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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Optimization of Drying Conditions of Kiwi Rings with Osmo-solar Dehydration*

Ozmo-solar Dehidrasyon Kurutma ile Kivi Halkalarının Kurutma Koşullarının Optimizasyonu

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Abstract

It is the oldest and most common traditional food preservation method known to dry by laying food products under the sun. However, if the food product is in direct contact with the sun light, there is a decrease in the color and nutrient values of the product. To solve these problems, solar dryers have been developed which can be utilized due to indirectly the effect of the sun. In this study, kiwi rings were dried by using osmosolar dehydration as a combination of osmotic dehydration and solar drying. Kiwi rings were first immersed in sucrose solutions and then dried in a solar dryer. Response Surface Methodology used to determine effects of the conditions ondrying performance and find out optimum levels drying conditions for the responses to a safe level. In the response surface method, the drying conditions were selected as the kiwi slice thickness (A), sucrose concentrations (B), immersed time (C) and solar drying time (D). The response to be optimized was chosen as water loss, diameter shrinkage ratio and greenness (*a*) color change. A successful mathematical model was obtained by the response surface method between the drying conditions and the responses. The suitable model is chosen quadratic for water loss, 2FI model for color change model and shrinkage ratio. The model R^2 value is 0.952 for water loss, 0.737 for *a* color change and 0.856 for shrinkage ratio. The regression coefficients, along with the corresponding P-values, for the model of production water loss, *a* color change and shrinkage ratio are described by ANOVA. Values of "Prob>F" less than 0.0500 indicate model terms are significant. In this case B, C, C^2 are significant model terms for water loss. A, B, C, AB, AC, AD, BC and CD are significant model terms for color change and B, C, AC, AD, BD, CD are significant model terms for shrinkage ratio. The optimum drying conditions levels was determined to sucrose concentration 12.7 %w/v, ring slice thickness 4.06 mm, solar drying time 125 min and immersed time 70.9 min, respectively. In addition, pretreatment of osmotic dehydration was found to be effective in drying kiwi rings with solar tray dryer.

Keywords: Kiwi drying; Solar dryer; Response surface method; Osmotic dehydration; Osmosolar dehydration

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Öz

Gıda ürünlerinin güneş altına serilerek kurutulduğu bilinen en eski ve en yaygın geleneksel gıda muhafaza yöntemidir. Ancak gıda ürünü güneş ışığı ile direkt temas ederse ürünün renginde ve besin değerlerinde azalma olur. Bu sorunları çözmek için güneşin dolaylı olarak etkisinden yararlanılabilen güneş kurutucuları geliştirilmiştir. Bu çalışmada kivi halkaları, ozmotik dehidrasyon ve güneşte kurutmanın bir kombinasyonu olarak ozmosolar dehidrasyon kullanılarak kurutulmuştur. Kivi halkaları önce sakaroz çözeltilerine daldırılmış ve ardından bir güneş kurutucusunda kurutulmuştur. Yanıt Yüzey Yöntemi metodu, koşulların kurutma performansı üzerindeki etkilerini belirlemek ve güvenli bir seviyeye tepkiler için optimum kurutma koşullarını bulmak için kullanılır. Yanıt Yüzey Yönteminde kurutma koşulları kivi dilimi kalınlığı (A), sakaroz konsantrasyonları (B), daldırma süresi (C) ve güneşte kurutma süresi (D) olarak seçilmiştir. Optimize edilecek yanıtlar nem kaybı, çapsal büzülme oranı ve yeşillik (*a*) renk değeri olarak seçilmiştir. Kurutma koşulları ile tepkiler arasında yanıt yüzeyi yöntemi ile başarılı bir matematiksel model elde edilmiştir. Nem kaybı için kuadratik model, renk değişimi ve büzülme oranı için ikili etkileşim modeli seçilmiştir. Model R^2 değerleri nem kaybı için 0.952, renk değişimi için 0.737 ve büzülme oranı için 0.856 dır. P değerine karşılık regrasyon katsayıları, nem kaybı, a renk değişimi ve büzülme oranı için ANOVA ile ifade edilmiştir. "Prob>F" değerleri 0.0500 de daha az ise model terimleri önemli bulunmuştur. Bu durumda B, C, C^2 nem kaybı için önemlidir. A, B, C, AB, AC, AD, BC ve CD renk değişimi için önemlidir. B, C, AC, AD, BD, CD büzülme oranı iiçin önemlidir. Optimum kurutma koşulları seviyesi sakaroz çözelti derişimi için %12.7, dilim kalınlığı için 4.06 mm, güneş kurutma süresi için 125 dakika ve ozmotik dehidrasyon süresi için 70.9 dakika belirlenmiştir. Ayrıca ozmotik dehidrasyon ön işleminin güneş enerjili raflı kurutucu ile kivi halkaları kurutma da etkili olduğu bulunmuştur.

