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Osmo-Dehydration of Strawberries Coated with Arabic Gum using Response Surface Optimization

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Abstract

The aim of present study was to optimize the osmo-dehydration process condition of strawberries coated with Arabic gum. The dependent variables were osmotic agent concentration (40% to 60% w/w), immersion time (12-48 h), coating concentration (0% to 2% w/w) and storage duration (0-4 months). The experiments were designed according to central composite design and osmo-air dehydrated strawberries were evaluated for density, water content, colorimetric parameters, total anthocyanin content and antioxidant activity. It was found that Arabic gum effectively contributed in retention of colour and nutrient content while it showed significantly negative effect on water content ($p<0.05$). Elongation of process duration and storage time led to major losses ($p<0.01$) of product quality. Response surface methodology (RSM) revealed that osmo-dehydration of strawberries coated with 1.3% Arabic gum in sucrose solution of 50.64% w/w concentration for 12 h would give best performance in term of nutrient content and colour retention as well as product humidity and density over 67 days of storage time.

Keywords: Strawberry; Arabic gum; Osmo-dehydration; Response surface methodology

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Introduction

Strawberries (*Fragaria vesca* L.) have a unique aromatic taste and prosperity of cherished nutrients [1]. The nutritional qualities of the berries are ascribed to the presence of phenolic compounds. Although not essential for human life, phenolic compounds may act as a health promoting factor, if consumed over a long period of time [2]. It is noteworthy that phenolic compounds demonstrated a suitable antioxidant and antimicrobial properties that nominate them as supportive to the natural defences of the human body and reducing the risk of certain cancers and cardiovascular diseases [3]. Strawberries rich in different phenolic compounds including ellagic acid, ellagic acid glycosides, p-coumaric acid derivatives, ellagitannins, gallotannins, anthocyanins, flavanols, flavanols and coumaroyl glycosides. The anthocyanidins were pelargonidin and cyanidin, found chiefly as their glucosides and rutinosides forms. The major flavanol aglycons were quercetin and kaempferol found as their glucuronides and glucosides [4,5]. Because of the seasonality and delicate texture, fresh strawberries are available only for a few months a year.

One of the approaches of extending the postharvest life of strawberries is osmotic dehydration, which also makes it possible to alter the composition of the hydration raw materials. The process consists in submerging hydration raw materials of cellular structure in a hypertonic solution [6]. During the process, the water existing in the tissues is liberated to the solution and mass transfer occurred between the solution and tissue components. Generated gradient of osmotic pressure between the osmotic solution and the vacuolar sap of the fresh raw materials exposed to dehydration is the main driving force of the process at low temperatures and short processing times. Water and substances from the sap are exchanged through the plant material semipermeable cell membrane [2]. It is observed that the osmotic dehydration process decreases the amount of initial water content to about 50%, reduces the weight and volume of the product and improves the organoleptic features of the finished products. Additionally, the lack of oxygen during the process can hinder the oxidation and enzymatic browning of plant constitutes [7]. Diffusion phenomena are responsible for controlling the transfers at higher temperatures and long process

times. Accordingly, unfavorable changes comprising the loss of semi-permeability of cell membranes, high sugar incorporation and substantial losses in valuable nutrients may achieved due to the inadequate handling of dehydration parameters in the dehydrated material [8]. So, the employing osmotic dehydration can result in substantial quality improvement and considerable economic benefits, due to increased product competitiveness compared to alternative processes.

Osmotic treatment can be used as a major pre-treatment prior to a wide range of processing schemes, including whole drying, pasteurization and freezing. Osmotic dehydration commonly includes substantial water removal (40% to 70% loss of initial moisture) with much lower uptake of osmotic solute, largely depending on osmotic solute and process conditions. Abundant solute uptake is considered undesirable for osmotic dehydration purposes, because of adverse impact on the natural product profile. Thus, many researches have focused on techniques to monitor solute uptake [9,10]. Former efforts have presented that, solute penetration mainly depends on solute molecular size and process parameters, comprising solution concentration and process temperature. Pre-coating the plant goods to be dehydrated with an artificial, edible barrier was also found as a way to efficiently hamper solute penetration, without a serious undesirable impact on the water removal rate [11].

