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Application of maltodextrin and gum Arabic in microencapsulation of saffron petal's anthocyanins and evaluating their storage stability and color

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ABSTRACT

In this work, anthocyanin stability and color of encapsulated freeze-dried saffron petal's extract with various matrices consisting gum Arabic (AG) and maltodextrin (M7 and M20) were studied. Total anthocyanins of powders and color parameters (a^*, b^*, L^*, C, H° and TCD) were measured immediately after production and during storage up to 10 weeks by pH differential method and computer vision, respectively. Different compounds of wall materials did not show any significant differences in terms of stabilizing anthocyanins ($P < 0.01$) and no significant decrease in anthocyanin content of the powders was observed after storage. The efficiency order of wall materials considering total color differences (TCD) was AG > M20 > M7. By evaluating 3D surface and Cox trace plots it was revealed that wall formulas which had the lowest amount of AG and highest amounts of M20 and M7 showed the lowest total color differences after storage ($P < 0.05$). To conclude, microencapsulation by freeze drying could be recommended as a suitable method for stabilizing anthocyanins of saffron petal's extract.

1. Introduction

The first property that the consumer observes in every food product is its visual color, which is an indicator of pigment concentration that is measurable immediately. Color can be changed during heat processing based on different reactions of pigments such as pigment degradation, browning reactions like Millard reactions, enzymatic browning and oxidation of ascorbic acid (Maskan, 2006). Most of the synthetic colors which are used in the food industry have chemical sources with harmful health effects. Since the anticancer and antioxidant properties of natural colorants are proven, today there are more tendencies to use natural colorants instead of synthetic ones (Andersen, Jordheim, Lew, & Hung-Wen, 2010).

Anthocyanins as natural pigments are found in roots, leaves, fruits and flowers of plants. Attractive color and functional properties (like prevention of neuronal and cardiovascular, cancer and diabetes illnesses) of anthocyanins make them a good substitute for synthetic pigments in the food industry (Castaoveda-Ovando, Pacheco-Hernondez, Priez-Hernandez, Rodriguez, & Galoan-Vidal, 2009). These natural soluble water colorants are rather unstable and influenced by final processing temperature, storage temperature, pH, chemical structure and concentration of anthocyanin, light, oxygen, enzymes, proteins and metallic ions (Patras, Brunton, O'Donnell, & Tiwari, 2010).

Saffron (*Crocus sativus*) which is produced largely in Iran, with more than 90% of total annual saffron production in the world (Kafi, 2006), has cyanic color flowers with major colorant of anthocyanins (Nørbæk, Brandt, Nielsen, Ergaard, & Jacobsen, 2002). The existence of anthocyanins in saffron's petal had been proven before by Williams, Harborne, and Goldblatt (1986) and Nørbæk et al. (2002) too. Since nearly 86.4% wet base or 96.36% dry base of total weight of saffron flowers is related to the petals (Hemmati, 2001) and a large scale of saffron flowers is disposed to the nature after picking stigmas annually; anthocyanins of petal extract can be used as a natural resource of colorants in the food industry adding to its other medicinal/industrial applications (Kafi, 2006).

Microencapsulation is a technique to package materials (like natural colorants) in the form of micro- and nano-particles. Microencapsulation can protect sensitive materials from moisture, heat, light or oxidation (Jafari, Assadpoor, He, & Bhandari, 2008). There are different methods for encapsulation in the food industry. Freeze drying which has a long dehydration period has been used as a simple technique in encapsulating water-soluble essences and natural aromas or drugs. During this procedure, core materials and matrix solutions are homogenized and then co-lyophilized to make dried materials (Fang & Bhandari, 2011).