Anahtar Kelimeler: Kivi kurutma, Güneş enerjili kurutucu, Yanıt yüzey yöntemi, Ozmotik dehidrasyon, Ozmosolar dehidrasyon

1. Introduction

Both efficient and economical drying methods are required to meet the increasing need for dry food products and to produce quality marketable products. Traditional solar is carried out loss of color and nutritional values, non-hygienic drying, and long drying time in the large areas (Yıldız and Akkari, 2021). The pre-treatments to be applied before drying have important effects on the quality and operating cost of the product to be dried (Yokuş, 2014; Gürel et al., 2016; Fernandes et al., 2006). Research on the application of osmotic dehydration as a drying pretreatment technique has attracted attention in recent years. This process is the partial removal of water from the tissues of the product immersed in an osmotic solution such as sugar, salt, honey, fruit juice, lemon juice, ascorbic acid and citric acid solutions (Abano and Sam-Amoah, 2011; Pandya and Yadav, 2014; Gürel et al., 2016). It is stated that the samples dried after osmotically dehydrated are products with high-water absorption ability and high sensory properties such as color, texture, appearance and are at an acceptable level in terms of aroma and taste. Solar dryers are becoming increasingly important as fresh and durable dried fruit is obtained as much as possible (Torringa et al., 2001; Lombard et al., 2008; Bórquez et al., 2010; Amer et al., 2010; Karaaslan, 2012; Akar, 2017). Studies are carried out on combining osmotic drying with new techniques to shorten the processing time. In addition, many studies have been carried out on hybrid drying techniques, where various drying methods are used together, such as vacuum drying, microwave drying and osmotic dehydration (Bórquez et al., 2010). It can be used in conjunction with osmotic dehydration to increase the efficiency of the solar drying process.

The drying process in which osmotic dehydration and solar dryer are used together can be called osmosolar dehydration drying process. Due to the loss of water during osmotic dehydration applied before drying, the water removal load of the dryer decreases, samples enter the dryer with a higher dry matter content. Thus, the osmotic dehydration pretreatment enables shortening the drying time and increasing the drying potential. In addition, osmosolar dehydration drying process takes place at low temperatures, and heat damage such as aroma change and oxidation in food is less. In this way, denser, quality in color, texture and appearance, and a dry product acceptable in terms of aroma and taste can be obtained. By drying the kiwi rings, both the spread of consumption to a wider area and the diversity and added value in the food industry and trade will be achieved. Studies on osmotic dehydration have focused on drying kinetics, optimization, modeling, mass and heat transfer.

Response surface methodology (RSM) usually has been used for optimization of drying process of vegetables and fruits (Uddin et al. 2004; Corzo and Gomez, 2004; Eren and Ertekin, 2007; Singh et al., 2007; Han et al., 2010; Abano et al., 2014; Sadeghi et al., 2020). RSM combines mathematics with statistics, modeling, evaluating the controlling drying conditions and optimization of the drying conditions. This method can be optimized with less experiments number with not need to any mathematical model. The experimental results statistically are employed on by using the analysis of variance (ANOVA). It is determined the optimum values which maximized the water loss, shrinkage ratio and color change in the study on the optimization of solar drying of kiwi slice by RSM. The condition levels such as kiwi slice thickness, drying time and kiwi slice load should be optimized.

2. Materials and Methods

2.1. Experimental analysis

Drying experiments were carried out with natural heat convection in the solar tray dryer and the effect of drying conditions on drying process was determined. The fresh organic kiwis were dried by using solar tray dryer in local market. Fresh kiwis were obtained from a local market, sorted visually for size, maturity level and physical damage. The product was stored at 4°C under refrigeration until used. The dirt, flower pit, shell, core house remnants, stalk, leaf parts, core, etc. found in or on the kiwi were cleaned. For these reasons, the kiwi samples were thoroughly washed with water to remove adhering soil and other debris. Kiwi samples were peeled and sliced to a ring shape form according to RSM experiment conditions as five kiwi samples. Kiwi rings were immerged in sucrose solution in order to osmotic dehydration. Solar drying trials were performed with the solar tray dryer shown in *Figure 1*.

