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# Thermal stabilization of the anthocyanin extract of saffron petal using encapsulation and its application in the model drink

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**ABSTRACT**

One of the most important challenge about using anthocyanin, is its low stability, especially against light and heat condition. Therefore, the main goal of this research was to increase the stability of the anthocyanin extract of the saffron petal in thermal and light condition. To reach this goal, encapsulation is the common method. Optimization of the anthocyanin encapsulation by Arabic gum, Persian gum, whey protein and maltodextrin was conducted to investigate the thermal stability in the model drink. Anthocyanin half- life during heat treatment (at 90 °C) was 100.8 min, which became the base of the heat treatment for the model drinks. Among the different wall material used in encapsulating of the anthocyanin extract, the highest total anthocyanin content was related to the maltodextrin microcapsule (191.7 mg cyaniding 3- glycoside/ 100g saffron petal powder). After that, there were the samples with two-part wall that one was maltodextrin. The lowest total anthocyanin was related to the microcapsules containing gum Arabic. After applying the microcapsule to the model drink, the highest anthocyanin retained (63.55%) was related to the microcapsule containing the combined maltodextrin and whey protein concentrate (at ratio of 1:1). Therefore the protein wall had the more positive effect on the retention of the anthocyanin in the model drink during thermal treatments.

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# 1. Introduction

In the yearIn the past, the market of natural colors has grown rapidly and it is expected to increase by 10-15% annually. Natural pigments are a very good alternative to synthetic ones and their use in foods and beverages is increasing. This problem is due to the growing awareness of society about the side effects of chemical compounds and their environmental hazards [1]. In addition to the food applications of natural colors, their consumption is also considered to reduce non-communicable diseases such as cancer, diabetes, obesity, etc. [2].

Anthocyanins are a group of natural phenolic compounds that are responsible for the bright red, blue and purple colors of fruits and vegetables. Anthocyanins are glycosides and acyl glycosides of anthocyanidins that are soluble in water and are derived from flavylium or 2-phenylbenzopyrillium ion in the form of polyhydroxylated and polymethoxylated heterosides [3]. The most abundant anthocyanidins include cyanidin, delphinidin, and pelargonidin, followed by malvidin, petonidin, and peonidin. The color of each of these depends on their replacement and whether they are smooth or not. Under acidic conditions, the color of monoacylated and non-acylated anthocyanins is mainly determined by substitution in the B ring of the aglycone [4].

The main sources of anthocyanins in the world are the skin and pomace of red grapes and black (or purple) carrots.Due to the fact that these resources are not native to our country, they are usually not prioritized. On the other hand, considering the annual production of about 300,000 tons of saffron petals in the country and its waste in farms, this source has a very good potential as a cheap, abundant and available source for anthocyanin production.

Saffron (Crocus sativus L.) is one of the valuable medicinal plants native to Iran, and about 336 tons (88.8% of the world's total production) are produced in the country every year [5]. 86.42% of fresh saffron flowers are related to petals and sepals, which are discarded after separating the stigma from the saffron flower. Saffron petals contain significant amounts of valuable compounds such as anthocyanins [6].

The main use of natural pigments, especially anthocyanins, to improve the appearance of food and beverages.Fruit juice, jam, jelly, pastille, cake, dairy industry, etc., as well as food supplements) or recovery of color loss caused by processing and storage as well as medicinal uses. Although anthocyanins have many uses in food and pharmaceutical industries, their technical disadvantages such as relatively low stability compared to synthetic dyes have created a challenge [7]. Various physicochemical factors such as pH of the product, exposure to light, temperature and creating complexes with other compounds in the product affect the stability of anthocyanins [8]. Various methods have been proposed to reduce the degradation of anthocyanins, the most important and common of which is microencapsulation of anthocyanins (in the form of powder or emulsion) [9]. In the latest research, the production of double emulsion has also been proposed to increase the stability of anthocyanins [10].

Microencapsulation of anthocyanins has often been done using different polysaccharides so that this bioactive compound is protected from the influence of environmental factors such as light, temperature and oxygen. The spray drying process is mainly used in the food industry because it has relatively low operating costs, it is possible to produce on a large scale, and finally a dry powder is obtained as the final product. Of course, it should be noted that if the inlet temperature of the spray dryer is high, the amount of anthocyanin will decrease. Since anthocyanins are soluble in water, they are compatible with formulations containing maltodextrin, gum arabic and starch [11].

Mahdavi Khazaei et al. (2016) investigated the stability of anthocyanin and color of saffron petal extract microcoated with different wall materials such as gum arabic and maltodextrin (7 and 20) and by freeze drying method [12] Jafari et al. (2016) investigated the microencapsulation efficiency of saffron petal anthocyanin extract using cress gum, as a native hydrocolloid, gum arabic and maltodextrin, and there was no difference between the amount of total anthocyanin in the four combined formulas. after production and also after 10 weeks of storage [13]. Chang et al. (2015) studied the color stability of anthocyanin cyanidin 3-o-glucoside (C3G) extracted from purple carrot with They evaluated the use of whey protein (natural and denatured) and pectin (complex and beet sugar). The best result was observed by using denatured whey protein, which reduced the negative effect of ascorbic acid on