Edible coatings mainly originated from lipids, polysaccharides, resins and proteins and also a mixture of these materials forms the new composite edible coatings which can limit lipid, oxygen, water vapor and flavor migration between food and the surroundings. Low-methoxyl pectinate, high-methoxyl pectinate, methyl cellulose, carboxyl methyl cellulose, maltodextrin, potato starch, corn starch, sodium alginate, chitosan and different gums can be employed as coating solutions to prevent solid gain and improve organoleptic properties, shelf-life and nutritive properties of vegetables and fruits during osmotic dehydration [12].

One of the gums that exploited as a coating agent is Arabic gum which widely used as an additive in food materials e.g. confectionery, ice-cream industries and bakery products. It is classified as an edible coating and it is used to increase stability and shelf-life by increasing the cell wall thickness and to enhance microbial safety of fruits.

The objective of this study was to optimize the influence of sucrose solution and Arabic gum pre-treatments on physicochemical properties and bioactive compounds alteration of osmo-hydrated strawberries during the storage which Arabic gum was not used to coating the osmo-hydrated strawberries till now.

Materials and Methods

Chemicals and reagents

Fresh strawberries cv. Kurdistan acquired from a local market in Sanandaj (Kurdistan, Iran) and stored at 30°C for two weeks before testing. Absolute methanol and 2,2-diphenyl-1picrylhydrazyl (DPPH) reagent were purchased from Merck (Darmstadt, Germany). Also, Arabic gum and citric acid were obtained from Scharlau Co. (Barcelona, Spain). All other chemicals used in this study were of analytical grade quality.

Preparation of osmotic solutions

The ingredients of prepared osmotic solutions were sucrose, Arabic gum, citric acid and distilled water. Calculating the concentrations was based on w/w. The solutions variables were the Arabic gum and sucrose concentrations, while the amount of citric acid (2%) and distilled water were constant. The fruit to osmotic solution ratio set at 1:5 in all experiments.

Osmotic dehydration and hot-air drying

Strawberry slices poured into plastic osmotic solution container after weighting so that slices immersed in the solution. During the immersion, the mixture is stirred periodically (every 2 hours for 5 min) to obtain uniform product. Dehydration process was conducted at constant temperature of incubator (30°C). After immersion, strawberry slices removed from osmotic solution and submerged in cold water to eliminate surface sucrose. Then, surface moisture removed with special filter papers, now samples are ready to transfer to hot-air dryer (at 30°C 122 for 8 h; with 1.2 m/s rate). Finally, osmo-hydrated slices were cooled for 10 min at room temperature, packaged in polyethylene bags and maintained in a dry place to carry out various experiments.

Physical parameters

Water content was determined first by oven-drying of the samples at 105°C for 48 h. for calculating the pH value, the samples were thoroughly uniformed with a mixer and pH were recorded by pH-meter (Modell A420, Orion, USA). In order to evaluate the density of samples, 100 strawberry fruits were randomly selected and weighted, then their apparent density were calculated as follow:

$$\rho_b = \frac{m}{v_b}$$

where m and v_b are the mass and volume of the selected samples, respectively.

Surface colour assessment

A colorimeter apparatus (Minolta CR 400 Series, Osaka, Japan) was employed to determine the colour of the strawberries. Previously, the apparatus was adjusted using a standard white plate and standard colour parameters (L'= 84.71, a'=+1.26, b'=−3.5). Then, the samples were 139 positioned on a standard white plate and colour parameters were determined. The calculated 140 parameters were L (lightness), a (red-green) and b (blue-yellow). Hence, total colour variation from standard (ΔE), browning index (BI), hue angle (H*) and chroma (ΔC or C*) 142 were calculated according to the following equations [13]:

$$\Delta E\sqrt{(L'-L)^2+(a'-a)^2+(b'-b)^2}$$

$$BI = \frac{100}{0.17}\left(\frac{a+1.75L}{5.645L+a-3.012b}-0.31\right)$$

$$\Delta C = \sqrt{(a)^2+(\mathrm{b})^2}$$

$$H = Tan^{-1}(b/a)$$

The results were expressed as the average of three measurements from five points of each sample.

