into the vial and their lids were tightly closed to prevent their evaporation and stored for 14 days. Creaminess index (in percentage) was calculated using equation (2):

[2] Golden delicious

[3] Scanning electron microscope

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THERE(%) $= \frac{HS}{HE} \times ۱۰۰ = \frac{HS}{HE} \times ۱۰۰$

In this regard, CI: creaminess index in percentage, HE: The total height of the emulsion is in millimeters and HS: the height of the emulsion serum layer is in millimeters. The creaming index provides indirect information about the amount of droplet coagulation in the emulsion and also estimates the stability of the emulsion.**[16].** It should be noted that the best emulsion in terms of creaming index was used for the next parts of the experiment.

2-2-2- Imaging and determining the size of emulsion droplets

In order to determine the size of the emulsion droplets, an optical microscope equipped with a digital camera was used. In this way, a drop of the emulsion was taken with a sampler and a drop of distilled water was poured on the glass slide to dilute the emulsion and spread completely. Then immediately and before the drop dried, the images were recorded with a light microscope with a magnification of 40 equipped with a digital camera. Also, the droplet size of pomegranate seed oil emulsion was measured by DLS method.

2-2-3- Emulsion flow behavior

The flow behavior of pomegranate seed oil emulsion was performed using Rheometer Compact Modular (Physica 302 model of Austria) and (equipped with double coaxial cylinders) at a temperature of 25 degrees Celsius. In this test, viscosity was evaluated at different shear speeds**[17].**

2-3- Preparation of apple juice enriched with pomegranate seed oil

The apple fruit was washed and its cores were removed, it was placed in a bain-marie at 65°C for 3 hours to soften its texture, then we grind it and pass it through a sieve. 120 grams of fruit pulp is added to the prepared emulsion in proportions (0.2, 0.5 and 1%) and it was placed in a thin layer on an aluminum tray that was already covered with cellophane to prevent the fruit pulp from sticking. prevent drying. Drying at a temperature of 60 degrees Celsius for 5 hours with an air speed of 2 m/s and the humidity was reduced to 78.33%.

2-3-1- Color assessment of apple juice

Determining color indices using a colorimeter device (Hunterlab*Colorflex* Model 0.45 A654-1005-60 made in America) was done. Thus, after measuring the color parameters a (redness-greenness index), b (yellowness-blueness index), L (transparency index), using equation (3) total color difference ($\Delta E \Delta E$) was also calculated.

$$\Delta E = \sqrt{(\Delta L)^{۲} + (\Delta a)^{۲} + (\Delta b)^{۲}}$$

$$\Delta E = \sqrt{(\Delta L)^{۲} + (\Delta a)^{۲} + (\Delta b)^{۲}}$$

In this regard $\Delta E \Delta E$: total color difference, $\Delta L \Delta L$: the difference in transparency of each sample compared to the witness, $\Delta a \Delta a$: Redness difference of each sample compared to the control and $\Delta b \Delta b$: The difference in yellowness of each sample is compared to the control**[18].**

2-3-2- Tensile test of apple juice samples

To perform the tensile test from the material testing machine (model STM-20 Sentam Company (made in Iran) was used. In this way, the samples were cut in dimensions of 1x10 cm with a surgical blade and placed between the fixed and movable jaws of the machine. In this experiment, the distance between the jaws was 50 mm, and the loading speed was 10 mm/min. The stress-strain graphs for each sample were stored in the machine's memory, and then the Young's modulus (or the elasticity coefficient as an index of the springiness of the lavash tissue in megapascals), the strain at the breaking point (as an index of elongation at the breaking point (flexibility index) of the tissue) lavash, in mm/mm), tensile stress (as an index of the tensile strength of lavash tissue, in megapascals) and rupture energy (the energy required to rupture lavash tissue, in millijoules) were calculated.**[19].**

2-3-3- Investigating sensory properties of apple juice samples

Sensory evaluation was done using panel test. All evaluations were done by single-taste method and with five-point hedonic scoring considering the characteristics of taste, color and appearance, chewability, dissolution ability in the mouth and general desirability. The evaluation group consisted of 12 food industry experts to examine the samples. In the form of a questionnaire, each person was asked 5 questions and for each question there were 5 options as answers. According to his taste, each person marks one of the very good, good, average, bad and very bad

options, and finally by giving points to each option (very good: 5, good: 4, average: 3, bad: 2) And very bad: 1) The results were analyzed**[20].**

2-4-Statistical analysis

In this research, analysis of variance and comparison of mean data was done using Duncan's test using SPSS software version 22, and then using Excel software version 2019, the results were presented in the form of graphs and tables.