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In various experiments on encapsulation of anthocyanins, different materials and compounds have been used in spray drying (Akhavan, Jafari, Ghorbani, & Assadpoor, 2013) or freeze drying techniques such as glucan gel (Xiong, Melton, Easteal, & Siew, 2006), maltodextrins with different DEs (Ersus & Yurdagel, 2007; Fang & Bhandari, 2011; Saenz, Tapia, Chavez, & Robert, 2009), maltodextrin and inulin (Bakowska-Barczak & Kolodziejczyk, 2010), pectin, caffeine, shellac (Berg, Bretz, Hubbermann, & Schwarz, 2012), maltodextrin, ascorbic acid (Ahmed, Akter, Lee, & Eun, 2011), mesquit gum (Kandansamy & Somasundaram, 2012), maltodextrin, kappa-carraginan (Krishnaiah, Sarbatly, & Nithyanandam, 2012) and maltodextrin, Arabic gum, and tapioca starch (Tonon, Brabet, & Hubinger, 2010).

Also, there have been some efforts on encapsulating of saffron extract and its individual ingredients (Cormier, Dufresne, & Dorion, 1995; Dufresne et al., 1999; Nair, Salomi, Varghese, Panikkar, & Panikkar, 1992; Selim, Tsimidou, & Biliaderis, 2000) but, encapsulation of saffron petal's extract as mentioned before, which is known as a good and huge source of anthocyanins has not been investigated. Therefore, encapsulation of saffron petal's anthocyanins with freeze drying technique through wall materials of maltodextrins and Arabic gum and then, evaluating stability of anthocyanin and color of encapsulated powders during storage could be an initial step to produce natural colorants with high stability.

2. Materials and methods

Saffron flowers were collected before sunlight from a farm near Torbat-E-Heydariyeh (Iran) in November, 2012. After removing stigmas and anther, the petals were dried in a dark and warm room (35 °C, 24 h) in front of a fan. Dried petals were crashed and sieved (1 mm meshes) and were kept in air-tight bags within a cold store.

In order to choose the best drying method of saffron petals, some primary experiments were done based on three different methods consisting oven drying (60 °C ± 1, 6 h), vacuum oven drying (45 °C, 500 mbar, 24 h) and drying in a dark warm room (35 °C, 24 h) in front of a fan. Results showed (data not given) that a lower temperature in drying procedure (drying in warm room) resulted in the least anthocyanin degradation during process.

Arabic gum (AG) was provided by Samchun Chemicals Company (Korea). Maltodextrin DE = 16–20 (M20) and DE = 4–7 (M7) was purchased from Sigma–Aldrich (Castle Hill, NSW, Australia). Analytical grade hydrochloric acid (HCL) and ethanol were purchased from Merck (Darmstadt, Germany). Distilled water was used for preparation of all solutions. All general chemicals used in this study were of analytical grade.

2.1. Saffron petal analysis

Some physicochemical properties of saffron's petal were analyzed including moisture content (AOAC, 2006), lipids (AOAC, 2006), proteins (AOAC, 2006), total ash (AOAC, 2006), total dietary fiber (AOAC, 2006), total reducing sugar (Fehling test) and total monomeric anthocyanins content by pH differential method (Lee et al., 2005).

2.2. Extraction and concentration of anthocyanins

For extraction of anthocyanins from saffron petals, the procedure of Srivastava and Vankar (2010) was adopted by some modifications. In every experiment, 12 g of dried saffron petals were mixed with 240 ml 50% ethanol (it was acidified with 2 N HCl up to pH = 2) in a dark colored bottle. After 24 h in 25 ± 1 °C, samples were filtered through a filter paper (Whatman no. 1). The ethanol content of permeate was removed under reduced pressure by a rotary evaporator (BÜchi 461, Switzerland) keeping the water bath temperature below 40 °C through 20 min until a level of 10 ± 0.5% soluble solids was reached.

Table 1
Physicochemical properties of saffron's petal and total monomeric anthocyanin content of its extract.

