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Scientific Research

Investigating the Functional properties of encapsulated phenolic compounds of Iranian pomegranate peel

Zahra Borjizadeh[1], Mohammad Goli[2*]

1- MSC graduated, Department of Food Science and Technology, Isfahan branch (Khorasgan), Islamic Azad University, Isfahan, Iran.

2- Professor, Department of Food Science and Technology, Laser and Biophotonics in Biotechnologies Research Center, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran

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*Corresponding Author E-Mgolifood@yahoo.com

ABSTRACT

Today, food is considered as a source of nutrition. Foods are known as health-giving substances for consumers due to their natural bioactive substances. Phenolic compounds that are found in the peel of pomegranate fruit are among the bioactive compounds. These materials can be used by nanocarriers to enrich food. The purpose of this study is to investigate the phenolic compounds present in five cultivar of Iranian pomegranate peels using the nano method and to further investigate the chemical properties of pomegranate peel extract, including antioxidant, extract extraction efficiency and phenolic properties. This investigation was done by standard curve of gallic acid according to folin-ciocalteu method. Also, the characteristics of the resulting encapsulation were investigated using particle size analysis and zeta potential. The purpose of their comparison is to achieve the highest efficiency among five pomegranate cultivars. The results of the study showed that the peels of the collected pomegranates have significant differences (at the probability level of one percent $p<0.05$) in terms of physicochemical properties. Examining the results obtained from the physicochemical properties of pomegranate peel extract indicated that white peel pomegranate (Grech Shahwar) had the highest amount of phenolic compounds (78.00±6.72 mg equivalent to gallic acid per 100 grams). It also had the highest antioxidant property of 42%. According to the results obtained from this research, it can be said that the capsules containing pomegranate peel extract (white skin type of Gherch Shahwar) have the best encapsulation efficiency (71%). The use of nanocarriers containing this cultivar of pomegranate in food can have a significant effect on the preservation and stability of compounds sensitive to environmental changes.

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1. Introduction

Pomegranate, Nar or Edible Pomegranate with scientific name (*Ponica grantum*)[1] [1] It is one of the fruits of a tree that has seeds that are often red and sometimes white or colors between the two. Its skin color is often red and sometimes black or almost yellow. Pomegranate tree is cultivated in tropical and subtropical regions and in different countries such as Iran, Egypt, India, Turkey, California, Italy, Spain and China. In the processing of pomegranate fruit, a large part of the factory waste, which varies from 30 to 60% depending on the variety, is the skin of the fruit. [2] In fact, pomegranate skin is one of the most important by-products of pomegranate juice factories, and it has received much attention in the last few years due to the proof of the presence of many polyphenolic and medicinal compounds and the health-giving properties of its extract. Many researches have proved the existence of phenolic compounds such as punicalgin and elagitannins derivatives in pomegranate peel and investigated the antioxidant properties of pomegranate peel extract. [4،3]، Also, the identification and evaluation of medicinal and nutritional compounds of pomegranate peel extract of 10 Iranian varieties by Rezaei Payandeh et al. (2014) and the studies of Rouhani et al.DPPH in the flag of saffron flower by ultrasound method]6،5[, clarifies the importance of studying these compounds. Determining the antioxidant capacity of pomegranate compounds and their derivatives by researchers and experts in the food and agricultural industries for their use in the food industry as natural additives instead of synthetic antioxidants (which are significantly limited due to adverse side effects) has been given more attention. For this reason, special attention has been paid to the antioxidant activity of pomegranate compounds in many studies, including the extraction of anthocyanin and the yield of pomegranate extract to measure the antioxidant activity by Mahdian et al. (2013).]7[All these activities are related to the phenolic compounds in pomegranate. The compounds in pomegranate are known for their antioxidant properties due to their scavenging properties of free radicals and stopping the oxidation of fats in laboratory conditions. Micro-coating means placing particles or components in the walls or small bags in sub-micron size, which is the same as nano size.]8[Encapsulation in food technology to cover flavor and taste, ensuring access to the bioactive compound at a certain rate at a certain time, compatibility with other compounds in a system, control of the actions of bioactive components with the food matrix, protection of bioactive compounds in It is used against biological or chemical decomposition during processing, storage, consumption, heat, humidity, as well as controlling the release of bioactive compounds.]9[. With the help of encapsulation, bioactive substances are enclosed in food and food enrichment is done. As in the study of Seyyed Hajizadeh et al. (1400), the effect of rosemary essential oil coating on preserving the quality and antioxidant activity of apricot fruit.]10[. Bojemehrani et al. (1401) found that the oxidative stability of soybean oil can be increased by using nanoliposome containing grape pomace antioxidant compounds.]11[. Due to its antioxidant properties, olive leaf was microcoated to reduce the oxidation of soybean oil by Mohammadi et al. (2015).]12[. Encapsulation of musk essential oil was done in order to preserve its effective compounds]13[. Due to the sensitivity of phenolic compounds and antioxidants to environmental conditions, today the inner cover has gained special importance, the purpose of this research is to investigate and compare the antioxidant activity between five varieties of Iranian pomegranate varieties to achieve the best and highest levels