Antioxidant activity

DPPH (2,2-diphenyl-1-picrylhydrazyl) scavenging capacity of the extracts was evaluated according to Garavand et al, with some modifications [14]. Briefly, after being diluted in distilled water (1:10), 0.1 mL of the extract was mixed with 3.9 mL methanolic DPPH 154 solution (25 mgL^{-1}). The mixture was vortexed severely and left to stand for 30 min at room temperature. A DPPH solution with no added extract was considered as the control. The inhibition percentage of DPPH was measured at 517 nm according to the following equation:

$$\text{Inhibition of DPPH}(\%) = \frac{A_{control} - A_{sample}}{A_{control}} \times 100$$

Where A_{sample} and $A_{control}$ are the absorbance of the extract sample with DPPH and the absorbance of the DPPH solution without extract, respectively.

Determination of total anthocyanin content (TAC)

The total anthocyanin content of the strawberries was determined by the pH differential method which is a spectrophotometric assay that involves absorbance measurement of extracts at pH 1.0 and 4.5 [15]. The absorbance of the samples was determined at 520 and 700 nm using spectrophotometer and total anthocyanin content (mg/L) was stated as cyanidin-3-glucoside according to the following equation:

$$TAC(mg/L) = \frac{A \times MW \times DF \times 1000}{\varepsilon \times C}$$

where A is absorbance of samples and calculated as follow:

$A=(A_{515} - A_{700})$ pH 1:0 – $(A_{51}5 - A_{700})$ pH 4.5

MW is molecular weight of malvidin-3-glucoside=449.2 g/mol; DF is dilution factor, ε is 171 molar absorptivity of cyanidin-3-O-glucoside=26,900; and C is the concentration of the buffer in mg/ml. The obtained results were represented as mg cyanidin-3-glucoside 173 equivalents/g Dry sample (mg c-3-gE/Kg Dry matter).

Experimental design and statistical analysis

The optimum osmo-dehydration process condition, coating concentration and storage time 177 for strawberries were determined according to a statistical design by RSM. The independent variables were osmotic agent concentration, immersion time, coating concentration and storage duration. Responses were density, water content, colorimetric parameters (L*, C* and H*), total anthocyanin content and antioxidant activity. A central composite design (CCD) with four factors at five levels was performed to generate 30 runs. Coded and decoded settings of the process parameters are presented in **Table 1**. The design comprised of 16 factorial points, 6 replicates of the central point and 8 axial points. Factorial points were employed to estimate the linear and interaction effects while center points provide the possibility of checking for curvature in response and axial points are used to estimate the quadratic terms [16]. A second-order polynomial equation was fitted to the experimental data of responses:

$$Y = \beta_0 + \sum_{i=1}^{5} \beta_i X_i + \sum_{i=1}^{5} \beta_{ii} X_i^2 + \sum_{i=1}^{4} \sum_{j=i+1}^{5} \beta_{ij} X_i X_j + \varepsilon_{ij}$$

where Y is the response, β0, βi, βii and βij are coefficients for intercept, linear, quadratic and 190 interaction coefficients, respectively and Xi and Xj are the independent variables. Minitab 15 Software was used for response surface analysis, plotting the graphs as well as response optimization.

Results and Discussion

Water content and density

The effects of process variables on water content and density of coated strawberries during and after osmotic dehydration are presented in **Table 2**. It is evident from the table that the density of osmotically dehydrated strawberries was remarkably ($p<0.01$) dependent on osmotic solution concentration while it only showed a negligible negative effect on their water content. It is believed that surrounding the fresh fruit by a highly concentrated solution during osmotic dehydration provides strong driving force between hypertonic solution and fruit tissue for mass transfer of fruit water into the solution and osmotic agent into the fruit tissue which in turn may lead to a denser dehydrated fruit [17]. There have been many researches on increased water loss and solid gain of osmo-dehydrated fruits with increasing the osmotic solution concentration [18-20]. However, it has been pointed out that increasing the sugar concentration beyond a certain level reduced the water loss attributed to crystallization of sugar at high solution concentration which prevented moisture removal from the fruit [21]. The results indicated that there would be drastic increase in density ($p<0.01$) and a decreased water content ($p<0.05$) as osmotic dehydration process progressed **(Table 2).** It has been found by some researchers that most of sucrose gain and water loss of strawberries took place in initial hours of immersion time [22]. This trend has also been observed by other researchers during osmo-dehydration of potato, pineapple, carrot, cucumber and so on [18,19,23,24]. This might be as a result of reaching equilibrium between cellular fluids and osmotic solution at longer process duration [21]. As deduced from the **Table 2**, the strawberries coated with higher concentration of Arabic gum significantly ($p<0.01$) showed resistance to water

Table 1 Coded and decoded levels of the process parameters for osmo-dehydration of 5 strawberries based on a central composite design.