3. Results and Discussion

3-1- particle size of chitosan-soy protein isolate complex

One of the non-destructive physical methods for determining the distribution and size of particles in solutions and emulsions is the use of dynamic light scattering (DLS). In general, DLS measures the intensity of scattered light in the suspension. In order to check the size of complex particles, DLS test was performed, the results of which can be seen in Figure (1). According to Figure (1), there are two peaks for particle size. One of the peaks is below one micrometer and in the range of 150 nm, and the second peak is in the range above one micrometer. The existence of two peaks caused the values of D and Span to be high. The Span index shows the uniformity of the particle and the smaller it is, the more uniform the particle size distribution**[21 and 22].**The presence of the first peak in the range of nanometers shows that the ultrasound waves were able to produce complex particles in the range of nanometers. It should be noted that the laboratory where the particles were prepared and the laboratory related to the particle size measurement were different, and therefore there was a time gap of several hours between the time of particle preparation and particle size measurement. This time interval has caused the particles to coagulate and create larger particles, and the presence of the second peak confirms this result. These results show that chitosan-soy protein isolate complex particles do not have long-term stability and if these particles are produced to stabilize Pickering emulsions, they should be used in the emulsion production process in a short period of time.

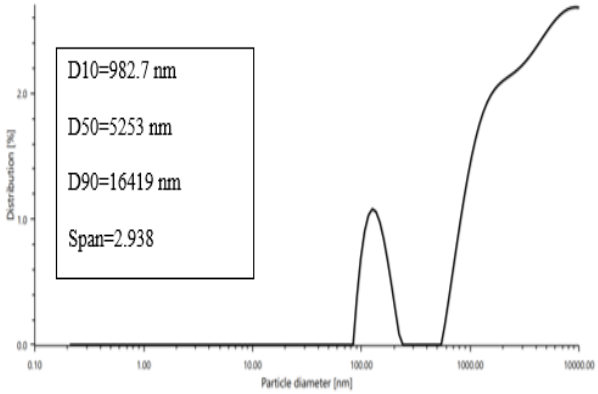

Fig 1 Particle size of chitosan-soy protein isolate

2-3- Examining the morphology of the particles with a scanning electron microscope (SEM)

The results related to the examination of the morphology of the particles of chitozoan-isolate soy protein produced using a scanning electron microscope (SEM) are shown in Figure (2). The images obtained from the scanning electron microscope provide very important information about how the particles interact, the dispersion between the constituents of the particles, the way the particles are placed on the surface of the sample, and the topography of the sample, such as the height, height, and prominence of the sample. According to figure (2), it can be seen that during the drying of the chitosan-soy protein isolate complex particles, the interaction between the particles occurred and larger and more coherent particles were created. This result was in confirmation of the previous section related to the measurement of particles using the DLS method. In the previous section, it was stated that chitosan-soy protein isolate complex particles have a strong tendency to interact with each other and therefore do not have long-term stability, and the results of the SEM test also confirmed the same result.

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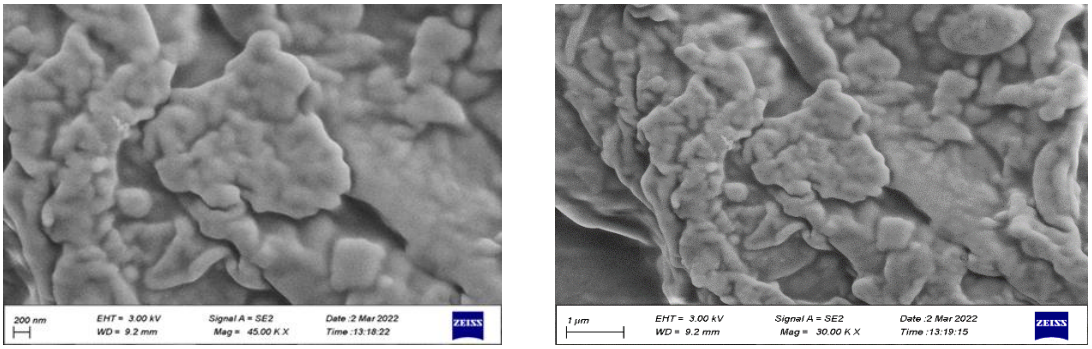