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absorption intensity by half. After that, there were sugar beet pectin, natural whey protein and citrus pectin [14]. Chang et al. (2016) also investigated the effect of gum arabic (0-5%) on increasing the color stability of anthocyanins in a beverage system containing ascorbic acid and observed that the half-life of anthocyanin in the sample without gum arabic was 24/ It was 2 days, but in the sample containing 1.5% gum arabic, this number reached 5.25 days [15]. Based on the research, the microcoating method using wall materials maltodextrin, gum arabic and whey protein using a spray dryer has a positive effect on the stabilization of anthocyanins. Of course, it should be mentioned that in some researches, the stability of anthocyanin in microcoated powder and in others, stability in a model drink has been investigated. In some studies, the stability of anthocyanin during storage time and in others, during heat treatment with high temperature has been investigated. Therefore, in this research, firstly, the stability of saffron petal anthocyanin extract in powder produced by microcoating method and using different wall materials individually and in combination (maltodextrin, gum arabic, whey protein, 1:1 mixture of maltodextrin and gum arabic, A 1-to-1 mixture of whey protein and maltodextrin, a 1-to-1 mixture of whey protein and gum Arabic, a mixture of maltodextrin and Persian gum, and a mixture of gum Arabic and Persian gum) were investigated. Then, the stability of anthocyanin in the model drink was investigated during heat treatment and storage in order to comprehensively investigate and compare the performance of different wall materials and to select and introduce the optimal wall.

# 2- Materials and methods

## 2-1-Chemicals

Dry saffron petals were obtained from Mashhad saffron farms. Laboratory grade ethanol was purchased from Dr. Majalli Company (Doctor Majalli Chemical Industries, Iran). Citric acid, sodium citrate, ascorbic acid and gum arabic were purchased from Titrachem. Maltodextrin with DE equal to 18 was purchased from Gold Fructose Company and whey protein concentrate (WPC) was purchased from Hilmar Company (USA). Farsi gum was purchased from Rihan Gam Parsian Company.

## 2-2-Methods

### 2-2-1- Extraction and measurement of anthocyanin extract

In order to extract the anthocyanin present in saffron petals, the optimized method by Belurian et al. (2019) was used [16]. First, dried saffron petals were crushed at a temperature of less than 40 degrees Celsius by a laboratory mill (model TS-1300, Tosshekan Khorasan, Iran) and powder was prepared with 16 mesh and after weighing, with a solvent (50% acidic ethanol It was treated with 1 normal hydrochloric acid until reaching a pH equal to 2) in a ratio of 1:25 (volume/weight) at a temperature of 30 degrees Celsius for 32 minutes for extraction. In the next step, the extracted extract was filtered using a centrifuge and Whatman filter paper. The resulting extract was concentrated using a rotary evaporator under vacuum (Heidolpg, Germany) at a temperature of about 40 °C (with a rotation speed of 30 rpm) to reach a Brix of about 9 and was kept in closed plastic containers until use. and covered with aluminum foil, kept at 4 degrees Celsius. Then this extract was used in different stabilization methods.

### 2-2-2- Optimization of anthocyanin microcoating with different polysaccharides

The wall materials including maltodextrin (dextrose equivalent 18), gum arabic, persian gum and whey protein were mixed and dissolved individually and in combination in warm distilled water for 30 minutes and then kept overnight in the refrigerator until Completely absorb water. Treatments include maltodextrin (MD), gum arabic (GA), whey protein (WPC), a 1-to-1 mixture of maltodextrin and gum arabic (MD+GA), a 1-to-1 mixture of whey protein and maltodextrin (MD+WPC), 1 to 1 whey protein and gum arabic (GA+WPC), mixture of maltodextrin and Persian gum (MD+GF) and mixture of gum arabic and Persian gum (GA+GF). In the mixtures containing Persian gum, the concentration of this gum was 4% because at higher concentrations, the viscosity of the solution increased drastically and it became gel-like [17]. Brix ratio of wall material to Brix of anthocyanin extract was chosen as 3:1 (wt/wt) [18]. Therefore, Brix wall solution reached 27. Then, the wall solution and saffron petal extract were homogenized in a ratio of 1 to 1 (weight/weight) for 30 minutes, and the Brix of the final mixture reached 13.5 to be sent to the

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spray dryer.

### 2-2-3- Model drink production

A model drink containing 8% (w/w) anthocyanin extract and 0.01% calcium chloride was prepared in 20 mM citric acid buffer with a pH of 3 [14].

### 2-2-4-physicochemical tests

#### *2-2-4-1- Measurement of anthocyanin concentration*

Anthocyanin concentration of the samples using UV-Vis spectrophotometer at two wavelengths of 520 and 700 nm and using two buffers of 0.025 M potassium chloride at pH=1 and 0.4 M sodium acetate at pH=4.5 and It was estimated using the following formula [13].

$$\text{(mg/L) anthocyanin pigment concentration} = \frac{A \times Mw \times DF}{\varepsilon} \times L$$

where A = (A530− A700) pH 1.0− (A530− A700) pH 4.5, Mw = molecular weight of anthocyanin (449.2 g/mol), DF = dilution factor, ε = coefficient (900/L/cmmol) 26), L = path length (1 cm).

Considering that the anthocyanins of saffron petals are mainly of cyanidin 3-glycoside type, few data indicate cyanidin 3-glycoside.became.