Dependent variables	Level				
	-2	-1	0	1	2
X1: Sucrose concentration as osmotic agent (g/100 ml)	40	45	50	55	60
X2: immersion time (h)	12	21	30	39	48
X3: gum Arabic concentration as coating material (g/100 ml)	0	0.5	1	1.5	2
X4: storage time (month)	0	1	2	3	4

loss and sugar gain. This is in line with the results of Khin et al. who observed that coating the apples with hydrophilic coating materials considerably decreased the water loss during osmotic dehydration over low process temperatures [25]. However, coating has been shown as an effective pre-treatment strategy to hinder sugar penetration into the food without a serious negative effect on water loss [11,26]. These differences between barrier properties of different coatings can be interpreted through their compositions and the methods used for their fabrication [11].

The interaction effect of coating concentration × osmotic agent concentration on density is depicted by response surface plot **(Figure 1)**. Model equations are visualized in the form of three-dimensional surface plots which are constructed by plotting the dependent variable on the Z-axis versus any two independent variables while the other variable is set on the middle level [16]. As can be seen, at lower osmotic solution concentration, the strawberries treated with higher concentration of Arabic gum were more resistant against sugar uptake and thus increasing density whereas, the rate of sugar gaining and increasing the density was promoted when osmo-dehydration was performed in

Table 2 Analysis of variance (ANOVA) 33 for density (Y1) and water content (Y2).

Source	DF	Sum of Squares		Mean Square		F-value		P-value	
		Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
Regression	14	0.123	26.31	0.008	1.87	9.78	12.1	0	0
Linear	4	0.099	17.53	0.024	4.38	27.58	28.22	0	0
Quadratic	4	0.014	7.07	0.003	1.76	4.05	11.38	0.02	0
Interaction	6	0.009	1.71	0.001	0.28	1.72	1.84	0.184	0.159
Residual Errors	15	0.013	2.32	0	0.15	-	-	-	-
Lack-of-Fit	10	0.011	1.63	0.001	0.16	2.88	1.17	0.128	0.457
Pure Error	5	0.002	0.69	0	0.13	-	-	-	-
Total	29	0.136	28.64	-	-	-	-	-	-

Other statistics	Y_1		Y_2	
Source	**b-coefficient**	**p-value**	**b-coefficient**	**p-value**
Intercept	1.37	0	18.048	0
X_1	0.09	0	-0.105	0.524
X_2	0.08	0	-0.398	0.026
X_3	-0.045	0.012	1.115	0
X_4	0.005	0.689	-1.228	0
$X_1 . X_1$	-0.06	0.019	0.142	0.643
$X_2 . X_2$	-0.07	0.008	0.442	0.162
$X_3 . X_3$	-0.04	0.101	0.627	0.055
$X_4 . X_4$	-0.04	0.101	1.987	0
$X_1 . X_2$	0.05	0.116	-0.085	0.832
$X_1 . X_3$	0.075	0.025	-0.06	0.881
$X_1 . X_4$	-0.025	0.418	0.46	0.261
$X_2 . X_3$	-0.015	0.624	-0.28	0.448
$X_2 . X_4$	0.015	0.624	0.17	0.672
$X_3 . X_4$	0.01	0.743	1.175	0.009
R^2	0.901	-	0.919	-
R^2-adjust	0.809	-	0.843	-

X_1, X_2, X_3 and X_4 are osmotic agent concentration, immersion time, coating concentration and storage time, respectively

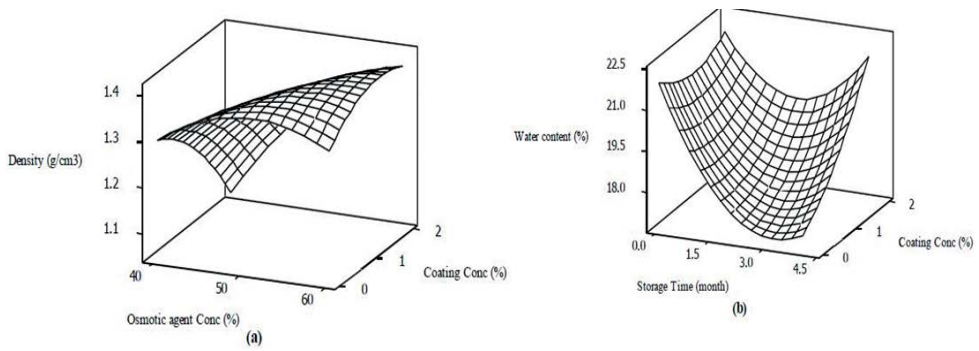

Figure 1 Response surface plots for interaction effects of (a) coating concentration × osmotic agent concentration on density and, (b) coating concentration × storage time on water content of strawberries during and after osmotic dehydration.