Figure 1. Solar tray dryer

Shrinkage ratio was determined by measuring of diameter. These experiments were replicated five samples and obtain a reasonable average. The water loss, *a* color change and shrinkage ratio were calculated according to the following Eq. 1 and Eq. 2 (Aboud, 2013; Ochoa-Martinez et al. 2006).

$$\text{Water Loss} = \frac{\mathrm{M_0} - \mathrm{M_t}}{\mathrm{M_0}} \qquad (\text{Eq. 1})$$

$$\text{Shrikange Ratio} = \frac{\mathrm{D_0} - \mathrm{D_t}}{\mathrm{D_0}} \qquad (\text{Eq. 2})$$

Where M_0 and M_t are the sample mass (g), D_0 and D_t are the sample diameter (mm), at the beginning and at time t, respectively. Air temperature and humidity in the drying cabinet were monitored by CEM brand DT-802 model air quality measuring device.

The color change of kiwi rings is a parameter that negatively affects the quality. In order to prevent the kiwi rings from darkening as a result of oxidation and to reduce the drying time, the kiwi rings were first immersed in sucrose solution at the determined concentrations. Color parameters are *L*, *a* and *b* values. *L* is the luminance value and it varies between 0-100. An *L* value of 100 indicates white, *a* 0 value indicates black. *b*-value gives information about the blue-yellow colors. The positive value of *b* denotes the yellow and the negative value the blue color (Yıldız et al., 2015). The *a* value ranges from (-60) to (+ 60) and gives the red-green color value. a positive value gives red (+60) and a negative value (-60) the green color (Askari et al., 2008, Çelen et al., 2016, Arslan et al., 2021). Kiwi rings are green in color and turn green-brown over time. Therefore, *a* value (greenness) for kiwi is important in color analysis. Color parameters *a* value of kiwi rings before and after drying were determined with the FRU marka WR18 Colormeter. Color measurement was made three times and the average value was taken. *a* color change was calculated according Eq. 3. a_0 indicates the color parameter of fresh kiwi rings and a after the drying period.

$$\frac{\Delta a}{a_0} = \frac{a_0 - a}{a_0} \qquad (\text{Eq. 3})$$

2.2. Statistical analyses

The response surface methodology was described as the optimization of the experimental results by using binary combination of mathematical and statistical methods in the analysis and modeling of problems. The parameters affecting the process are called independent variables and the responses are called dependent variables. A mathematical model, describing the relations between the drying conditions and the responses in a second-order equation, was developed. Code value of the variables was done according to the following Eq. 4:

$$y = b_0 + \sum_{i=1}^{k} b_i X_i + \sum_{i=1}^{k} b_{ij} X_i^2 + \sum_{i_j<j}^{k} \sum_{j}^{k} b_{ij} X_i X_j + e \qquad (\text{Eq. 4})$$

Where *i* and *j* are linear and quadratic coefficients, respectively, *b* is a regression coefficient, *k* is the factor optimized in the experimental design, and *e* is random error. The suitable value of the equation was expressed by the coefficient of determination R^2 and its statistical significance was determined by the F-test. The coefficients of the equation were determined by employing Design Expert software. It was done ANOVA for the final predictive equation by the design expert software. The equation was optimized for maximum yield in the range of the variables by using the software.

3. Results and Discussion

3.1. RSM analysis

RSM was used to decide the optimum levels of drying conditions. Face centered design for three independent variables was used. The independent variables selected for the optimization were the influence of drying conditions (kiwi ring load, drying time and kiwi ring thickness) and come out optimal drying conditions for the water loss (WL), shrinkage ratio (SR) and *a* color change (CC). The response was selected Y_{WL}, Y_{SR} and Y_{CC}. A five level central composite rotatable design (CCRD) design was used with kiwi ring thickness (2-6 mm), B sucrose concentrations (0- 40 %w/v), C immersed time (60-150 min) and D solar drying time (60-480 min), were chosen independent variables as drying conditions. The five levels chosen were -α, -1, 0, 1 and α as shown in *Table 1*.