#### *2-2-4-2- Determination of particle diameter*

In order to measure the specific size and surface area of the powder particles obtained from the spray dryer, first their dispersion was prepared in methanol and then it was measured using the Etasizer Nano ZS Particle Size Analyzer, manufactured by Malvern Company from England [19].

#### *2-2-4-3- Determining the saturation index[1]*

The dispersion index was calculated according to the particle size distribution curve by the software of the Particle Size Analyzer device and the measurements were carried out at room temperature [20]. The particle size dispersion between 0.10-0.25 indicates the low dispersion of particles and the narrowness of the particle dispersion diagram. Values greater than 0.5 indicate a wide dispersion of particles.

#### *2-2-4-4-determining the efficiency of microcoating[2]*

After determining the content of total anthocyanin and anthocyanin in the Romand solution, the microcoating efficiency can be calculated from the following equation [18].

%EF=TA-TS/TA×100

where EE is the efficiency of microencapsulation, TA is the amount of total anthocyanin and TS is the amount of anthocyanin in Romand solution. To measure total anthocyanin, the prepared powder was completely dissolved in distilled water and centrifuged (4200 g for 20 minutes) using a centrifuge (Sigma model, made in Germany) to precipitate impurities. To determine the amount of anthocyanin in Romand solution, powder samples are dissolved in ethanol and after centrifuging the mixture, the supernatant is used to determine the amount of anthocyanin in Romand solution.

### 2-2-5-Thermal stability test and investigation of anthocyanin degradation kinetics

A model drink (20 mM citric acid buffer at pH equal to 3) containing 0.01% calcium chloride and anthocyanin extract was prepared. The prepared model drinks were heated at 90°C for 0, 15, 30, 45, 60, 90 and 120 minutes using a hot water bath (Memert, Germany) and then cooled to room temperature. . The half-life of anthocyanins ($T_{1/2}$) was calculated from the following equations and the mentioned treatments were evaluated at that time to check the effect of stabilization [14 and 15].

$$\frac{C}{C0} = \exp(-Kt)$$

In this formula, C is the concentration of pigments at time t (heating at different temperatures), $C_0$ It indicates the concentration of primary pigments. K ($day^{1-}$ ) is the reaction rate constant [21].

$$T1/2 = \frac{-\text{Ln } 0.5}{K}$$

### 2-2-6- Color index measurement

CIELab system was used to evaluate the color of the samples (powder and drink), during which three lightness/darkness indicators (*L**), red/green (*a**) and yellow/blue (*b**) were measured. These indicators were determined using the Hunter Lab device [13]. For this purpose, about 10 grams of powder or 30 ml of model drink (volume of a glass bottle) was poured into a special glass container for Hunter Lab and the color indicators were read.

[1]. Polydispersity index (PDI)

[2]. Encapsulation Efficiency (EE%)

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## 2-3- Data analysis method

for comparisonThe effect of walls on indicators such as particle size, water activity, color indicators, anthocyanin content and microcover efficiency from a one-factor design Used at one time. Experiments were performed in at least two repetitions, and then the mean and standard deviation of the data were obtained. To study the existence of significant statistical differences between different treatments, ANOVA and Tukey's test were used. In all stages, statistical analysis of data was done using Minitab 17 and Matlab 16 software.

# 3. Results and Discussion

## 3-1-Thermal stability of the model drink containing anthocyanin extract

As seen in Figure 1, with increasing heating time, the amount of anthocyanin decreased drastically. Based on Figure 1 and also using the first-class model in MATLAB software, it was determined that the half-life time of anthocyanin degradation is 100.8 minutes.

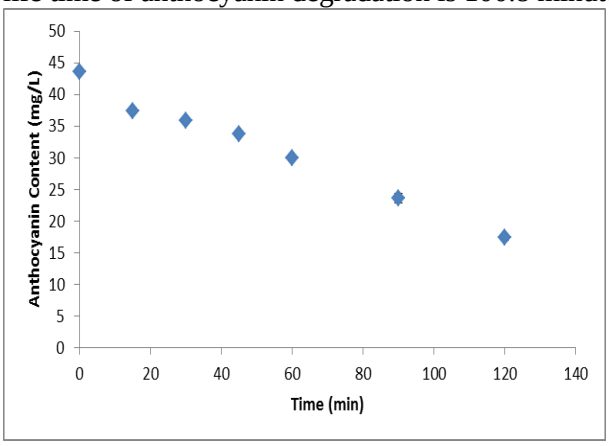


**Fig 1** Heat stability in the model drink

The redness index of the model drink was also checked at different heating times at 90 degrees Celsius and as can be seen in Figure 2, with increasing heating time, the redness index significantly ($p<0.05$) ) decreased, which has a good correlation with the amount of anthocyanin (Figure 1) and indicates the degradation of anthocyanin [22].