more concentrated osmotic solution. From the response surface graph **(Figures 1a and 1b)**, at initial days of storage, coating showed higher water permeability possibly due to larger driving force for mass transfer of water but the longer the storage time, the more effective were coatings against humidity reduction. In consistent with our results, Castell et al. reported notable water lost for non-coated osmo-dehydrated strawberries during storage. On the other hand, Garcia et al indicated that coating the minimally processed strawberries with cassava starch enhanced their resistance to water vapor during storage [27,28].

Colour changes

The results revealed that strawberries osmotically dehydrated in higher concentration of sucrose solution showed better performance in term of colour retention **(Table 3)**. As presented in the **Table 3**, there is a significant enhancement in lightness and C* value with osmotic agent concentration ($p<0.01$). Similarly, it was reported that an increase in redness of carrot cubes dehydrated in more concentrated osmotic solutions [20]. It is thought that increased diffusion of osmotic agent into the fruit cell at higher solution concentration **(Table 2)** might cause disruption of plasma membranes and cell walls resulted in spreading out the carotenoids, responsible for redness and yellowness of fruits, throughout the cell which in turn might lead to higher C* value [29]. **Figures 2a-2c** shows that rising trend of C* with increase of osmotic solution concentration experienced a reduction as coating concentration was promoted possibly due to barrier effect of coating against sugar uptake.

In disagreement with our results, in an effort to study the process variables on colour retention of cherry tomato during osmotic dehydration found a decreased lightness over higher osmotic solution concentration [29]. Our observation on increasing the L* with osmotic solution could be explained by limited enzymatic browning reaction at higher osmotic solution concentration [13]. The results indicated a strong positive relationship between process duration and H* value ($p<0.01$) while L* ($p<0.01$) and C* ($p<0.05$) values were affected negatively as osmotic dehydration progressed **(Table 3)**. Similar results were reported by other researchers and [20,29]. The reducing effect of process length on food lightness during osmotic dehydration seems to be mainly because of shrinkage of cellular structure due to water loss which consequently resulted in sample opacity [29]. Likewise, less saturation must be responsible for changing the vivid colour of fresh strawberries to the pale appearance (lower C* and higher H*) of the dehydrated samples [30]. The deceased lightness might be as well arisen from increased oxygen solubility at longer immersion time which might promote enzymatic browning [13]. A better colour retention has been reported for

Table 3 Analysis of variance 46 (ANOVA) for colorimetric parameters.

Source	DF	Sum of Squares			Mean Square			F-value			P-value		
		L*	C*	H*	L*	C*	H*	L*	C*	H*	L*	C*	H*
Regression	14	754.51	352.95	0.067	53.89	25.21	0.0048	6.68	20.75	9.55	0	0	0
Linear	4	600.39	309.64	0.054	150.09	77.41	0.0135	18.62	63.7	26.96	0	0	0
Quadratic	4	69.97	9.14	0.009	17.49	2.28	0.0023	2.17	1.88	4.6	0.122	0.166	0.013
Interaction	6	84.16	34.16	0.003	14.02	5.69	0.0006	1.74	4.69	1.24	0.18	0.007	0.341
Residual Errors	15	120.95	18.22	0.007	8.06	1.21	0.0005	-	-	-	-	-	-
Lack-of-Fit	10	103.45	8.32	0.005	10.34	0.83	0.0005	2.96	0.42	1.1	0.122	0.886	0.486
Pure Error	5	17.49	9.9	0.002	3.49	1.98	0.0004	-	-	-	-	-	-
Total	29	875.46	371.18	0.074	-	-	-	-	-	-	-	-	-