Constituents	Data	Ref. method
Proteins (g/100 g)	1.64 ± 0.09	AOAC (2006)
Lipids (g/100 g)	0.32 ± 0.01	AOAC (2006)
Total ash (g/100 g)	0.74 ± 0.01	AOAC (2006)
Fiber (g/100 g)	8.25 ± 0.04	AOAC (2006)
Total sugar (g/100 g)	1.67 ± 0.02	AOAC (2006)
Moisture (g/100 g)	87.11 ± 0.04	AOAC (2006)
Anthocyanins (mg/l extract)	1712.19 ± 60.24	Lee et al. (2005)

2.3. Preparation of microencapsulated powders

Wall materials including AG, M20 and M7 were mixed based on Response Surface Methodology (RSM) experiment design (Table 1) and dissolved in distilled water at ambient temperature (25 ± 1 °C) to obtain 40% total solids concentration. The solution was kept in refrigerator for complete hydration in 24 h. Then, extract of anthocyanins from saffron petal and wall materials were mixed in a weight ratio (w/w) of 1:5 (extract:wall material). The pH of mixtures was decreased to pH = 2 with HCl (1.5 N) to stabilize anthocyanins (Berg et al., 2012), then mixed with a rotor-stator (120 rpm, 10 min). Total anthocyanins of samples were measured through differential pH method (Lee et al., 2005) before drying. The solutions were dried in a freeze drier (Operon-Korea) for 42 h (−86 °C, 5 mbar). Dried materials were ground using a pestle and mortar and passed through a 0.71 mm mesh and stored in brown glass bottles with screwed caps in a freezer (−18 °C) until usage. In Fig. 1 the schematic procedure of the microencapsulation of saffron petal's extract by freeze drying technique has been depicted.

For preparation of blank sample, the concentrated extract (10 ± 0.5% soluble solids) without wall materials was acidified with HCl 1.5 N up to pH = 2 and then freeze-dried in similar conditions with other samples (−86 °C, 5 mbar) in 42 h.

2.4. Determination of physical properties of the powders

The moisture content of the powders was determined by vacuum drying (Schutzart, Germany) at 70 °C and 500 mbar for 24 h, followed by cooling to room temperature in desiccators, in the presence of excess amount of silica gel (Fang & Bhandari, 2011). Hygroscopic moisture of every 2 g powder samples was measured under saturated solutions of Na_2SO_4. After 1 week, hygroscopic

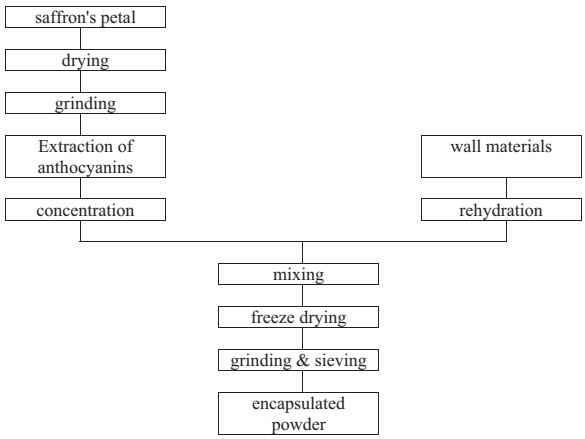

Fig. 1. Schematic description of the microencapsulation of saffron petal's extract by freeze drying technique.

moisture was expressed as gram of moisture per 100 g dry solids (g/100 g) to determine hygroscopicity (Ersus & Yurdagel, 2007). Water activity of powders was determined using a Lab master water activity meter (MinovaSina, Switzerland). Temperature was maintained at 25 ± 0.1 °C during the tests.

Bulk density (ρ_{bulk}) of powders was measured by weighing 10 g of samples and pouring them into a 10 ml graduated cylinder. The bulk density was calculated through dividing the powder mass by the volume occupied in the cylinder (g/cm^3) (Tonon et al., 2010).

2.5. Total anthocyanin content of the samples

0.2 g of each sample was dissolved in 10 ml of distilled water in a volume flask far from the light. The amount of anthocyanin was evaluated by pH differential method (Lee et al., 2005). Absorbance was measured at 510 nm and 700 nm. ACN was calculated as gram of cyanidin-3-glucoside per kilogram dry matter of powder after omitting weight of wall materials, using an extinction coefficient of 26,900 L cm^{-1} mg^{-1} and a molecular mass of 449.2 g mol^{-1}. Duplicate analysis was performed for each treatment.