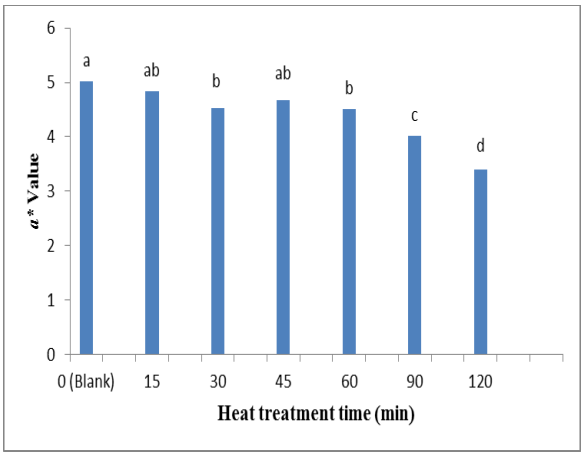


**Fig 2** The effect of the heating time at 90 °C on the a* value of the anthocyanin in the model drink

## 2-3- The effect of the type of wall on the efficiency of microcoating and the amount of total anthocyanin

Microencapsulation efficiency refers to the potential of the wall material in retaining the core material inside the microcapsules. The microcoating efficiency is also related to the durability of the material enclosed inside the wall. A successful microencapsulation leads to the production of microcapsules with minimal surface materials on the microcapsule particles and maximum retention of core materials [23].

The microencapsulation efficiency of all walls was more than 96% and there was no significant difference ($p<0.05$) between microcapsules prepared using different wall materials (Figure 3). According to Figure 4, the highest amount of anthocyanin in microcapsules was related to MD microcapsule. After that, there were samples whose wall was two components and one component of which was maltodextrin. The amount of total anthocyanin in WPC microcapsules was similar to the second category and did not differ significantly from them. The lowest amount of total anthocyanin was related to microcapsules containing gum arabic (GA). In addition, the amount of anthocyanin of the samples remained constant during storage at accelerated temperature (40°C) and no significant change was observed.

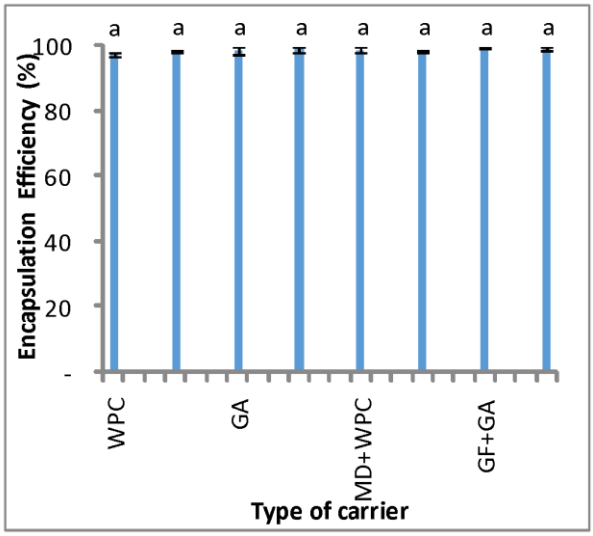


**Fig 3** The effect of the wall type of the microcapsule on the encapsulation efficiency of the microencapsulated anthocyanin powder

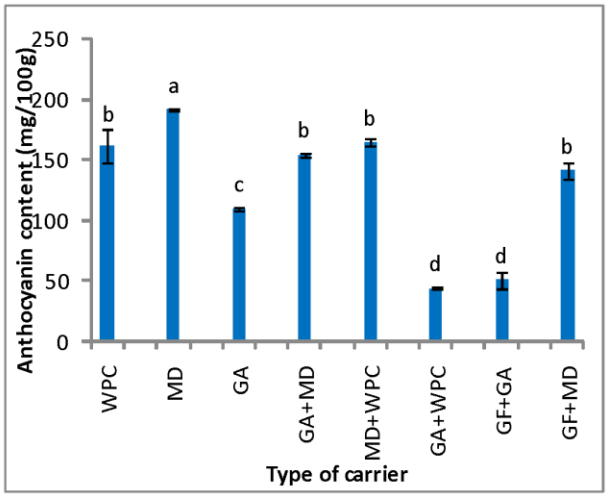


**Fig 4** The effect of the wall type of the microcapsule on the anthocyanin content of the microencapsulated anthocyanin powder

The use of wall materials in the right ratio for the microcoating of active compounds can protect them and maintain their efficiency [24]. Da Rosa et al. (2018) microcoated the anthocyanin extract extracted from blueberry using maltodextrin and corn starch (hi-maize) (with a concentration of 18% wall substances) and checked its stability [11]. The microcoating efficiency of the samples was in the range of 74.4-85.22%. Gay et al. (2018) reported the microencapsulation efficiency of anthocyanin microencapsulated with chitosan derivatives in the range of 16-44% [18]. When proteins were used for microencapsulation, efficiencies of 17-98% and when polysaccharides were used in microencapsulation, efficiencies of 32-99% were reported, although lipids showed lower efficiencies (25-53%). ).

Idaham et al. (2012) microencapsulated sour tea anthocyanin extract with maltodextrin and gum arabic and obtained a microencapsulation efficiency of 99.69%. They concluded that formulations containing high concentrations of maltodextrin showed higher microencapsulation efficiency [25]. The results of Kai et al. (2019) indicated that the microcoating efficiency of all samples was above 96% and there was no significant difference between the samples [26], which is in accordance with the results of this article.