Fig 2 Scanning electron microscope (SEM) Images of chitosan-protein isolate soy particles

3-3- Stability and size of emulsion droplets

In the continuation of this research, chitosan-soy protein isolate complex particles were used to stabilize pomegranate seed oil emulsion in three concentrations of 20, 30 and 50% oil. According to Figure (3), it can be seen that the 20% pomegranate seed oil emulsion had the lowest amount of creaminess after 14 days of storage at room temperature. This result shows that the amount of creaminess has increased with the increase of oil percentage, which is in agreement with the findings of other works. For example, Agziav et al. (2016) found this result in their research, when the amount of oil increased from 0.3 to 0.7 with a fixed concentration of kafirin, the protein particles decreased for the stability of the interface, and with the increase in oil concentration, the The particle size increased gradually**[21].** Also, Shah et al. (2016) investigated the stability of Pickering emulsion by chitosan-tripolyphosphate nanoparticles and concluded that with the increase in the amount of oil, the size of the emulsion particles increased due to the decrease in the number of particles for the stability of the emulsion, and the emulsion became unstable at a high amount of oil.**[22].**

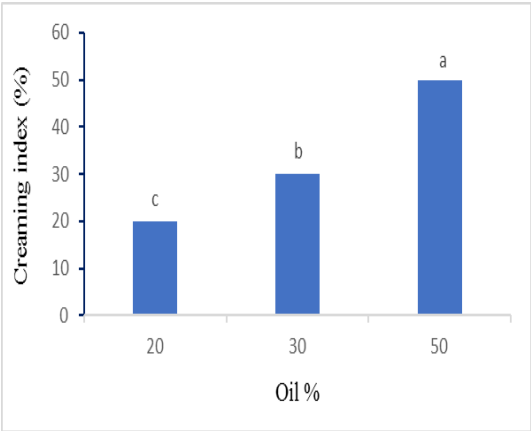

Fig 3 Creaming index of different emulsions stabilized by chitosan-soy protein isolate particles

Due to the greater stability of 20% emulsion, in the continuation of this research, 20% oil emulsion was used to perform subsequent tests, including checking the size of emulsion droplets and checking viscosity. Also, 20% emulsion was used to enrich lavashk formulation with pomegranate seed oil. In the continuation of this investigation, the 20% emulsion was photographed using an optical microscope. Also, to check the emulsion droplet size more precisely, the emulsion droplet size distribution was measured by the DLS method, the results of which are shown in Figure 4. According to Figure 4, it can be seen that D emulsion droplets were about 1 micrometer. Usually, the emulsions used in the food industry have larger droplet sizes. The small droplet size of the emulsion in the present work can be related to the use of ultrasound waves during the preparation of the emulsion. Ultrasound waves at low frequencies can make the emulsion droplets smaller by creating cavitation in the environment.

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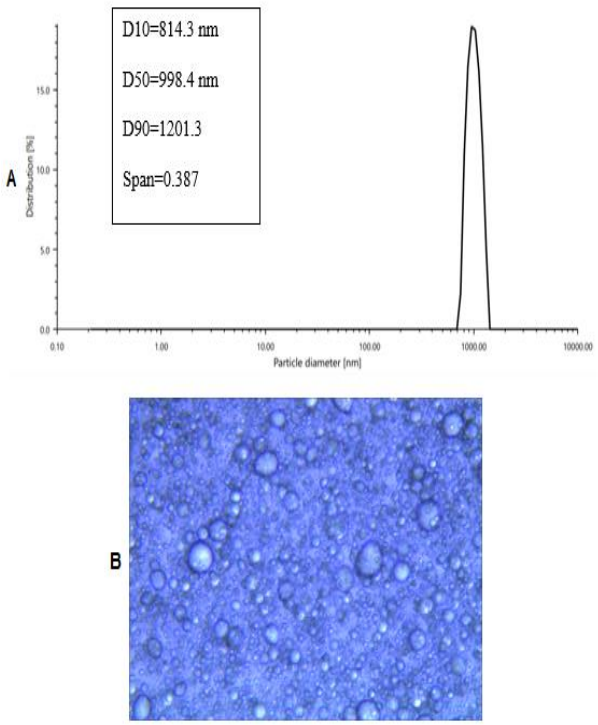