2.6. Storage stability evaluation

Encapsulated powders were stored within brown bottles in 35 °C as an accelerated method (Tonon et al., 2010) to determine the effect of storage on anthocyanin contents of powders. Degradation of anthocyanins was monitored for 10 weeks and the anthocyanin content was analyzed weekly according to Lee et al. (2005).

2.7. Color measurement

In order to investigate the effect of storage on the color of encapsulated powders, for all samples after production and after 10 weeks storage, color was measured using computer vision adapted from Koocheki, Taherian, Razavi, and Bostan (2009) with some modifications. The system comprised of a digital camera (Canon A550, Kuala Lumpur, Malaysia), image-capturing box and image analysis software (Clemex Vision Professional, PE4, Longueuil, Canada). 0.5 g of powders was dissolved completely in 25 ml of distilled water. The indices of Hue angle ($H^o = \tan^{-1}(b/a)$), chroma ($C = \sqrt{a^2 + b^2}$) and total color differences (TCD) (TCD = $[(L_0 - L)^2 + (a_0 + a)^2 + (b_0 - b)^2]^{1/2}$) were calculated and the mean of three replicates were reported.

2.8. Scanning electron microscopy

Particle structures of the encapsulated powders were evaluated by S-360 scanning electron microscope (Cambridge, England). Powders were attached to SEM stubs using a 2-sided adhesive tape and left in desiccators containing phosphorous pentoxide for 48 h. Samples were coated with 200 Å gold under vacuum before examination. SEM was operated at an accelerating voltage of 8.80 kV.

2.9. Experimental design and statistical analysis

Simplex lattice design with augmented axial points in mixture design was used to obtain various properties of three wall materials including M20, M7 and AG to study the effect of different wall material formulas on stability and color properties of encapsulated freeze-dried powders. The entire triangular region consisting of 10 design points were performed twice. Design Expert 8.0 software (Statease Inc., Minneapolis, USA) was used for regression analysis, and to generate 3D surface and Cox response trace plots. Composition of wall materials at different design points is listed in Table 1.

General linear model of SPSS (Version 16.0, 2007) was used to conduct ANOVA for determination of differences between means. The probability levels of $P \leq 0.01$ and $P \leq 0.05$ were considered to be significant for statistical procedures. Some graphs were drawn by Excel (Microsoft Office 2007) and some by Design Expert 8.0. All measurements and trials were done in duplicate.

3. Results and discussion

3.1. Physicochemical characteristics of saffron's petal

In Table 1 some physicochemical properties of saffron's petal and the total anthocyanin of its extract based on cyanidin-3-glucoside have been represented.

3.2. Physical properties of encapsulated powders

Table 2 summarizes the results for physical properties of samples with different wall materials. As it can be seen, there were significant differences among samples in terms of bulk density ($P < 0.05$). This property varied between 1.35 and 2.22 g/cm^3 which the highest bulk density was related to the sample with 100% AG. Size of the crashed particles, frangibility and flow properties may influence the bulk density of produced powders. Tonon et al. (2010) in evaluating the bulk density of spray dried powders reported that higher molecular weight of Tapioca starch compared with maltodextrins (DE = 10 and 20) and Arabic gum made better movement of particles in empty areas, decreasing the total volume and increasing the bulk density.

The variation of a_w in samples was low (maximum a_w was 0.29) and there were no significant differences ($P < 0.01$) in a_w of final powders except in 100% M20 sample which had the highest a_w (0.29). Differences in hygroscopicity and moisture content were also significant ($P < 0.05$). There were no special trends in moisture content or hygroscopicity of samples but generally, the powders with a higher ratio of AG had less moisture contents.