Table 1. Codes and actual levels of the input variables for design of experiment

Inpendent Variables	Symbols	Codes levels				
		-2	**-1**	**0**	**1**	**+2**
Kiwi ring thickness (mm)	A	2	3	4	5	6
Sucrose concentrations (%w/v)	B	0	10	20	30	40
Immersed time (min)	C	30	60	90	120	150
Solar drying time (min)	D	60	120	240	360	480

The correct spacing for the axial parameter (α) is chosen for the CCRD experiment design. It is α=2 for our experimental design (input variables, k=4). The input variables and their ranges were selected on the basis of the preliminary experiments avoiding that any experimental point get burn (Yıldız, 2017; Bilen et al. 2018). The experimental design consisted of a total of 30 experimental runs ($n=2^k+2k+m$, n=total experimental points, k=4 and central point, m=6) which included eight factorial points, six axial points, and six replicated central points as shown in *Table 2*. The results of experiments in the design expert are shown in *Table 2*.

Based on the experimental response, Y_{WL} produced by the water loss ranged from 0.009 to 0.819, Y_{SR} produced by shrinkage ratio ranged from 0.006 to 0.823 and Y_{CC} produced by color change the ranged from 0.006 to 0.389. Standard no 13 and no 21 had the maximum and minimum for the water loss and shrinkage ratio respectively. Standard no 15 and no 14 had the maximum and minimum for shrinkage ratio respectively. Standard no 2 and no 3 had the maximum and minimum for color change ratio respectively.

An F-value several times greater than the tabulated F-value shows that the model predicts the experimental results well and the estimated factors effects were real. The R^2 is one of the measures of degree of fit of a model. There is only a 0.01% chance that a Model F-Value this large could occur due to noise. ANOVA suggests the model to be significant at $P<0.0001$. All the variables have significant effects on the water loss, color change and shrinkage ratio. The suitable model is chosen among linear, 2FI, quadratic, cross-product, cubic. The suitable model is chosen quadratic for water loss. It is determined 2FI model for color change model and shrinkage ratio. The cubic model is not aliased. Adjusted R^2 (Adj R^2) and the Predicted R^2 (Pred R^2) focus on the model. A negative Pred R^2 implies that the overall mean is a better predictor of the response than the current model. Adeq precision measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 18.802, 11.216 and 12.723 indicates an adequate signal for water loss, color change and shrinkage ratio respectively. The Pred R^2 of 0.7510 is in reasonable agreement with the Adj R^2 of 0.9072 for water loss. A negative Pred R^2 implies that the overall mean is a better predictor of your response than the current model for *a* color change. The Pred R^2 of 0.4494 is not as close to the Adj R^2 of 0.7804 as one might normally expect for the shrinkage ratio *(Table 3*). This may indicate a large block effect or a possible problem with your model and/or data. Things to consider are model reduction, response tranformation, outliers, etc. This model can be used to navigate the design space. The quadratic model showed for Y_{WL} and Y_{SR}, and the 2FI model for Y_{CC}, a good fit and effectively represented the relationship among the variables selected.

Table 2. Four-level CCRD and the experimental responses

Std No	**A**	**B**	**C**	**D**	Y_{WL}	Y_{SR}	Y_{CC}
1	-1	-1	-1	-1	0.412	0.063	0.201
2	1	-1	-1	-1	0.265	0.187	0.389
3	-1	1	-1	-1	0.209	0.105	0.006
4	1	1	-1	-1	0.246	0.035	0.102
5	-1	-1	1	-1	0.607	0.053	0.245
6	1	-1	1	-1	0.735	0.168	0.253
7	-1	1	1	-1	0.545	0.234	0.131
8	1	1	1	-1	0.635	0.070	0.149
9	-1	-1	-1	1	0.361	0.039	0.069
10	1	-1	-1	1	0.451	0.079	0.067
11	-1	1	-1	1	0.218	0.014	0.042
12	1	1	-1	1	0.249	0.071	0.083
13	-1	-1	1	1	0.819	0.244	0.266
14	1	-1	1	1	0.774	0.006	0.236
15	-1	1	1	1	0.711	0.823	0.212
16	1	1	1	1	0.679	0.113	0.170
17	-2	0	0	0	0.621	0.207	0.107
18	2	0	0	0	0.548	0.136	0.152
19	0	-2	0	0	0.637	0.009	0.197
20	0	2	0	0	0.469	0.201	0.100
21	0	0	-2	0	0.009	0.232	0.023
22	0	0	2	0	0.779	0.221	0.252
23	0	0	0	-2	0.515	0.096	0.112
24	0	0	0	2	0.475	0.128	0.121
25	0	0	0	0	0.556	0.137	0.169
26	0	0	0	0	0.584	0.136	0.179
27	0	0	0	0	0.548	0.138	0.168
28	0	0	0	0	0.586	0.138	0.165
29	0	0	0	0	0.584	0.142	0.174
30	0	0	0	0	0.584	0.146	0.175