Fig 4 Emulsion droplet size distribution (A) and appearance image (B) of pomegranate seed oil emulsion stabilized by chitosan-soy protein isolate particles

3-4- Flow behavior of pomegranate seed oil emulsion

In this research, the flow behavior of pomegranate seed oil emulsion (20% oil) was determined using a rheometer device, and the result is shown in Figure 5. The results show that the 20% emulsion behaved like a Newtonian fluid in a wide range of shear rates. Newtonian behavior shows that there was no significant interaction between chitosan-soy protein isolate complex particles. In addition, the Newtonian behavior of the emulsion can be related to the presence of abundant water in the continuous phase, which is about 80% of the emulsion environment. Considering the Newtonian behavior of water, it can be concluded that the predominance of water in the emulsion environment, the absence of strong interactions between particles, has led to the predominance of Newtonian behavior.

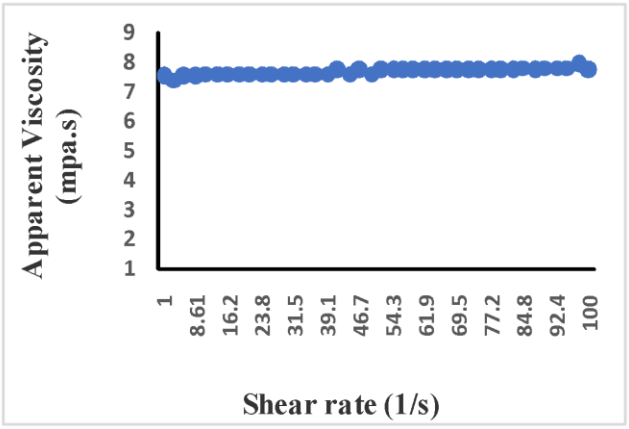

Fig 5 Apparent viscosity versus shear rate of Pickering emulsion (20% oil) stabilized by chitosan-soy protein isolate

3-5- Evaluation of the color of apple juice containing pomegranate seed oil emulsion

The results of the evaluation of the color characteristics of the samples are summarized in Table (1).

Table 1 determination of color evaluation (T1) control, (T2) 0.2% emulsion treatment, (T3) 0.5% emulsion treatment, (T4) 1% emulsion treatment

	a	b	L	ΔE
T1(control)	22.5c	40.5b	36.5b	-
T2 (0.2% emulsion treatment)	20.5d	47.5a	42a	10.48a
T3(0.5% emulsion treatment)	32b	42.5b	31b	10.27ab
T4(1% emulsion treatment)	35.5a	36c	42.5a	9.8b

Values with different letters in same column are significantly different, $p<0.01$.

As it can be seen, all the values of a, b, L and ΔE have a significant difference at the level of 1% compared to the control sample, and except for the total color difference, which has decreased with the increase in the amount of emulsion oil in apple lavash, the rest of the color parameters do not show a clear trend. This can be caused by the simultaneous effect of these three parameters (a, b and L) on the total color difference. Ozan et al. (2021) investigated the qualitative characteristics of apple slices dried by ultrasound and hot air drying methods. The results showed that the a and b values of the samples increased significantly compared to the control in both drying methods. Also, no significant difference was observed in the amount of L of ultrasound-dried treatments compared to fresh apples and ultrasound-drying treatments. But a significant decrease was

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observed in drying treatments in hot air. They also reported that the reason for this difference is due to the occurrence of oxidative reaction during the drying process in hot air**[18].** Sona et al. (2019) reported that the a parameter of the fresh sample increased compared to the vacuum dried samples, while the hot air samples decreased.**[11].** Rouzi et al. (2012), evaluating the quality during the storage of apple juice, which in this study investigated that the browning index did not have a significant difference ($P<0.05$), which is probably due to the high concentration of reducing sugars.**[23].** Gujral et al. (2007) in evaluating the color of mango fruit pulp reported that with increasing hydrocolloid concentration, the amount of redness (a) and yellowness (b) of the samples decreased, but there was no significant difference in the changes in brightness (L).**[24].**

6-3- The results of the sensory evaluation of apple juice samples

Figure (6) shows the graphs of the comparison of the average results of the panel test.