1- Punica granatum

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Antioxidant activity and phenolic compounds, as well as the highest covering power among these varieties.

2- Materials and methods:

2-1- Materials

Pomegranate samples, which include five varieties of Iranian varieties (Gerch Shahwar - Red Skin Ramhormoz - Tehran - Black Skin Yazd - Red Skin Bafghi) were purchased from Yazd Research Center. After washing and peeling, the pomegranate is dried in the shade at ambient temperature and then milled (Molinex-684-French) Powdered, pomegranate peel powder was kept at 4 degrees Celsius for one day until use. Ethyl alcohol 96% by volume (Sepahan Bio-Products Company - Iran), distilled water and other ingredients such as Span 60 (sorbitan monostearate), Tween 80 (polyoxyethylene sorbitan or polysorbate), sodium carbonate 7.5%, Folin reagent 10%, methanol Chloroform was purchased from Merck and Sigma-Aldrich, Germany.

2-2- Methods

2-2-1- Pomegranate peel extract

5 grams of the sample was mixed with 50 ml of 96% ethanol by volume in a closed sampling container. Then the sample was placed in a shaker incubator (108 liters - Kiagen Teb Sadra - Iran) for 24 hours at a temperature of 25 degrees Celsius. According to Rahmon et al.'s studies (2015), 96% ethanol has the highest extraction rate at 25 degrees Celsius for 24 hours.]14[. The resulting solution was filtered with Whatman No. 1 filter paper in two steps. After filtration, the solution was transferred to a rotary device under vacuum (IKA-Rontgen-Germany) They were transferred with a speed of 110 rpm and a temperature of 38 degrees Celsius and concentrated to one fifth of the initial volume. The extracts were kept at -18°C until use[15].

2-2-2- Evaluation of extract extraction efficiency

To check the extraction efficiency, the weight of the dried extract is needed. For this purpose, 5 ml of the concentrated extract was transferred to a pre-weighed Petri dish and placed in an oven (50 liters - Behdad - Iran) at a temperature of 40 degrees Celsius for three The clock was set, and after that, the sample was weighed with a scale at a time interval of 15 minutes to 15 minutes (TE 15025- Sartorius- America) It was weighed until it reached a constant weight, the resulting constant weight for each sample was subtracted from the Petri weight until the weight of the dry extract was obtained. The amount of powder obtained from the skin of the sample, which was used to extract the extract, was entered into the formula for calculating the extraction efficiency. According to the above parameters, the extraction efficiency of the extract was obtained.

$$Efficiency\ extraction = \frac{dried\ extract\ weight}{Primary\ dry\ skin\ weight} \times 100$$

2-2-3- Measurement of total polyphenol compounds

Amount of total phenolic compounds based on Folin's method – Ciocultivation was measured as described by Esfehalan et al. (2009). The amount of polyphenolic compounds was reported using the gallic acid standard curve drawn in terms of milligrams of gallic acid per 100 grams of extract.]17،16[.