Table 3. ANOVA values of the regression parameters for RSM

Response	**Regression**	**df**	R^2	**Adj** R^2	**Pred** R^2	**F value**	**Pr > F**
WL	Linear	4	0.891	0.873	0.837	50.853	< 0.0001
	2FI	6	0.902	0.850	0.723	0.363	0.894
	Quadratic	4	0.952	0.907	0.751	3.926	0.0225
	Cubic	8	0.988	0.950	0.168	2.607	0.112
	Residual	7					
	Total	30					
CC	Linear	4	0.236	0.114	-0.193	1.936	0.136
	2FI	6	0.737	0.599	-0.160	6.034	0.00114
	Quadratic	4	0.770	0.555	-0.326	0.530	0.716
	Cubic	8	0.983	0.928	-1.51	10.684	0.00267
	Residual	7					
	Total	30					
SR	Linear	4	0.566	0.496	0.324	8.144	0.000239
	2FI	6	0.856	0.780	0.449	6.388	0.000823
	Quadratic	4	0.868	0.744	0.237	0.324	0.858
	Cubic	8	0.966	0.859	-3.90	2.535	0.119
	Residual	7					
	Total	30					

Table 4. ANOVA for the model on responses

Source	**Sum of Squares**	**df**	**F**	**P > F**
Water Loss				
Model	1.0411	14	21.2587	< 0.0001
A	0.0000	1	0.0002	0.990
B	0.0671	1	19.1914	0.000537
C	0.8951	1	255.8972	< 0.0001
D	0.0116	1	3.3161	0.0886
A^2	0.0013	1	0.3580	0.559
B^2	0.0000	1	0.0121	0.914
C^2	0.0462	1	13.2102	0.00245
D^2	0.0068	1	1.9389	0.184
AB	0.0006	1	0.1787	0.678
AC	0.0010	1	0.2944	0.595
AD	0.0002	1	0.0699	0.795
BC	0.0026	1	0.7357	0.405
BD	0.0017	1	0.4811	0.499
CD	0.0061	1	1.7550	0.205
Residual	0.0525	15		
Lack of Fit	0.0455	10	3.2820	0.101
Pure Error	0.0069	5		
Cor Total	1.0935	29		
$R^2 = 0.952$				
Color Change				
Model	0.1661	10	11.3034	< 0.0001
A	0.0056	1	3.7808	0.0668
B	0.0437	1	29.7465	< 0.0001
C	0.0565	1	38.4452	< 0.0001
D	0.0040	1	2.7301	0.115
AB	0.0002	1	0.1125	0.741
AC	0.0086	1	5.8258	0.0261
AD	0.0073	1	4.9736	0.0380
BC	0.0015	1	1.0302	0.323
BD	0.0202	1	13.7581	0.00149
CD	0.0186	1	12.6307	0.00212
Residual	0.0279	19	11.3034	
Lack of Fit	0.0279	14	3.7808	
Pure Error	0.0000	5	29.7465	
Cor Total	0.1661	29	38.4452	
$R^2 = 0.737$				
Shrinkage Ratio				
Model	0.4534	10	5.3307	0.000882
A	0.0407	1	4.7868	0.0414
B	0.0426	1	5.0102	0.0374
C	0.0501	1	5.8889	0.0254
D	0.0120	1	1.4143	0.249
AB	0.0536	1	6.3072	0.0212
AC	0.0824	1	9.6861	0.00574
AD	0.0458	1	5.3887	0.0315
BC	0.0520	1	6.1086	0.0231
BD	0.0290	1	3.4123	0.0803
CD	0.0451	1	5.3040	0.0327
Residual	0.1616	19		
Lack of Fit	0.1616	14	1392706.5856	< 0.0001
Pure Error	0.0000	5	5.3307	
Cor Total	0.6150	29	4.7868	
$R^2 = 0.856$				