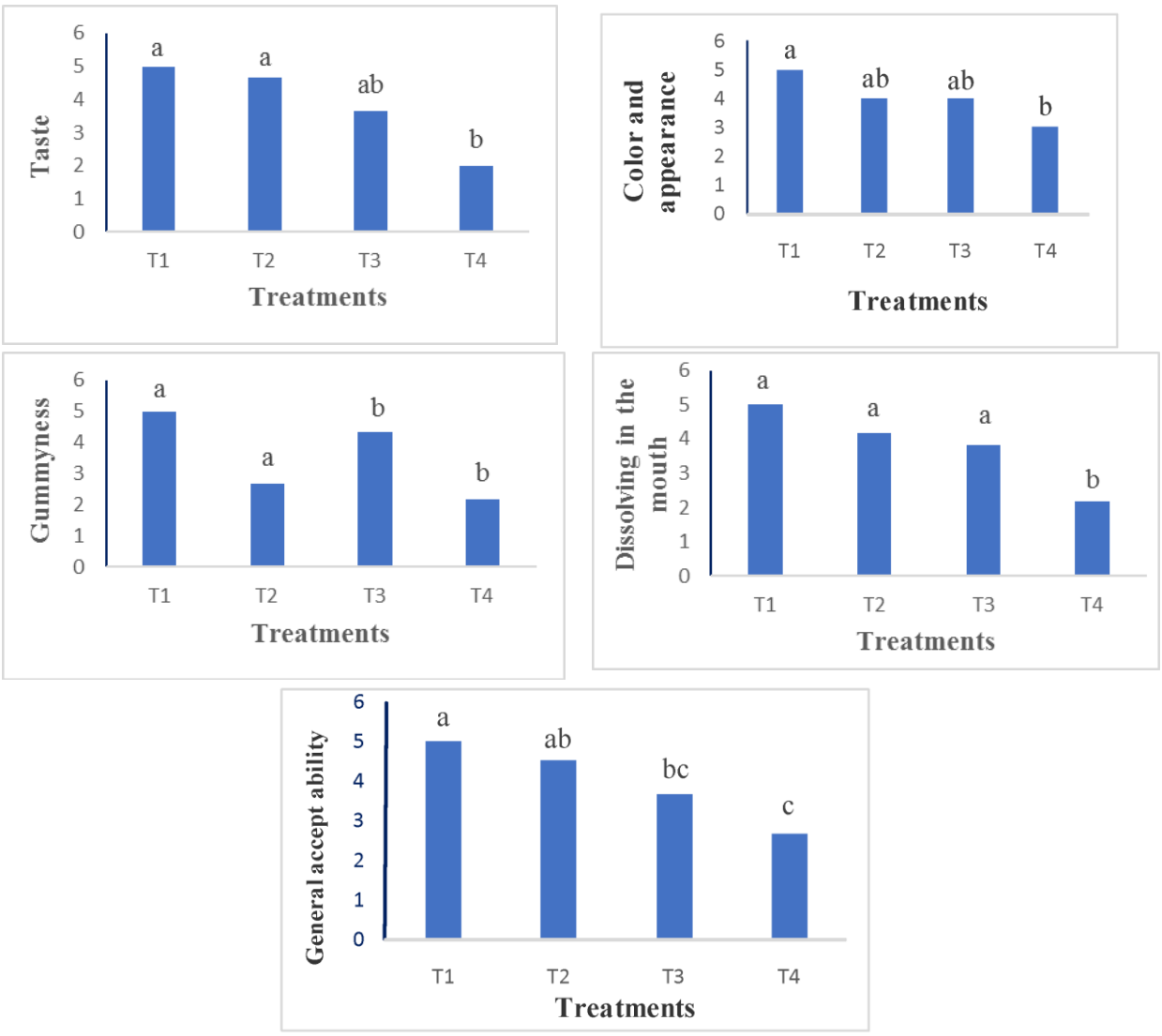

Fig 7 The result of Duncan's test for Panel test of treatments with pomegranate seed oil emulsion in concentrations (0.2%, 0.5%, 1%)

As can be seen, treatment T4, which contains a 1% emulsion of pomegranate seed oil (the highest amount of oil), has obtained the lowest score in terms of taste, color and appearance, chewability, dissolution ability in the mouth, and overall acceptability. . In terms of the mentioned characteristics, food industry experts did not observe any significant difference between the T2

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treatment and the control sample, which is also true for the T3 treatment.