The microcapsules containing maltodextrin had the highest amount of total anthocyanin, and the microcapsules containing gum arabic and the mixture of gum arabic and Persian gum had the lowest amount of anthocyanin. According to Tonen et al.'s (2010) research, in microcapsules containing a high percentage of gum arabic, due to the decrease in mass density, the empty space between the particles increases and the oxidation reactions increase due to the increase of oxygen between the particles, which ultimately leads to a decrease in the amount It becomes anthocyanins.Also, in another mechanism, by increasing the amount of gum arabic in the microcapsules, the humidity also increases, which causes increased molecular mobility, and oxygen penetration and oxidation reactions increase, and as a result, the amount of anthocyanins decreases [27]..

Cranioti et al. (2015) stated that maltodextrin provided the greatest protection of saffron anthocyanins during several weeks of storage, followed by gum arabic [28]. Ferrari et al. (2015) found that the use of maltodextrin or gum arabic increases the stability of anthocyanin produced by the spray drying method during storage at temperatures of 25 and 35 degrees Celsius [29].

Metini et al. (2017) observed the highest amount of anthocyanin in the sample coated with maltodextrin and gum arabic in a ratio of 50-50 [30]. Mahdavi Khazaei et al. (2014) microcoated the anthocyanin extract of saffron petals with a combination of gum arabic, maltodextrin with DEs of 7 and 20 and did not observe a




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significant difference between the total anthocyanins in different walls even after 10 weeks of storage. [9]. Jafari et al. (2016) also reached a similar conclusion about horsetail gum and reported that wall materials act as a physical barrier that can reduce the effects of oxygen, light, heat, and moisture. Also, reducing the amount of moisture that occurs during microcoating can act as a protective factor by reducing the fluidity of the molecule and increasing the viscosity [31].

The absence of oxygen can also reduce the negative effect of heat on natural pigments [28].

Abdullazadeh (2017) reported the highest amount of anthocyanin in the microcapsule containing 50% maltodextrin and 50% gum arabic and the lowest amount in the microcapsule containing 90% maltodextrin and 10% gum arabic, which was contrary to the results of our research. . SheThe reason for this result was stated as gum arabic has better coating properties than maltodextrin, thus anthocyanin is optimally protected [32]. Also, in microcapsules containing a large percentage of maltodextrin, due to the smaller particle size compared to microcapsules with more arabic gum, the contact surface with oxygen increases and the oxidation of anthocyanins increases, as a result, microcapsules containing maltodextrin have a lower amount of anthocyanin than microcapsules containing a high proportion of gum. They have Arabic [9].

OverallThe results indicated that all wall materials individually or in combination had very good performance for micro-coating and there was no significant difference between them. Use of courseMaltodextrin alone or in combination with other substances (WPC) is one of the best options for microencapsulation of anthocyanin, and by using this method, anthocyanin can be preserved for a longer period of time, which is similar to the results of some researchers.

### 3-2-1-The effect of wall type on color indicators

As can be seen in Table 1, the highest redness index (*a**) was related to MD microcapsule, which is consistent with the total anthocyanin test of microcapsules [22]. . Therefore, the higher redness index in MD microcapsules is related to the higher concentration of anthocyanin in them.

The highest brightness index (*L**) and jaundice index (*b**) related to GA+WPC microcapsules and the lowest was related to MD microcapsules.

**Table 1** The effect of the wall type of the microcapsule on the color values of the anthocyanin extract powder

| Type of carrier | *L** | *a** | *b** |
|---|---|---|---|
| **WPC** | 78.09 ± 0.10 [b] | 0.82 ± 0.01 [f] | 4.38 + 0.02 [c] |
| **MD** | 66.31 ± 0.05 [f] | 23.32 ± 0.01 [a] | -7.21 ± 0.01 [h] |
| **GA** | 66.63 ± 0.23 [f] | 3.18 ± 0.01 [d] | 2.48 ± 0.01 [d] |
| **GA+MD** | 66.49 ± 0.11 [f] | 8.01 ± 0.03 [c] | -3.19 ± 0.03 [f] |
| **MD+WPC** | 77.03 ± 0.12 [c] | 3.09 ± 0.01 [d] | 0.26 ± 0.01 [It is] |
| **GA+WPC** | 80.24 ± 0.01 [a] | -0.05 ± 0.01 [g] | 9.64 ± 0.02 [a] |
| **GF+GA** | 73.42 ± 0.01 [d] | 1.37 ± 0.01 [It is] | 7.92 ± 0.01 [b] |
| **GF+MD** | 69.33 ± 0.01 [It is] | 16.39 ± 0.01 [b] | -4.96 ± 0.01 [g] |

Cranioti et al. (2015) observed that the use of gum arabic wall for microencapsulation of saffron petal anthocyanin extract compared to maltodextrin increased the redness index, although after 10 weeks of storage, the redness index of maltodextrin was higher. Also, the brightness index of the microcoated extract with Arabic gum was higher than that of maltodextrin [28], which is contrary to the results of our research and may be related to other compounds in the anthocyanin extract.