2-2-4- Measurement of free radical inhibition power DPPH

In order to measure the anti-radical power of the extract in absorbing free radicals DPPH (2 and 2-diphenyl-1-picrylhydrazine) method of Yim et al. (2013) was used. After 30 minutes of dark housing at room temperature of the laboratory, the optical absorption of the samples at a wavelength of 517 nm was read by a spectrophotometer (Photonics-Spectrosanj-Iran) in front of a control. The antioxidant activity of the extracts was reported according to the following formula based on the inhibition percentage [18,19].

$$Percent\ inhibition = \frac{Absorption\ control - absorption\ sample}{Watch\ Attraction} \times 100$$

2-2-5- Production of nano niosomes containing pomegranate peel extract

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Nanoniosomes were produced using the combined method of thin layer hydration and sonication, so that first, 1 gram of Tween 80, 1 gram of Span 60, and 0.1 ml of pomegranate peel extract were weighed and homogenized on a shaker for 15 minutes, then 20 ml of isopropyl alcohol was added to the sample as a solvent and mixed on a shaker for 30 minutes. To remove the solvent, the sample was placed under vacuum in the evaporator and finally a thin layer of the sample was created on the balloon wall. In this step, which is known as thin layer hydration, a thin layer attached to the balloon wall was dissolved little by little by 40 ml of distilled water at 40 degrees Celsius. The resulting sample was placed in a refrigerator to reduce the temperature to 4 degrees Celsius. In the next step, a sonicator with a probe (power 400 watts and 20 Hz - ultrasonic technology - Iran) was used to obtain the size of the particles in the nano scale. It should be noted that sonication was performed along with applying an ice bath to control and maintain the temperature below the phase transition point [20].

Measurement of average particle diameter and particle size:

To measure particle size distribution and average particle diameter from the device DLS (Japan-Horiba-SZ100) used. For this purpose, the amount of one milliliter of the micro-coated sample, in the previous steps, was diluted with some distilled water in the capillary tube of the device and was evaluated by the sensors of the device, so that three repetitions were considered for each sample and each Repetition was also analyzed twice and the results were presented as a graph [21].

for the parameter particle size distribution PDI they report The basis of this device is based on dynamic light scattering. The samples were diluted in different concentrations within the detection range of the device. For dilution, the solution used in the sample, which is distilled water, was used. Finally, the droplet size is based on the average equivalent volume ($D_{4,3}$) or the average volumetric diameter was calculated and reported by the device.

$$D[4,3] = \frac{\sum_1^n (D_i . v_i)^4}{\sum_1^n (D_i . v_i)^3}$$

One of the important factors in determining the stability of colloidal nanoparticles is the size distribution of the particles in the system. The smaller the particle size in the system, the more stable the system will be.

Zeta potential measurement:

This parameter determines the electrostatic charge on the surface of nanoemulsion droplets [22، 23، 24]. In scientific terms, it is electrokinetic potential in colloidal systems [24].It is the simplest and most obvious method to measure the stability of nanoemulsion and it is easily concluded by evaluating the data related to concentration, distribution and absorption.]25[. To measure this parameter from the device DLS It was used as mentioned in the previous paragraph. So that each of the samples were diluted 1:20 with the solution used in the sample itself, which is distilled water. Then the samples were transferred through a syringe into the capillary tube and their zeta potential was measured. Three replicates were considered for each sample and each replicate was analyzed twice [21].

Measuring the efficiency of the overlay:

500 microliters of the sample was mixed in 3.5 milliliters of ethanol and centrifuged at 2000 rpm for two minutes in a microfalcon.(K3-30-Sigma-America) became The free part of the sample was placed on the top of the container and the encapsulated part was placed on the bottom of the container. The upper part was separated and its absorbance was read at the maximum wavelength of 760 nm. For the microcoated part, 2 ml of it was mixed with 2 ml of chloroform, it was placed on a shaker for 5 minutes to destroy the produced nanocarrier, then its absorbance was read at 760 nm

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(maximum wavelength). [26]. Then calculate the concentration of each of them.