3.3. Accelerated storage stability test

Stability of anthocyanins was evaluated during 10 weeks storage at 35 °C. Represented results are mean of two replicates (Fig. 2a and b). Least significant differences (LSD) test in SPSS software was used to determine the significance of differences between mean treatments. In all 10 formulas of encapsulated powders, there were no significant differences among total anthocyanins immediately after production and after 10 weeks storage ($P < 0.01$). Different compositions of AG, M20 and M7 as wall materials in represented 10 formulas did not show any significant differences in terms of protecting anthocyanins of saffron petal's extract ($P < 0.01$). Degradation of total anthocyanins in control sample (freeze-dried saffron petal's extract without encapsulation) during storage was significant ($P < 0.01$) and total anthocyanin decreased approximately 32% after 10 weeks storage in 35 °C.

Stability of anthocyanins within encapsulated powders in comparison with anthocyanins in control sample which degraded during storage showed the strong protective effect of encapsulation and wall materials against heat during storage. Jafari et al. (2008) reported that wall materials are physical obstacles which can decrease the effects of oxygen, light, heat and moisture on encapsulated ingredients. Oxygen is the most deteriorative agent for anthocyanins and its absence may decrease the negative effect of heat on anthocyanins too (Jackman, Yada, Tung, & Speers, 1987). Decrease in moisture content and a_w of extract which occurs during encapsulation (Jafari et al., 2008) are other protective agents in which their effects are totally based on reducing molecular mobility and increasing the viscosity of matrix in the glassy state (about

Table 2
Different treatments of wall materials based on mixture design for encapsulating saffron petal's extract and obtained physical properties for encapsulated powders.

Type of wall material and its content in formula				Physical properties of encapsulated powders			
Point type	Maltodextrin DE = 20	Maltodextrin DE = 7	Arabic gum	Moisture (%)	Hygroscopicity (%)	a_w	Bulk density (g/ml)
1	0	100	0	$3.85 \pm 0.01^{h*}$	$47.5 \pm 3.1^{a*}$	$0.055 \pm 0.0^{a**}$	$1.35 \pm 0.01^{a*}$
−1	16.7	16.7	66.7	2.2 ± 0.02^{c}	53.0 ± 1.0^{b}	0.031 ± 0.02^{a}	2.0 ± 0.01^{f}
2	50	50	0	3.13 ± 0.07^{g}	61.74 ± 2.6^{d}	0.126 ± 0.01^{a}	1.87 ± 0.02^{d}
−1	16.7	66.7	16.7	4.38 ± 0.04^{i}	58.41 ± 0.42^{c}	0.07 ± 0.02^{a}	1.53 ± 0.01^{b}
0	33.3	33.3	33.3	2.59 ± 0.03^{f}	$55.5 \pm 1.5b^{bc}$	0.043 ± 0.00^{a}	1.92 ± 0.03^{e}
2	0	50	50	3.9 ± 0.05^{h}	62.98 ± 1.89^{d}	0.031 ± 0.01^{a}	1.6 ± 0.02^{c}
−1	66.7	16.7	16.7	2.46 ± 0.04^{e}	63.47 ± 2.7^{d}	0.151 ± 0.02^{a}	2.00 ± 0.03^{f}
1	0	0	100	1.66 ± 0.02^{a}	58.3 ± 0.5^{c}	0.02 ± 0.00^{a}	2.22 ± 0.05^{h}
1	100	0	0	1.88 ± 0.06^{b}	46.6 ± 1.61^{a}	0.289 ± 0.03^{b}	1.90 ± 0.02^{de}
2	50	0	50	2.31 ± 0.04^{d}	47.26 ± 0.41^{a}	0.069 ± 0.02^{a}	2.16 ± 0.01^{g}

* significant at 0.05 level.
** Significant at 0.01 level.

10 Pa s) (Tonon et al., 2009). Roos (1995) and Fang and Bhandari (2011) reported that high molecular weight of wall materials and lower humidity made the molecular diffusivity of ingredients to be declined also made glass transition temperature to be increased and thus more entrapment of dispersed molecules happened. Overall these mentioned agents may describe the reasons of stabilizing effects of encapsulation for anthocyanins of saffron petal's extract.