## 3-3- Effect of wall type on particle size

The largest particle size was obtained in MD, GA

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and WPC microcapsules (Figure 5). Except for the combined wall of maltodextrin and Farsi gum (MD+GF), the use of combined walls caused a significant decrease ($p<0.05$) in the particle size. The smallest particle size was obtained in microcapsules with maltodextrin and gum arabic walls. The reduction of microcapsule particles can be caused by the proper interaction of the tensile forces between the wall materials. Abdulzadeh (2017) observed that the largest particle size in the sample containing 90% maltodextrin and 10% gum arabic was 4.34 micrometers and the smallest particle size was obtained in the sample containing 70% maltodextrin and 30% gum arabic [32]. Tonen et al. (2010) showed that particles coated with gum arabic had a smaller diameter than tapioca starch and maltodextrin [27], while in our research, there was no significant difference between the size of particles produced with maltodextrin and gum arabic. The combination of these two wall materials reduced the size of the particles. In another study, Legacco and Donford (2010) reported the non-uniformity of the shape and size of the microcapsules due to the difference in the moisture content of the resulting microcapsules [33]. The results of Handri et al. (2015) showed that different wall compositions and microcoating techniques both significantly affect the size, shape and overall structure of microcapsules [34].

Da Rosa et al. (2018) found the size of microcapsules in the range of 12.8 to 20.7 µm [11]. Farang and Bhandari (2010) reported the size of microcapsules obtained by spray drying in the range of 10-100 µm, which was much larger than the size of the particles obtained in this research. This index is affected by the size of the nozzle, the flow rate used, the pressure and the concentration of the solution [35].

Ansari and Hojjati (2017) observed that the size of anthocyanin pigments microencapsulated in onion skin using maltodextrin was much smaller than gum arabic (1.6 vs. 28 µm), although in the case of cabbage anthocyanin pigments microencapsulated with these two carriers The sizes were similar. They stated that microcoated particles with maltodextrin had surfaces with more rounded corners than gum arabic [36].

Borin et al. (2010) observed that maltodextrin-cyclodextrin and maltodextrin-gum arabic microcapsules were similar in size, smaller and rounder than maltodextrin microcapsule, which is consistent with our research [37].

Therefore, the results of different researchers show that the different composition of wall materials has caused different changes in the size of particles, which depended on the production conditions, the type of wall materials and the composition of wall materials. Since the use of composite walls in our research resulted in a significant ($p<0.05$) reduction in particle size, it seems that a reaction (such as hydrogen bonding) between the wall materials has taken place, leading to a reduction The particle size has been.

## 3-4- The effect of the type of wall on the dispersion index

Dispersion index as a measure of molecular weight distribution[3] It is theoretically very important [32]. The dispersion of particle size between 0.1-0.25 indicates the low dispersion of particles and the narrowness of the particle dispersion diagram. Values greater than 0.5 indicate a wide dispersion of particles.

According to Figure 6, the highest dispersion index was related to WPC and GA microcapsules, and the combination of wall materials caused a significant decrease in this index. The microcapsule with maltodextrin wall also had a low dispersion index (0.159).

Due to the significant size of dispersion index of WPC and GA microcapsules, there is a wide dispersion in their particle size. Arabic gum in combination with other wall materials has caused a significant decrease in the spattering index. Abdullazadeh (2017) reported the highest dispersion index in the sample containing 90% maltodextrin and 10% gum arabic with a value of 0.658 and also the lowest index in the sample containing 70% maltodextrin and 30% gum arabic with a value of 0.023 [ 32].

3. molecular weight distributions (MWD)

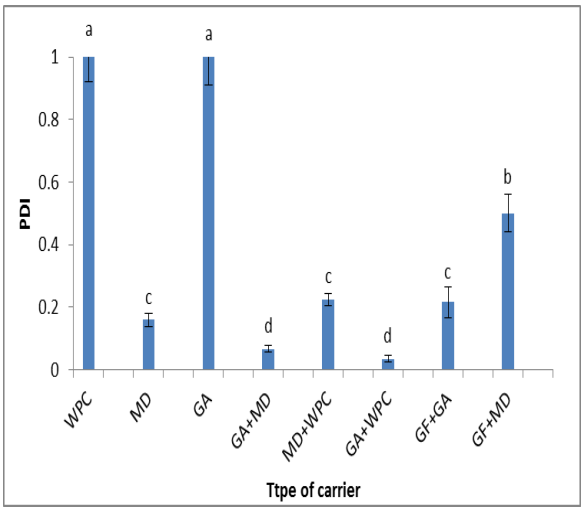


**Fig 6** The effect of the wall type of the microcapsule on the polydispersity index (PDI) of the microencapsulated anthocyanin

The results of Korshian et al.'s research (2014) regarding the dispersibility index of microcapsules of wild black raspberry anthocyanin extract prepared by the spray drying method under the influence of different ratios of carrier materials including maltodextrin and gum arabic showed that a higher ratio of maltodextrin led to an increase in dispersibility index. became [20].

## 5-3-The effect of micro-covering on stable Making anthocyanins in a model drink

The microcapsules produced in the previous step were dissolved in the model drink and the effect of heat treatment at 90°C for 100.8 minutes (half-life time of anthocyanin) was investigated on the stability of anthocyanin. As can be seen in Figure 8, the highest retention rate of total anthocyanin (lowest degradation rate) was related to WPC+MD microcapsule and there was no significant difference between other microcapsules. Therefore, the mixture of whey protein concentrate and maltodextrin has been able to significantly increase the stability of anthocyanin in the model drink.