Other statistics	L*		C*		H*	
Source	b-coefficient	p-value	b-coefficient	p-value	b-coefficient	p-value
Intercept	44.5767	0	30.1667	0	0.597	0
X_1	5.0558	0.001	4.4383	0	0.017	0.075
X_2	5.0575	0.001	2.3483	0.012	0.032	0.003
X_3	6.4958	0	4.6283	0	0.085	0
X_4	2.5942	0.041	2.23	0	0.017	0.075
$X_1 . X_1$	4.9821	0.036	1.3758	0.123	0.039	0.035
$X_2 . X_2$	1.7371	0.436	1.6208	0.073	0.029	0.105
$X_3 . X_3$	2.0921	0.35	1.3808	0.122	0.064	0.002
$X_4 . X_4$	4.5371	0.054	0.0642	0.94	0.014	0.408
$X_1 . X_2$	4.9225	0.103	0.13	0.908	0.007	0.743
$X_1 . X_3$	6.1875	0.066	5.38	0	0.017	0.447
$X_1 . X_4$	0.3225	0.911	0.08	0.943	0.017	0.447
$X_2 . X_3$	0.9275	0.049	1.185	0.299	0.017	0.447
$X_2 . X_4$	0.9225	0.75	1.855	0.113	0.002	0.913
$X_3 . X_4$	4.4525	0.138	0.595	0.597	0.052	0.033
R^2	0.862		0.951		0.899	
R^2-adjust	0.733		0.905		0.805	

X1, X2, X3 and X4 are osmotic agent concentration, immersion time, coating concentration and storage time, respectively

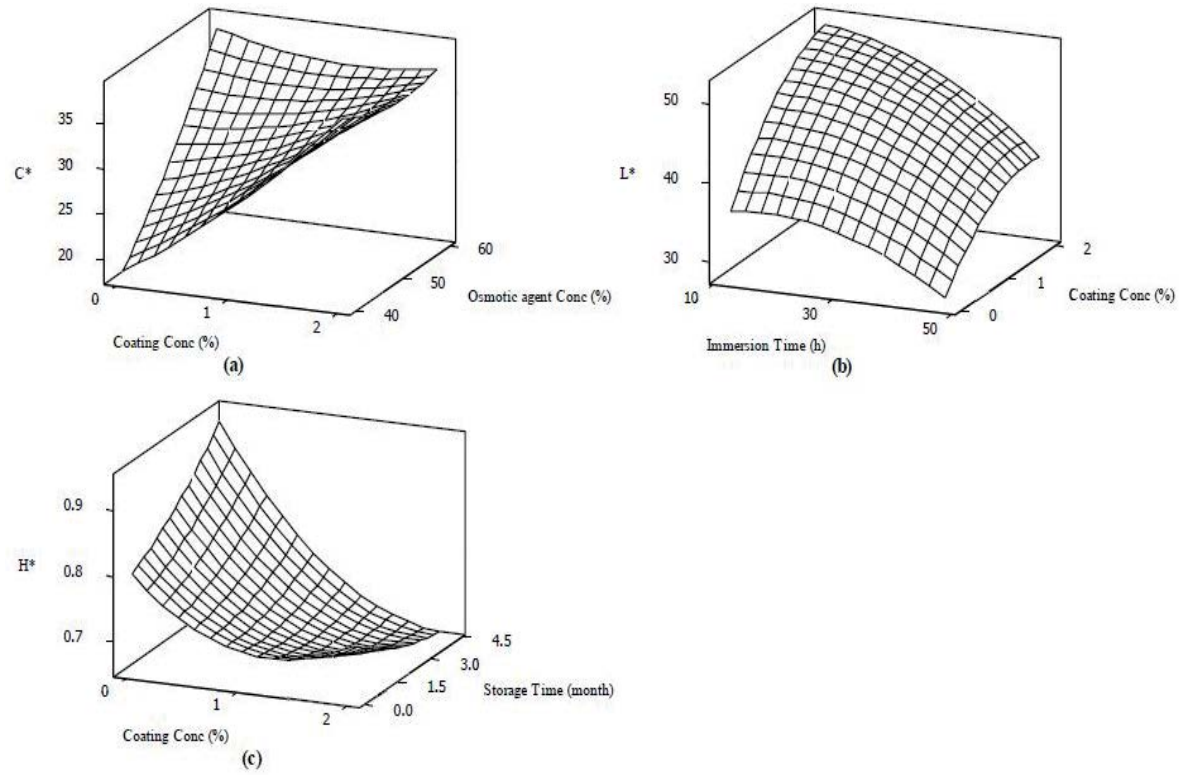

Figure 2 Response surface plots for interaction effects of (a) coating concentration × osmotic agent concentration on C*, (b) coating concentration × immersion time on L* and, (c) coating concentration × storage time on H* of strawberries during and after osmotic dehydration.