The P-values confirmed the significance of each of the coefficients, which are essential to recognize the pattern of the common interactions between the independent variables. Values of P less than 0.0001 indicate that the model terms are significant. The P-values used as a tool to check the significance of each of the coefficients in turn indicate the pattern of interactions between the variables. A smaller value of P was more significant to the corresponding coefficient. ANOVA of the regression model for Y_{WL}-Y_{CC}-Y_{SR} response established that the model was significant due to a very low probability value (P model >F-0.001). ANOVA (F-test) for the model explained the response of the dependent variable. The regression coefficients, along with the corresponding P-values, for the model of production water loss, *a* color change and shrinkage ratio are described by ANOVA. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case B, C, C^2 are significant model terms for water loss. A, B, C, AB, AC, AD, BC and CD are significant model terms for *a* color change and B, C, AC, AD, BD, CD are significant model terms for shrinkage ratio (*Table 4*). Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms that not counting those required to support hierarchy, model reduction may improve the model.

ANOVA results of the models, indicating a good model performance with an R^2 value of 0.952 and an F value of 21.259 for water loss. The Model F-value of 21.26 implies the model is significant. R^2 value of 0.737 and F value of 11.303 for color change and with an R^2 value of 0.856 and an F value of 5.33 for shrinkage ratio. The model R^2 values of 0.952 (for water loss), 0.737 (for color change) and 0.856 (for shrinkage ratio) imply that the variations of 95% for water loss, and 74% for *a* color change and 86% for shrinkage ratio can be attributed to the independent variables. The corresponding second-order model and 2FI models in coded variables were assembled for each response (Eq. 5-7).

$$Y_{WL}=0.550-0.000159A-0.05289B+0.193124C+0.021984D+0.006756A^2-0.00124B^2-0.04105C^2-0.01572D^2+0.006251AB+0.008022AC-0.00391AD+0.012682BC-0.01026BD+0.019588CD \quad \text{(Eq. 5)}$$

$$Y_{cc}=0.1452-0.04119A-0.042138B+0.045683C+0.0223888D-0.0519AB-0.07176AC-0.05352AD+0.056985BC+0.04259BD+0.053099CD \quad \text{(Eq. 6)}$$

$$Y_{SR}=0.1566-0.0152A-0.0427B-0.0485C-0.0129D-0.0032AB-0.0231AC-0.0214AD+0.0097BC+0.0355BD+0.0341CD \quad \text{(Eq. 7)}$$

A statistically significant multiple regression relationship between A, B, C, D and the $Y_{WL,}$ Y_{CC}, Y_{SR} can be established. The optimum drying condition levels were obtained for the water loss, the color change and the shrinkage ratio values predicted by RSM optimization tool box. The optimum parameter levels were selected according to desirability from different solutions with a (desirability) value of 1, considering their cost. The optimum drying point was chosen for the corresponding experimental values were sucrose concentration 12.7 %w/v, ring slice thickness 4.06 mm, solar drying time 125 min and osmotic dehydration time 70.9 min, respectively.

4. Conclusions

In the solar dryer, the kiwi rings dry out in a shorter period of time due to the fact that it is more heat and less water loss than drying in the sunshine and drying in the shadows. The air humidity in solar drying is an important problem in the regions where the air humidity is high. The air humidity is less in the drying cabinet, and to solve the problem by using the solar dryer. In addition, the parameters of the drying process are optimized to make process designs and process efficient and solar dryers can be expanded by increasing their applicability in the industry. The present study aims to model the water loss, shrinkage ratio and color change as a function of the drying conditions and to find the optimum drying conditions that maximize the water loss, minimum shrinkage ratio and minimum *a* color change by using RSM. The method experimentally was optimized and modelled with 30 experiments number. RSM analysis results statistically are suitable for the experimental results. The quadratic model a good fit and effectively represented for water loss (R^2 = 0.952) and shrinkage ratio (R^2 = 0.856), and the 2FI model selected for *a* color change (R^2 = 0.737). Optimum results of solar tray dryer parameters were determined to be 12.7 %w/v for sucrose concentration, 4.06 mm for ring slice thickness, 125 min for solar drying time and 70.9 min for osmotic dehydration time for maximum water loss, minimum both shrinkage ratio and color change. It was significantly found that sucrose concentration and osmotic dehydration time had effect on the responses. This result showed that osmotic dehydration has a positive effect on the solar drying process.

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