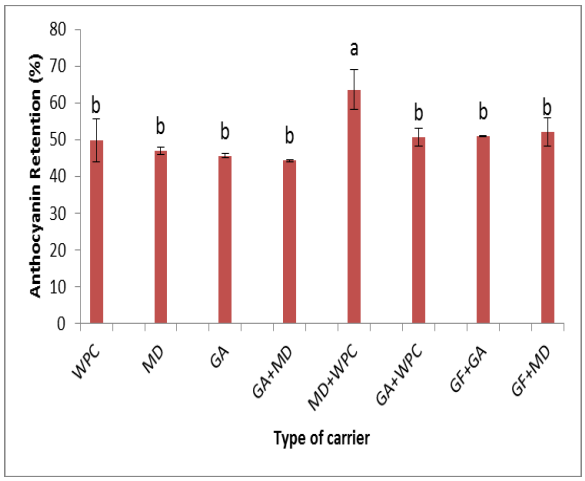


**Fig 8** The effect of the wall type of the microcapsule on the retained anthocyanin in the model drink

The redness index of the model drink containing microcapsules was significantly affected by heat treatment and decreased drastically. The type of wall also significantly affected the redness index.

According to Figure 9, the highest redness index was related to the model drink containing MD+WPC microcapsules, followed by the model drink containing WPC microcapsules. The lowest redness index was related to the microcapsules containing a mixture of gum Arabic and Persian gum (GA+GF). Therefore, the use of microcapsules containing Persian gum or Arabic gum has reduced the redness index in model drinks, and the microcapsule containing both of these gums has caused the lowest redness index in the drink.

The highest amount of anthocyanin stability (protection) and also the highest redness index were obtained in the model drink containing MD+WPC. Although the index of total anthocyanin in the model drink containing other microcapsules was similar, the redness index of the model drinks containing microcapsules with Persian gum or gum arabic walls was greatly reduced, and the microcapsule containing both of these gums had the lowest redness index. created in the drink. Mahdavi Khazaei et al. (2014) also observed the highest amount of total color change in extracts coated with gum arabic, which indicated the browning of pigments [9].




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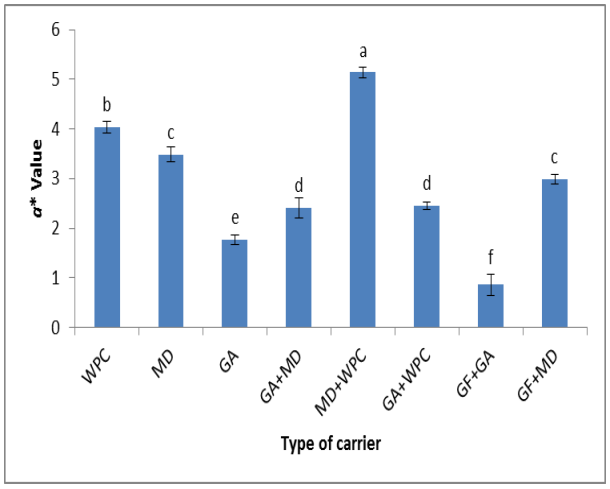


**Fig 9** The effect of the wall type of the anthocyanin microcapsule on the *a** value in the model drink

Chang et al. (2016) observed that gum arabic increased the stability of anthocyanins, which could be due to the reaction of anthocyanin with the glycoprotein part of the gum arabic molecule. According to their results, the highest stability of anthocyanin was obtained in the drink containing 1.5-0.35% gum arabic. However, increasing the concentration of gum arabic to 5-2.5% decreased the stability of anthocyanin. This problem may be caused by overcrowding[4] Gum arabic molecules are in high concentrations, which leads to compact formation of gum molecules. As a result, the reaction between anthocyanin and glycoprotein may decrease due to the steric hindrance effect [15]. Arabic gum is widely used as an emulsifier in food and beverage systems and can have a good potential to prevent anthocyanin degradation in the presence of ascorbic acid.

Guan and Zhong (2015) investigated the effect of gum arabic on the stabilization of anthocyanin in a model solution (pH=5) containing them at temperatures of 80 and 126 degrees Celsius and a time of 0-80 minutes. The model solution contained 0.51 mg/ml of anthocyanin and the concentration of gum arabic was considered to be 10 mg/ml. By adding gum arabic, the half-life of anthocyanins degradation increased by 2 and 1.8 times at 80 and 126 degrees Celsius, respectively [38]. They also observed that the redness index of the solution decreased after heating, which could be due to the loss of the flavylium cation and the hydrolysis of the double bond of the C ring in the anthocyanin molecule. In addition, the sugar part of anthocyanin (glucose or sucrose) can be decomposed during heat treatment and the sugar and glycogen created accelerate the reduction of redness [39]. Sadilova et al. (2009) reported that water-soluble carbohydrates are able to improve the stability of anthocyanins through the mechanism of copigmentation, which may also be true for water-soluble gum arabic [40].