osmo-dehydrated samples when a blanching step was carried out before process [31,32]. It is important to mention that decreasing effect of process duration on lightness was less strong for strawberries coated with higher concentration of Arabic gum **(Figure 2b)**. The beneficial effect of coating on colour retention of strawberries can also be observed during storage **(Figure 2c)**. The osmo-dehydrated samples tended to show larger H* during storage but at higher coating concentration, their tendency was affected negatively it was observed that there was severe decrease in L* and b* of osmo-dehydrated seaweed over shelf life [32]. As shown in **Table 2**, elongation of storage time resulted in a significant reduction in C* and L* of dehydrated strawberries. This could be closely related to microstructure modification of strawberries during mass exchange of osmotic dehydration which might damage fragile membrane of carotenoids facilitating their oxidative or enzymatic degradation over storage [33]. However, scanning electron microscopy results of some researchers indicated that cellular structure of the coated apples was better maintained compared to the non-coated samples against mechanical damages during osmotic dehydration [25].

Total anthocyanin content and total antioxidant activity

Data showed that fresh strawberries experienced substantial losses of 53.28-74.69% in total anthocyanin compounds during osmotic dehydration and shelf life concluded that anthocyanin concentrations of dehydrated blueberries are significantly lower in those osmotically pre-treated compared to untreated ones [2]. Changes in anthocyanin content and antioxidant activity of strawberries followed the same pattern **Table 4** as the antioxidant properties in berries mainly come from anthocyanins and phenolics [34].

Statistical analysis revealed that immersion time had the most significant negative effect ($p<0.01$) on the total anthocyanin content and antioxidant activity. observed an approximately 60% losses in anthocyanins and phenolics for blueberries osmo-concentrated in sucrose solution for 12 hours. This phenomenon is mostly related to migration of anthocyanin compounds to dehydrating solution along with water transfer [7,34]. As implied by **Figure 3**, increasing the coating concentration could effectively prevent anthocyanin leakage into the osmotic solution.

Our results indicated that storage duration had the same effect on anthocyanin content and antioxidant activity of strawberries as immersion time **(Table 4)**. Significant reduction of anthocyanin during storing has previously been reported for cherries [35].

Optimization

Optimization of the osmotic dehydration condition for strawberries was conducted to reach maximum colour retention and nutritional quality and minimum density and humidity during dehydration process as well as storage time. The optimum conditions yielded by RSM are presented in **Table 5**. The performance of models in predicting the optimum condition was verified using one-sample t-test. The strawberries were osmotically dehydrated under optimum condition and the responses of

Table 4 Analysis of variance (ANOVA) for anthocyanin content (Y1) and antioxidant activity (Y2).

Source	DF	Sum of Squares		Mean Square		F-value		P-value	
		Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2
Regression	14	133617	317.64	9544.1	22.68	5.92	9.18	0	0
Linear	4	122236	248.16	30559	62.04	18.97	25.1	0	0
Quadratic	4	2250	15.025	562.5	3.75	0.35	1.52	0.841	0.247
Interaction	6	9131	54.455	1521.8	9.07	0.94	3.67	0.493	0.019
Residual Errors	15	24165	37.084	1611	2.47	-	-	-	-
Lack-of-Fit	10	10923	30.221	1092.3	3.02	0.41	2.2	0.891	0.199
Pure Error	5	13242	6.863	2648.4	1.37	-	-	-	-
Total	29	157782	354.7	-	-	-	-	-	-