These results are consistent with the understanding of food industry experts in the research of Garsiav et al. (2019).**[20].** Mirzaei Moghadam (2019) also reported that the chewability of pastille samples decreased with increasing oil content.**[25].** Therefore, in general, from the point of view of food industry experts, the T2 treatment did not have a significant difference compared to the other treatments compared to the control sample, and it was as favorable as the control sample.

7-3- The results of tensile test

As can be seen in Figure (7), with the increase of oil percentage in the emulsion, the breaking strain (length increase at the breaking point as an index of flexibility) increased at low concentrations (2T and 3T) and decreased at 1% concentration (4T). which can be caused by the reduction of adhesion between the molecules of lavash tissue due to the increase in the amount of oil. Mirzaei Moghadam (2019) also reported in the research he conducted on pastille enriched with coated fish oil that by adding oil percentage, the amount of adhesion and flexibility of the samples decreased.**[25].**

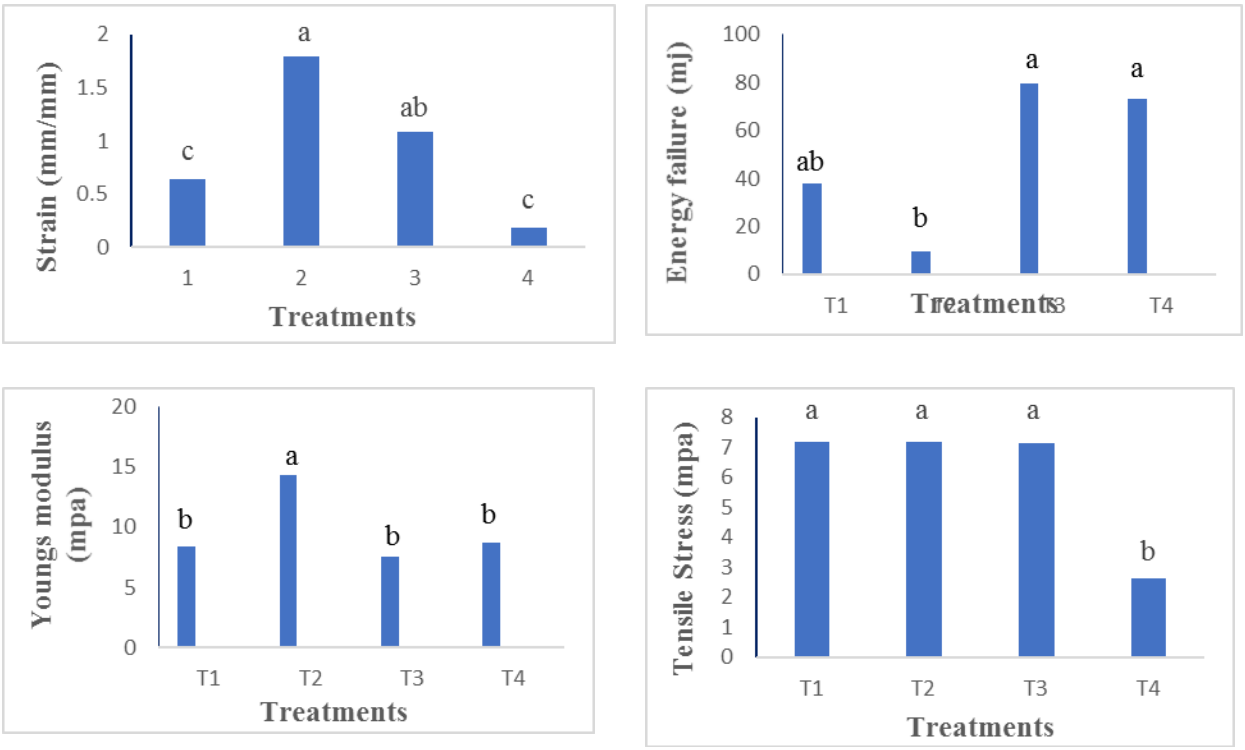

Fig 7 The result of Duncan's test for mechanical properties (tensile test) of treatments with pomegranate seed oil emulsion in concentrations (0.2%, 0.5%, 1%)