3.4. Particle size and microstructure of encapsulated powders

Amorphous glassy shapes which were formed during dehydration, grounding and sieving of freeze-dried solid materials in the same condition, are clear in SEM micrographs of particles in Fig. 3.These glassy structures can protect entrapped anthocyanins from exposure to heat and oxygen (Roos, 1995). The micrographs also showed that higher amount of AG in wall formula made more friability of solids and then produced more tiny particles during crashing, so that, from images A to C in Fig. 3, the produced tiny particles are rising. There was more specific surface (rounded corners) and less particle differences in image A (100% M20). Differences in size of particles which is more obvious in sample C (100% AG) may indicate its highest bulk density and lowest special volume (2.22 ± 0.05 g/cm^3) (as shown in Table 1).

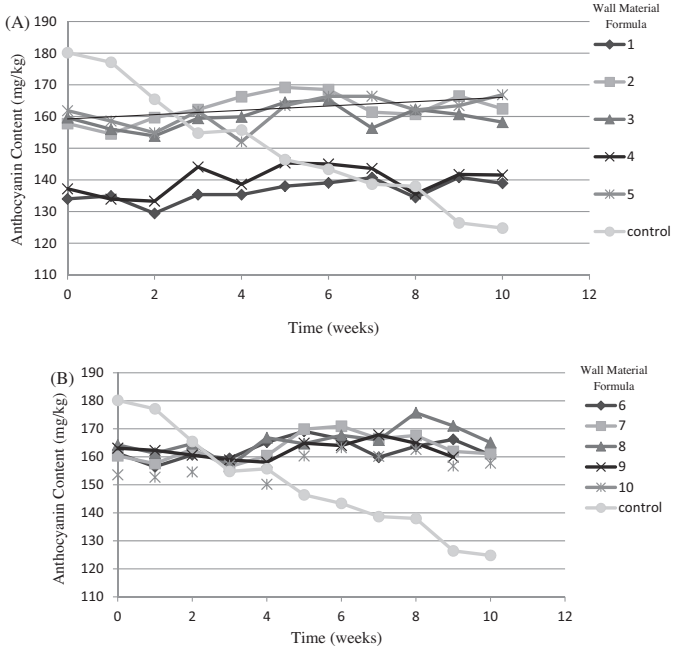

Fig. 2. Anthocyanin content of freeze dried microencapsulated powders with different wall materials during storage at 35 °C. (A) Formula 1: M7 (100), 2: M20, M7, AG (16.7, 16.7, 66.7), 3: M20, M7 (50, 50), 4: M20, M7, AG (16.7, 66.7, 16.7), 5: M20, M7, AG (33.3, 33.3, 33.3). (B) Formula 6: M7, AG (50, 50), 7: M20, M7, AG (66.7, 16.7, 16.7), 8: AG (100), 9: M20 (100), 10: M20, AG (50, 50).

3.5. Color evaluation of encapsulated powders

Results of color indices (a^*, b^*, L^*, C, H° and TCD) in encapsulated powders immediately after production and after 10 weeks storage in 35 °C are revealed in Table 3. All powders had a high value of color parameter a^* which was attributed to high anthocyanins content (Jimenez-Aguilar et al., 2011). Resulted differences of a^* after 10 weeks storage in formulas showed fluctuations but totally the highest differences of a^* and b^* (significant or not) was observed in the presence of 50% or more AG. All samples except powder with wall formula of M20, AG: 50, 50 showed a falling in b^* after treatment (in other words, the blueness increased). This mentioned sample and the one with wall formula M20, M7, AG: 16.7, 16.7, 66.7 had growth in L^* unlike others which had a reduction in lightness and their color got darker after storage. In the later sample, there was an increase in H° too, unlike other samples in which the hue angle decreased. Hue angle is attributed to the perceived color and showed the redness of all samples because hue angles were <10° (Jimenez-Aguilar et al., 2011). Skerede (1985) reported a decrease in b^* factor of black currant syrups during storage too. In general, changes of chroma (C