To calculate the efficiency of the overlay (EE%) The following formula is used:

$$Coverage\ within\ efficiency\ percentage = \frac{Amount\ of\ capsule\ extract}{Capsule\ extract\ quantity + free\ extract\ quantity} \times 100$$

statistic analysis

The statistical analysis of the test data was done in three repetitions in the form of a completely randomized design. Data analysis and evaluation was done using Duncan's multiple range comparison test at the 95% probability level ($P<0.05$) to confirm the existence of differences between the data. Also, the data was analyzed by SPSS statistical software (Version 19.0 for Windows, SPSS Inc.) Was investigated. Data were reported as mean deviation and standard deviation.

3- Discussion and conclusion

Extraction efficiency:

According to the results reported in Table 1, the efficiency of extract extraction is the highest in Bafghi red skin pomegranate and the lowest in Tehran pomegranate. Meanwhile, there is no significant difference with pomegranates: Garchshehwar white skin, Ramhormezpoost Siah Yazd red skin pomegranates. In the investigations conducted by Rahmon et al. (2015), on the physicochemical properties of the extract, using a 96% alcohol solution for 24 hours at a temperature of 25°C, they achieved an extraction efficiency of over 20%.]14[. The extraction efficiency of phenolic compounds with 96% ethanol was reported by Yasobi et al. [27]. Also, extraction of the peel extract of three varieties of pomegranate by four solvents (ethanol, ethyl acetate, acetone, and an equal mixture of four solvents) in three repetitions, the highest extraction efficiency is related to the ethanol solvent of 96% with the extraction efficiency of 77/. ± 18/55 has the highest extraction efficiency and the reason is related to the polarity and composition of the solvent, among which ethanol is the most polar solvent. [2], Rahmon et al. also achieved the highest extraction efficiency at 25 degrees Celsius, which is consistent with the results of this research. [14]. Research has shown that the speed and efficiency of alcohol extraction increases due to the destruction of the cell wall and the increase in the availability of soluble substances. [28]. The amount of differences in the extraction efficiency between different varieties of pomegranate as stated by Miguel et al.]29[.

Total phenolic compounds:

In Table 1, according to the presented results, the highest amount of total phenolic compounds was found in the white skin pomegranate of Gerach Shahwar, while there is no significant difference with the black skin pomegranate of Yazd, and the lowest amount of total phenolic compounds is related to the red skin pomegranate of Bafghi, so In the research of Tehranifar et al. (2009) they also presented similar results regarding the observation of the highest amount of total phenolic compounds in white-skinned molasses and the lowest amount in the sour pomegranate of Shahwar Kashmer.] 30[. After the experiments, it was found that this extract contains high amounts of phenolic compounds. Rahmon et al. (2015) obtained the highest amount of phenolic compounds from extraction at 25 degrees Celsius and in 24 hours. [14]. Wijnegaard et al. (2013) stated that ethanol increases the rate of extraction of bioactive compounds, including phenolic compounds, due to the destruction of the cell wall. [28]. The amount of total phenolic compounds in the extracted extract was obtained based on the absorption values resulting from the reaction of the extract with Folin's reagent and based on its comparison with the standard curve in terms of milligrams of gallic acid per 100 grams of extract.] 17[. In the research of Tehranifar et al. (2009) on twenty pomegranate cultivars, since all the twenty pomegranate cultivars used in this research were cultivated in the same place and with the same agricultural methods, the difference in phenolic compounds showed that genetic diversity leads to changes in the biosynthesis of metabolites. Phenol has been

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secondary in them, which corresponds to the differences in the amount of phenolic compounds in the skin of five pomegranate cultivars in this study [30].

Antioxidant activity:

Examining the results of Table 1 shows that the highest antioxidant property is related to the white-skinned pomegranates of Garch Shahwar, while the black-skinned pomegranates of Yazd, red-skinned Bafghi, Ken-Tehran and red-skinned Ramhormoz are at the same level and there is a significant difference. do not have The results obtained from this research are consistent with the findings of Tehrani Fard et al. (2009) regarding the highest and lowest antioxidant activity that was observed in the white-skinned and sour cashmere melass, respectively. Among all the available methods to determine the antioxidant properties of the radical scavenging test DPPH It is done because of the convenience and speed of the test compared to others]30[. Gilmi et al. (2009) found that the antioxidant activity of pomegranate extract is 3 times higher than that of red wine or green tea, and it is 2, 6, and 8 times higher than the antioxidant activities identified in grape juice, grapefruit, and orange, respectively. [31]. The differences in the amount of antioxidant properties of the skin of different pomegranates are due to the differences in the varieties of pomegranates, so that investigating the effect of the type of pomegranate variety cultivated in Iran, Georgia, Turkey and Israel on the antioxidant activity has also been the goal of some researchers. [32، 33، 34]. Brochauneori et al. (2008) investigated the importance of harvesting time and its effect on the amount of phenolic compounds and their antioxidant activity. [34]. Miguel et al.'s research (2003) on different samples of pomegranates harvested from different gardens showed a strong difference in polyphenolic compounds. The findings of this research are based on the fact that phenolic compounds may be responsible for the important antioxidant activity of pomegranate samples that change significantly from one garden to another, the reason for the slight differences in the amount of antioxidant compounds in the samples of the present study is also for this reason. [29]. The antioxidant property (removal of free radicals) of the fruit skin is the same as compared to other parts of the fruit such as petals, stamens, and nettles, but this property is less in the leaves. [35]. Lee et al.'s experiments (2008) indicated a very strong antioxidant activity of pomegranate peels due to the large amount of polyphenols in them compared to seeds and fruit juice. [36].

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Table 1 Physicochemical properties of peel extract of five pomegraranate cultivar

Treatment	Total phenolic compounds (mg GAE/100g Peel extract)	Extract efficiency (%)	Antioxidant properties (RSA)
Yazd black peel pomegranate	72.34 ± 8.82^{ab}	24.67 ± 6.50^{ab}	10.95 ± 4.38^{b}
Bafghi read peel pomegranate	34.19 ± 5.00^{d}	30.67 ± 0.50^{a}	19.03 ± 2.76^{b}
Kan Tehran pomegranate	61.33 ± 3.34^{bc}	23.00 ± 1.00^{b}	11.09 ± 4.06^{b}
Ramhormoz read peel pomegranate	51.00 ± 9.00^{c}	27.00 ± 5.00^{ab}	15.90 ± 0.65^{b}
Garcheshahvar white peel pomegranate	78.00 ± 6.72^{a}	30.00 ± 0.00^{ab}	42.30 ± 8.11^{a}

Determining the encapsulation efficiency of nanoniosomes:

According to the results reported in Table 2, the highest percentage of efficiency is related to Ramhormoz red skin pomegranate, while there is no significant difference with Garchshawar white skin sample. The lowest percentage of microcovering without significant difference is related to the samples of black skin of Yazd, Ken Tehran and red skin of Bafghi. In the conducted research, the microcoating efficiency of the treatments was over 50%, which shows the proper performance of the bioactive substances and surfactants used and the control of the test conditions. Pando et al. (2014), in their research, concluded that for nisomes prepared with SPEN 60, the values of encapsulation efficiency between 16.8٪ and 5/72٪, with an average amount 42٪ It is consistent with the results of this research]37[. Most of the researchers including Lee et al. pH, temperature conditions, chemical structure of bioactive substances (lipophilicity or hydrophilicity of the active substance and its tendency to interact with. The two-layer structure of the membrane), the constituents of the layers of nisome vesicles, the size of the particles, the rate and speed of stirring, etc. The degree of encapsulation of most bioactive compounds in niosomes is probably due to the greater solubility of bioactive substances in stabilizers. Because these materials, in addition to the role of stabilization, also have the role of solvent, so that the solubility of quercein in Tween is 0.38, 80. ± They reported 4.7 mg/ml [36]. Span 60 has the

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highest phase transition temperature among the surfactants used in the preparation of these niosomes (the phase transition temperature of Span 60 is 53 degrees Celsius). A higher phase transition temperature increases the encapsulation efficiency, while a low phase transition temperature decreases the encapsulation efficiency percentage of that nisome. [38، 39]. The difference in the percentage of encapsulation in different treatments can be related to the method of determining the percentage of microencapsulation because the method of determining the amount of microencapsulated material is also effective on the encapsulation percentage.]40[.