The lowest amount of energy required for rupture is related to the 2T treatment, this is if this amount is not significantly different from the control sample, and also the highest Young's modulus (Fenerite index) is returned to the 2T treatment, that is, the Fenrite of this treatment is more than the other treatments. and there is no significant difference between the other treatments compared to the control sample in terms of the amount of pheneritis (elastic property). Mirzaei Moghadam (2019) also reported that adding oil to pastille samples reduced the amount of phenrite**[25].** It is also observed that the lowest tensile stress (tensile strength of lavash tissue) is related to 4T treatment. In other words, this treatment breaks with the least tensile force applied to the lavash, which could be due to the high concentration of oil, and no significant difference is observed between the other treatments compared to the control sample. Valenzuela et al. (2013) in the study of the effect of sunflower oil on the physical properties of chitosan and protein composite film reported that the oil decreased the strength of the films. The researchers attributed the decrease in the strength of the gelatin films, which have

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similar behavior to the liquid, due to the addition of oil, to the heterogeneity of the structure, as well as the negative effect on the adhesion forces of the structure.**[26].** Gujral et al. (2003) investigated the effect of hydrocolloids on the texture of mango pulp and the results of this research showed that by adding hydrocolloids with concentrations (1, 2 and 3%), the amount of rupture energy and Young's modulus of mango pulp samples at all concentrations , Increased**[27].** Therefore, considering that the 2T treatment, which contains an emulsion with a concentration of 0.2% pomegranate seed oil, has the highest elongation (flexibility) and the lowest energy required at the breaking point and the highest amount of phenrite, and also because Its tensile strength was not significantly different from the control sample, it can be introduced as a desirable treatment in terms of tensile test.

4 - Conclusion

The results showed that the emulsion with lower oil percentage (20%) had more physical stability. Also, the use of ultrasonic waves in the emulsion production process was able to reduce the size of the emulsion droplets to the range of 1 micrometer. In the sensory evaluation of Lavashk samples, T2 treatment was more favorable than the other treatments compared to the control sample from the point of view of food industry experts and there was no significant difference with the control sample. In the examination of mechanical properties, the 2T treatment, which contains emulsion with 0.2% pomegranate seed oil, had the highest degree of flexibility, the lowest energy required in breaking, and the highest phenrite, and in terms of its tensile strength, there was a significant difference compared to the control sample. was not observed. Therefore, 2T treatment can be introduced as a desirable treatment.

5- Resources

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مطالعه برخی خواص کیفی و حسی لواشک سیب غنی شده

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چکیده

هدف از این پژوهش غنی سازی لواشک سیب با روغن هسته انار درونپوشانی شده با ذرات کیتوزان-ایزوله پروتئین سویا و در ادامه بررسی خواص کیفی رنگ، بافت و حسی لواشک های سیب بود. در ابتدا ذرات کمپلکس کیتوزان-ایزوله پروتئین سویا تهیه شدند و سپس برای پایدارسازی امولسیون های روغن هسته انار (۲۰، ۳۰ و ۵۰ درصد روغن) استفاده شدند. نتایج ضریب خامه ای شدن نشان داد که امولسیون ۲۰ درصد کمترین میزان خامه‌ای شدن را پس از ۱۴ روز نگهداری داشت. در ادامه، اندازه قطرات و ویسکوزیته امولسیون ۲۰ درصد ارزیابی شد. نتایج نشان داد که اندازه قطرات امولسیون در حد ۱ میکرومتر و رفتار جریان امولسیون نیوتنی بود. سپس اثر امولسیون روغن هسته انار (با غلظت‌های ۰/۲، ۰/۵ و۱ درصد) بر خواص رنگ، بافت و ارزیابی حسی لواشک سیب بررسی شد. نتایج ارزیابی حسی نشان داد که لواشک سیب بدون امولسیون در مقایسه با نمونه‌های که دارای درصد امولسیون بیشتر بودند رنگ روشن‌تری داشت. مقبولیت کلی لواشک ها برای نمونه شاهد و۰/۲ درصد امولسیون تفاوت معنی داری نداشت و بنابراین می توان بیان کرد که استفاده از روغن هسته انار در لواشک سیب به شکل امولسیون تا حد ۰/۲ درصد مناسب است.