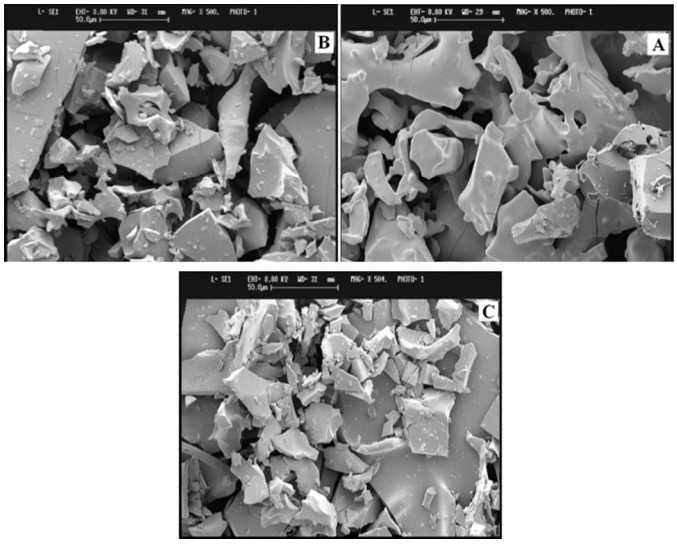

Fig. 3. Scaning electron micrographs of freeze-dried encapsulated powders. A (100% M20), B (50% AG), and C (100% AG).

Table 3
Color indices (a^*, b^*, L^*, C, H° and TCD) in different formulas of encapsulated saffron petal's extract after production (0) and after storage at 35 °C for 10 weeks (t).

Matrix components	a^*		b^*		L^*		C		H°		TCD
	a_0^*	a_t^*	b_0^*	b_t^*	L_0^*	L_t^*	C_0	C_t	H_0^o	H_t^o	
M7 (100)	22.11	22.96[m]	−5.62	−6.17[n]	64.54	60.21	22.81	23.77	−14.26	−15.04	4.48[c]
M20, M7, AG (16.7, 16.7, 66.7)	26.77	31.96	−9.38	−9.01[n]	40.62	55.94	28.77	33.21	−19.31	−15.74	16.13[h]
M20, M7 (50, 50)	26.34	26.60[m]	−6.50	−7.15[n]	62.28	57.65	27.13	27.54	−13.86	−15.04	5.11[d]
M20, M7, AG (16.7, 66.7, 16.7)	30.56	29.41[m]	−6.84	−7.59[n]	59.99	56.61	31.32	30.37	−12.62	−14.47	3.68[b]
M20, M7, AG (33.3, 33.3, 33.3)	28.84	28.78[m]	−6.71	−7.31[n]	61.11	57.42	29.61	29.69[n]	−13.10	−14.25	3.76[b]
M7, AG (50, 50)	28.20	31.53[m]	−6.77	−7.76	61.49	55.03	29.00	32.47[m]	−13.50	−13.83	6.48[f]
M20, M7, AG (66.7, 16.7, 16.7)	31.45	29.62[m]	−6.94	−7.68[n]	59.54	57.05[m]	32.21	30.60	−12.44	−14.53	3.21[a]
AG (100)	26.86	40.35	−5.79	−9.17	62.25	51.82	27.47	41.38	−12.16	−12.80	17.19[i]
M20 (100)	37.73	39.91[m]	−8.56	−9.18[n]	56.95	51.82	38.69	40.96	−12.78	−12.95[*]	5.64[e]
M20, AG (50, 50)	40.10	25.83	−7.40	−6.69	55.69	58.93	40.79	26.68	−10.46	−14.52	14.61[g]

[a–i] Means with different letters in columns differed significantly ($P < 0.05$).
[m] Insignificant differences in 0.05 level.
[n] Insignificant differences in 0.01 level.

factor) were influenced by a^* variations and there was no observed special trend for it and samples with wall formula of M20, AG: 50, 50 showed the deepest decline in chroma after storage.