Zeta Potential:

According to Table 2, the highest value of potential in nano niosomes is related to Yazd black skin and Ramhormez red skin samples, which have no significant difference with each other. Zeta potential shows the total charge of the particle in a liquid environment, which is the best indicator to determine the surface electric state of emulsions. Charged niosomes have the most stability against aggregation and aggregation, compared to uncharged niosomes. The reason for the lower zeta potential is the lower electrostatic force [41]. The acceptable limit of the zeta potential (30 mV±) which indicates the stability of nanoemulsion]42[. The zeta potential of nanoemulsion is influenced by several factors such as surfactant, ionic strength, morphology, cosurfactant and system pH.]22[. Choosing the right emulsifier contributes to changing the zeta potential, such as anionic surfactants such as Span 60, which introduce a negative zeta potential.]43[. The absolute value of the negative value obtained from the samples must be within the mentioned range in order to achieve the most appropriate stability. As in Murty et al.'s research (2013), the zeta potential of black pepper and curcumin was found to be -29.7, which is consistent with the values obtained from this research. [44].

Particle size:

The size of the particles for all the samples are statistically at the same level and at their lowest value and there is no significant difference. The smaller the particle size, the greater the bioavailability of Nisome. Smaller particle size causes greater solubility of food in the aqueous medium. The amount of particle size dispersion plays an important role in the properties of colloidal systems. The lower this parameter is, the more uniform the samples are. Since the size of nisome particles and their distribution (dispersion index) in colloidal systems is an important parameter that affects the characteristics of vesicles, including their encapsulation efficiency and stability. [45]. Kim et al. (2013) stability of lycopene nanoemulsion using technique DLS Check out. The reduced degradation of lycopene with the presence of the liquid phase also has a direct effect on the properties of the particle as well as its stability. The average droplet size was less than 100 nm compared to the nanoemulsion with an average droplet size of more than 100 nm.]46 [. In a recent study by Algotani et al. (2019), DLS was successfully used to determine the characterization parameters of nanoemulsion for curcumin formulation.]47.[They showed a direct relationship between the oil phase concentration and the average droplet size of the nanoemulsion. In 18% of the oil concentration, the average droplet size was 10 nm, while in 24% it increased to more than 50 nm.]47[. In addition, when the oil concentration was reduced to half of the initial concentration, the average droplet size decreased to less than 50 nm]47[. Similarly, Maher et al. (2016) evaluated the stabilized beta-casein nanoemulsion. They reported a direct relationship between protein content and average nanoemulsion droplet size. It was shown that when the amount of protein increased up to 7.5% w/w beta casein, the average particle size increased from 187 nm to 199 nm, however, further increase in beta casein up to 10% w/w resulted in a decrease

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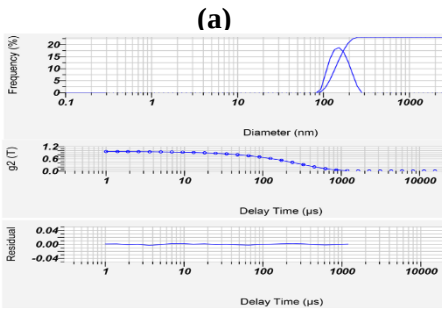
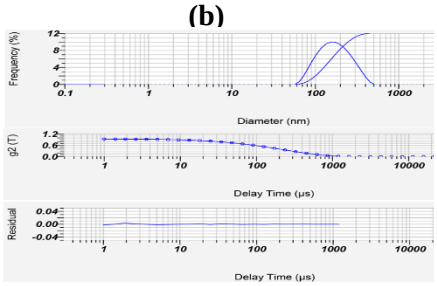
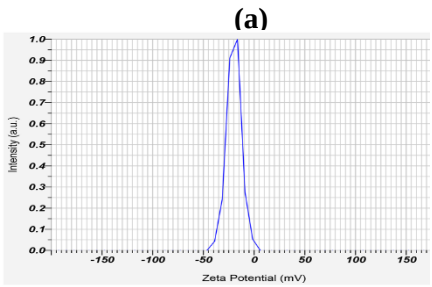
in size. becomes a particle (nm 193). It is suggested that the increase in average particle size due to self-sustaining field theory (SCF) which forms layers in protein around oil droplets]48[. Likewise, Cheong et al. (2017) reported that relatively increased oral bioavailability of hemp seed oil nanoemulsion with small nano size droplets was observed.]49[. Rahmon and colleagues found that reducing the size of the particles to the nanometer scale increases desirable characteristics such as increasing the surface-to-volume ratio, stability, transparency, and encapsulation efficiency of the system, as well as reducing PH It increases the size of the particles [14].