Other statistics	**Y1**		**Y2**	
Source	**b-coefficient**	**p-value**	**b-coefficient**	**p-value**
Intercept	515.578	0	79.358	0
X_1	0.278	0.987	0.875	0.193
X_2	99.452	0	4.143	0
X_3	78.79	0.003	4.41	0.002
X_4	65.377	0.005	1.995	0.007
$X_1 . X_1$	4.139	0.894	0.219	0.858
$X_2 . X_2$	15.491	0.622	1.194	0.336
$X_3 . X_3$	23.921	0.447	2.544	0.051
$X_4 . X_4$	25.896	0.412	1.644	0.191
$X_1 . X_2$	61.18	0.148	0.2	0.9
$X_1 . X_3$	1.065	0.979	0.71	0.658
$X_1 . X_4$	13.8	0.736	0.405	0.8
$X_2 . X_3$	9.415	0.818	6.79	0.001
$X_2 . X_4$	24.99	0.543	0.735	0.647
$X_3 . X_4$	66.955	0.116	2.665	0.111
R^2	0.847		0.895	
R^2-adjust	0.704		0.798	

X1, X2, X3 and X4 are osmotic agent concentration, immersion time, coating concentration and storage time, respectively

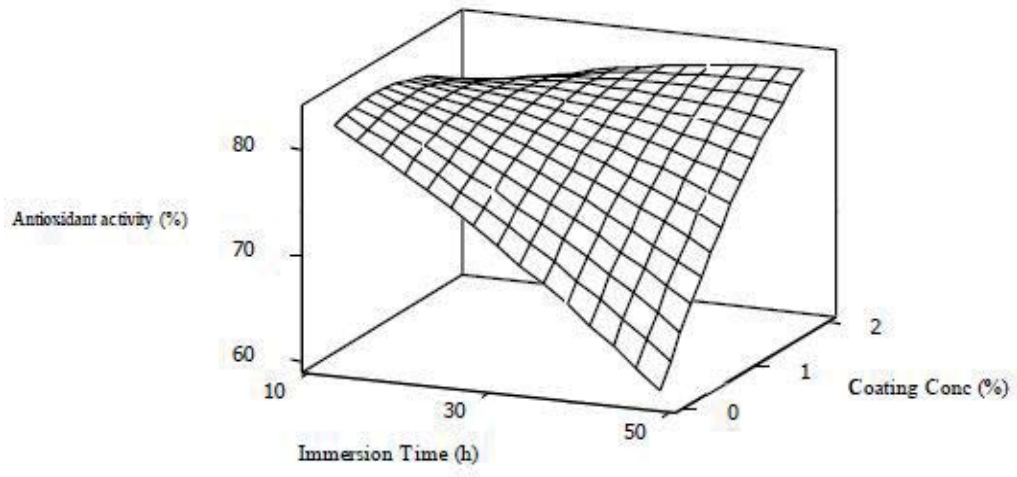

Figure 3 Response surface plot for interaction effects of coating concentration × immersion time on antioxidant activity of strawberries during and after osmotic dehydration.

interest were determined at the end of the desire storage time. The results of one-sample t-test confirmed that predicted and measured characteristics of osmo-dehydrated strawberries did not statistically differ with a 95% of confidential level.

Table 5 Performance of models in predicting optimum 70 storage time and osmo-dehydration 71 condition. *Mean ± standard deviation (n=3).

Response	Optimum storage time and osmo-dehydration condition				Predicted value	Experimental value *	Std. error mean	Mean difference	p-Value
	Sucrose conc (%)	Immersion time (h)	Coating conc (%)	Storage time (d)					
	50.64	12	1.23	67					
Water content (%)	-	-	-	-	19.13	18.87 ± 0.96	0.56	-0.45	0.695
Density (g/cm3)	-	-	-	-	1.21	1.22 ± 0.04	0.023	0.71	0.549
Lightness (L*)	-	-	-	-	49.11	42.55 ± 3.12	1.803	-3.64	0.068
Chroma (C*)	-	-	-	-	34.73	33.11 ± 5.41	3.126	-0.52	0.657
Hue angle (H*)	-	-	-	-	0.681	0.725 ± 0.044	0.021	2.18	0.161
Anthocyanin content (mg/kg)	-	-	-	-	612.92	502.77 ± 45.27	26.13	-4.21	0.052
Antioxidant activity (%)	-	-	-	-	81.58	73.15 ± 4.29	2.47	-3.4	0.077

Conclusion

The osmotic dehydration process can be employed for prolonging the shelf-life of food products for the purpose of use during off-season. Our results revealed that despite having negative effect on water loss, Arabic gum played a decisive role in retention of colour and nutrient content of strawberries not only during osmotic dehydration but also over shelf life. So, the osmo-dehydrated strawberries in this study have a good capability to be used as preserves, fruit juice, pies, ice creams, milkshakes, and chocolates.

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