TCD in samples was significantly changing from 3.21 to 17.19 and Duncan test showed the dispersion of data (Table 3). More TCD means more color changes during storage (Maskan, 2006). The powder with AG 100% showed the biggest TCD (17.19) and the sample with wall formula of M20, M7, AG: 66.7, 16.7, 16.7 represented the lowest TCD (3.21). Bchir et al. (2012) observed that in drying pomegranate seeds by increasing the air-drying temperature from 69 °C to 84 °C the hue angle and lightness values decreased and TCD increased. They reported that decrease in L^* values and increase in TCD indicate the seeds have become brownish. TCD in 3D surface plot (Fig. 4) showed that area for maximum TCD was closed to the points with higher AG. On the other hand, points with higher amounts of M7 and M20 showed lowest content of color differences. As it could be seen from contour plot (Fig. 5) between M20 and M7, the M20 had somehow more effect on TCD and it may refer to its higher free aldehydes heads and their ability to interact with anthocyanins during storage. Ersus and Yurdagel (2007) observed that color of anthocyanins during spray drying with increasing the DE of maltodextrins became more pale (bright and purple shade of red color) in comparison with maltodextrins with lower DE.

By looking at Cox trace plot (Fig. 5) it is obvious that color differences during storage increased as the amount of AG increased from midpoint of triangular simplex design (where all three components were in equal proportion). Cox plot showed that color differences decreased with a reduction in M7 or increase in AG in compositions and increase or decrease of another compound, respectively. Yousefi, Emam-Djomeh, and Mousavi (2011) in their investigation on microencapsulation of pomegranate juice with spray drying

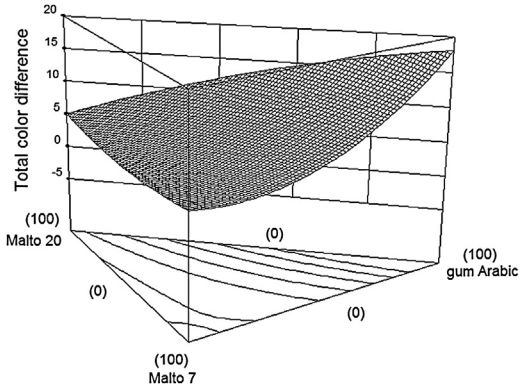

Fig. 4. 3D surface plot of total color differences (TDC) in encapsulated freeze dried saffron petal's extract during 10 weeks storage at 35 °C.

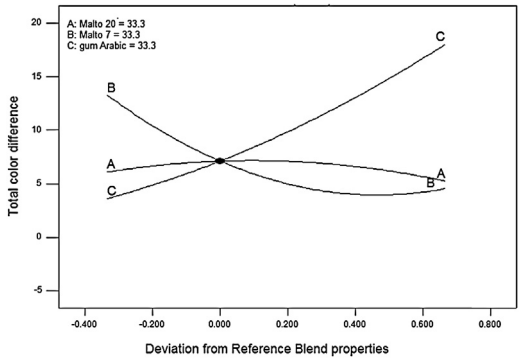

Fig. 5. Cox response trace plot of total color differences in encapsulated freeze dried saffron petal's extract during 10 weeks storage at 35 °C.

observed that between maltodextrin, Arabic gum and waxy starch as wall materials, Arabic gum had the highest effect on TCD. They obtained a high browning index for powders with Arabic gum and reported that high TCD was related to structural properties. They also reported that coloring agents may be absorbed into the carrier agents.

4. Conclusion

In conclusion, encapsulation of saffron petal's extract with freeze-drying technique and wall materials AG, M20 and M7 could protect anthocyanins during storage. However, Arabic gum due to its suitable properties could be used in microencapsulation of such ingredients widely and in different techniques. Our results showed that M20 and M7 in comparison with AG made less TCD during treatment. This fact, along with their low cost and ability to stabilize anthocyanins can make them appropriate wall materials in freeze drying microencapsulation of anthocyanins.

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