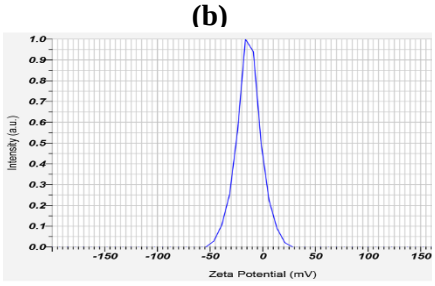
Table 2 Physicochemical properties of nano-capsules of peel extract of five pomegraranate cultivar

Treatment	Particle size (nm)	Entrapment efficiency (%)	Zeta sizer (mv)
Yazd black peel pomegranate	214.7 ± 67.8[a]	53.33 ± 5.43[c]	17.90 ± 1.15[a]
Bafghi read peel pomegranate	250.8 ± 78.8[a]	63.67 ± 11.6[bc]	11.97 ± 0.85[b]
Kan Tehran pomegranate	207.1 ± 49.8[a]	54.00 ± 5.81[c]	11.23 ± 1.05[b]
Ramhormoz read peel pomegranate	244.9 ± 22.0[a]	82.00 ± 2.86[a]	15.93 ± 3.80[a]
Garche shahvar white peel pomegranate	187.9 ± 18.2[a]	71.00 ± 4.18[ab]	12.13 ± 0.80[b]









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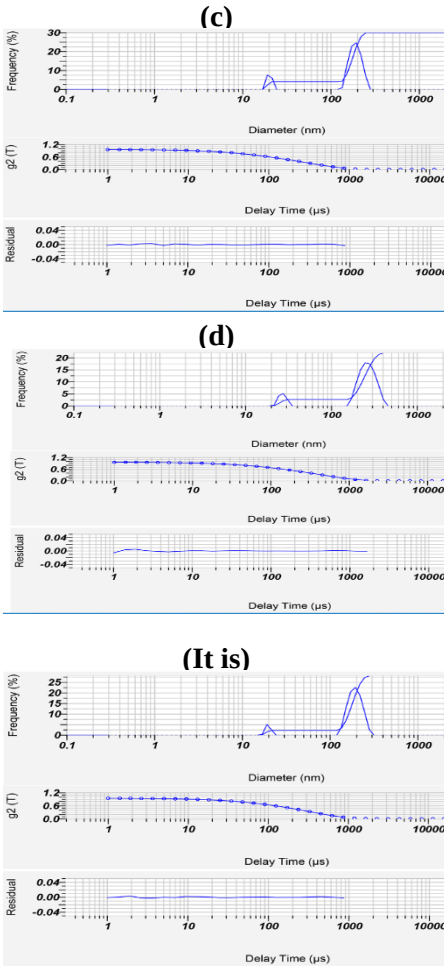

Fig 1 Particel size of nano-capsules of peel extract of five pomegraranate cultivar; Yazd black peel (a), Bafghi read peel (b), Kan Tehran (c), Ramhormoz read peel (d) and Garche shahvar white peel (e).