Idham et al. (2012) microcoated anthocyanin with gum arabic, maltodextrin and a mixture of gum arabic-maltodextrin using a spray dryer and prepared the resulting powder in a solution with a pH equal to 3 and at temperatures of 60, 80 and They heated to 98 degrees Celsius. The rate of anthocyanin degradation in the control sample at 60°C was similar to the sample containing gum arabic, although the samples containing maltodextrin and the mixture of maltodextrin and gum showed less degradation. At 80°C, even the half-life of anthocyanin degradation in the sample containing gum arabic was shorter than the control sample. At 98°C, the stability of anthocyanins improved in all samples, which could be due to the effect of water-soluble carbohydrates through the copigmentation mechanism [25].

Burin et al. (2010) observed the highest stability of microencapsulated anthocyanins in isotonic drink in the microencapsulated extract with maltodextrin-gum arabic mixture and the lowest stability in the microencapsulated extract with maltodextrin. They stated the reason for the lower stability of the maltodextrin wall is the lower ability of this compound to form a film [37]. Qarsalvi et al. (2007) stated that single carriers alone are not capable of effective microencapsulation and the use of a mixture of carriers can protect compounds [41].

Chang et al. (2015) observed that whey protein isolate resulted in greater anthocyanin stability in a model beverage than pectin. Pectin clouded the appearance of the model beverage, which may not be desirable for product manufacture,

[4]. Overcrowding




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but beverages containing WPI were clear. The heat-denatured WPI solution was more effective in preventing color degradation (change) than the original (undenatured) WPI, indicating that protein denaturation and decyclicization may enhance the interaction with anthocyanin due to increased exposure of groups. increased hydrophobicity. Their hypothesis was that denatured WPI could improve the stability of anthocyanins through reaction with anthocyanin or reaction with ascorbic acid, which is the process of copigmentation. Although their supplementary tests indicated that the reaction of protein with anthocyanin was the main effective factor in preventing the degradation of anthocyanin in the model drink, that probably the formation of this complex was able to prevent the degradation of anthocyanin by ascorbic acid [14].

Therefore, based on the research, the microcapsule containing WPC can be denatured during heat treatment and protected through the reaction with anthocyanin. In addition, the use of a mixture of WPC and MD may have caused the effect of maltodextrin copigmentation and better protection of anthocyanin.

## 4- General conclusion

Among the walls used for microencapsulation of anthocyanin extract, maltodextrin was more effective than others and retained more anthocyanin during drying, but after using the microcapsules in the model drink, the most anthocyanin remained (protected) related to the WPC+MD microcapsule. Was. In addition, the index of total anthocyanin in the model drink containing other microcapsules was similar, but the redness index of the model drinks containing microcapsules with Persian gum or Arabic gum walls was greatly reduced, and the microcapsule containing both of these gums had the lowest redness index. has created in the drink. Therefore, compared to Persian and Arabic gums and maltodextrin, the protein wall has a more positive effect on the protection of anthocyanins during thermal processes in the food environment.

## 5- Thanks and appreciation

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مقاله علمی_پژوهشی

# پایدارسازی حرارتی عصاره آنتوسیانین گلبرگ زعفران با استفاده از روش ریزپوشانی و کاربرد آن در مدل غذایی

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**چکیده**

**یکی از چالش های مهمی که در زمینه استفاده از آنتوسیانین‌ها وجود دارد، پایداری نسبتا پایین آن‌ها مخصوصا در برابر نور و حرارت می‌باشد. بنابراین، هدف اصلی این پژوهش، افزایش پایداری عصاره آنتوسیانینی استخراجی از گلبرگ زعفران در برابر تیمارهای حرارتی و شرایط نوری می‌باشد. برای رسیدن به این هدف، در بیشتر موارد از روش ریزپوشانی استفاده می‌شود. برای پایدارسازی عصاره آنتوسیانینی گلبرگ زعفران، بهینه‌سازی ریزپوشانی آنتوسیانین‌ها با صمغ عربی، صمغ فارسی، مالتودکسترین و پروتئین آب‌پنیر انجام شد و پایداری حرارتی آن‌ها در نوشیدنی مدل بررسی شد. نیمه عمر آنتوسیانین طی تیمار حرارتی (در دمای ۹۰ درجه سانتی‌گراد) ۱۰۰/۸ دقیقه بود و مبنای تیمار حرارتی برای نمونه‌ها قرار گرفت. از میان ترکیبات دیواره‌ای مورد استفاده برای ریزپوشانی عصاره آنتوسیانینی، بیشترین میزان آنتوسیانین کل ریزکپسول ها مربوط به ریزکپسول مالتودکسترین (۱۹۱/۷ میلی گرم سیانیدین ۳- گلیکوزید به ازای ۱۰۰ گرم پودر گلبرگ) بود. بعد از آن، نمونه‌هایی که دیواره آن دوجزئی بود و یک جزء آن را مالتودکسترین تشکیل می داد، قرار داشتند. کمترین میزان آنتوسیانین کل نیز مربوط به ریزکپسول های حاوی صمغ عربی بود. پس از بکار بردن ریزکپسول ها در نوشیدنی مدل، بیشترین آنتوسیانین باقی مانده (۶۳/۵۵ درصد) مربوط به ریزکپسول حاوی دیواره ترکیبی مالتودکسترین و کنسانتره پروتئین آب پنیر (به نسبت ۱ به ۱) بود. بنابراین دیواره پروتئینی، تاثیر مثبت بیشتری بر محافظت از آنتوسیانین‌ها در نوشیدنی مدل طی فرآیندهای حرارتی داشته است.**