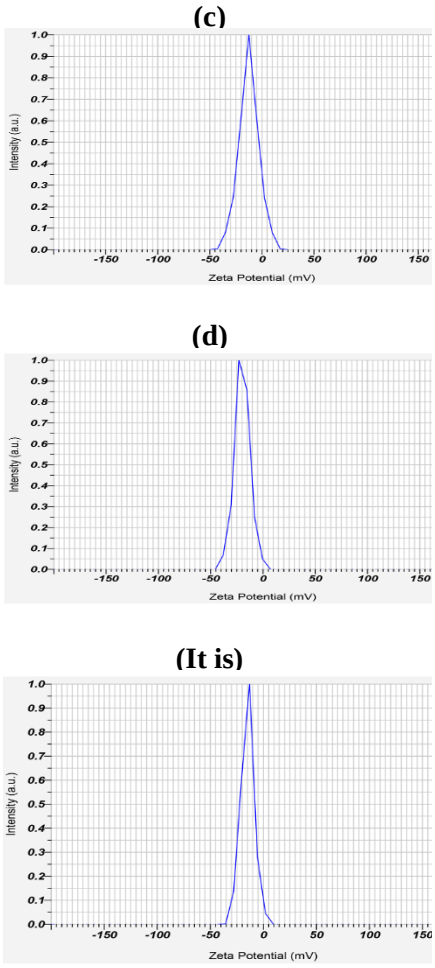

Fig 2 Zeta potential of nano-capsules of peel extract of five pomegraranate cultivar; Yazd black peel (a), Bafghi read peel (b), Kan Tehran (c), Ramhormoz read peel (d) and Garche shahvar white peel (e).

4- Resources

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بررسی خواص فراسودمندی ترکیبات فنولی کپسوله شده پوست انار ایرانی

زهرا برجی‌زاده[۱]، محمد گلی[۲*]

۱- کارشناسی ارشد علوم و مهندسی صنایع غذایی، دانشگاه آزاد اسلامی، واحد اصفهان (خوراسگان)، اصفهان، ایران

۲- استاد گروه علوم و صنایع غذایی، مرکز تحقیقات لیزر و بیوفوتونیک در فناوریهای زیستی، دانشگاه آزاد اسلامی، واحد اصفهان (خوراسگان)، اصفهان، ایران

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* مسئول مکاتبات:

Mgolifood@yahoo.com

چکیده

امروزه مواد غذایی علاوه بر اینکه به عنوان یک منبع تغذیه‌ای به‌حساب می‌آیند، همچنین به علت داشتن مواد زیست‌فعال طبیعی به عنوان مواد سلامتی بخش برای مصرف‌کنندگان نقش دارند. ترکیبات فنولیک که در پوست میوه انار به فراوانی دیده می‌شوند از جمله ترکیبات زیست‌فعال می‌باشند که می‌توان بوسیله‌ی نانو حامل‌ها برای غنی سازی مواد غذایی به آنها افزود. هدف از این مطالعه درون پوشانی ترکیبات فنولیک موجود در پنج رقم پوست انار واریته‌های ایرانی با روش نانونیوزوم و بررسی خصوصیات شیمیایی عصاره پوست انار از جمله فعالیت آنتی‌اکسیدانی، راندمان استخراج عصاره و خاصیت فنولی توسط منحنی استاندارد اسید گالیک طبق روش فولین–سیو کالتیو و همچنین بررسی خصوصیات ریز پوشش‌های حاصل با استفاده از تجزیه‌وتحلیل اندازه ذرات، پتانسیل زتا و مقایسه آنها برای دست یافتن به بیشترین کارایی در بین پنج رقم انار می‌باشد. نتایج مطالعه نشان داد که پوست انارهای جمع‌آوری شده تفاوت‌های معنی‌داری (در سطح احتمال یک درصد $p<0/05$) از نظر خصوصیات فیزیکوشیمیایی دارند. بررسی نتایج حاصله از خصوصیات فیزیکوشیمیایی عصاره پوست انار، حاکی از آن بود که انار پوست سفید رقم گرچ‌شهوار بالاترین میزان ترکیبات فنولیک (۷۸/۰۰±۶/۷۲ میلی‌گرم معادل اسید گالیک در ۱۰۰ گرم) و همچنین بیشترین خاصیت آنتی اکسیدانی ۴۲٪ را دارد. با توجه به نتایج بدست‌آمده از این پژوهش می‌توان گفت که کپسول‌های حاوی عصاره پوست انار رقم پوست سفید گرچ شهوار بهترین کارایی کپسوله‌کردن (۷۱٪) را دارد، که استفاده از نانو حامل‌های حاوی این رقم انار در مواد غذایی می‌تواند تأثیر قابل ملاحظه‌ای در حفظ و پایداری ترکیبات حساس به تغییرات محیطی داشته باشد.

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