Modeling and optimizing apricot drying parameters using response surface methodology (RSM)

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Abstract: Optimizing osmotic dehydration techniques for apricots performs a significant role in enhancing food preservation and nutritional value. This is due to the increasing demand for sustainable and efficient food processing methods. The study examined various osmotic solution concentrations (sucrose-salt 55%-5%, 50%-10%, and 45%-15%) of apricot drying treatment to obtain the best model and optimum conditions for dried apricot production. The temperatures varied at 40°C, 50°C, and 60°C for three different treatment times (1, 3 and 5 h). Response Surface Methodology (RSM) was used to predict solid gain (SG), ratio to water loss (WL), water ratio (WR), salt, sugar, and vitamin C during osmotic dehydration of apricot slices. The results revealed that with increasing of temperature and time, the values of SG (linearly from 0.5% to 12.4%), WL (quadratically from 15.2% to 49%), WR (quadraticlly from 13.4% to 49.8%), salt (quadratically from 0.07% to 0.7%), and sugar (linearly from 9% to 13.5%) increased. In contrast, the amounts of vitamin C (11 to 4 mg/100 g) decreased quadratically ($P<0.05$). RSM also suggested the optimum dehydration conditions as immersion time of 5 h, temperature 59°C with response variables (SG 2.325%, 1.46% and 0.206%, WL 45.449%, 48.269% and 49.314%, WR 41.347%, 45.480%, 46.8%, Salt 0.277%, 0.487%, 0.675%, sugar 12.465%, 12.211% and 11.882% and vitamin C 7.556, 5.915 and 5.314 mg/100g) for solution of 55-5, 50-10 and 45-15, respectively. Therefore, osmotic dehydration has potential advantages for the processing industry (such as the drying process) in maintaining food quality and preserving the nutrition of the food.

Keywords: apricot processing, modelling, osmotic, optimization, sucrose-salt solutions

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1 Introduction

The dehydration process by means of osmosis is a useful technique aimed at decreasing the activity of water in foods such as fruits and vegetables to enhance the nutritional, functional, and sensorial properties of

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the product. It involves immersion of the product by placing fruits or vegetables in a concentrated aqueous solution with a high osmotic pressure, such as salt or sugar. Two simultaneous flows occur in the opposite direction during the osmotic process (Oo et al., 2020). Water flows from the product into the aqueous solution, while the solute flows into the product, caused by the different activity between water and solute in the membrane cell.

Osmotic dehydration can reduce the moisture content of food prior to the drying process by immersion in hypertonic solutions (usually with concentrations of 30% to 70%) (Khoyi and Hesari, 2007; Rastogi et al., 2002; Rigi et al., 2020; Segui et al., 2006; Sereno et al., 2001). Osmotic dehydration is economical and could increase resistance to heat treatment. However, the process is greatly influenced by a number of factors, e.g. osmotic solution ratio, temperature, agitation, and process time (Devahastin and Niamnuy, 2010; Sirousazar et al., 2009). It should be noted that osmotic drying is a complementary method used as a pretreatment step before the drying process to obtain dry fruit ingredients with a lower water content and a natural colour without additives, which allows it to be applicable for various purposes (Wiktor et al., 2022). It facilitates the storage of agricultural products, decreases water activity in foods for an extended period, maintains flavour and nutritional attributes, avoids microbial harm, and thus enhances the quality of the product. The technique of osmotic dehydration is relatively less energy-intensive since no phase change occurs. It has attracted considerable attention due to improved product quality and reduced energy consumption (El-Aouar et al., 2003). Garcia-Nogueira et al. (2010) used ultrasound pretreatment for drying strawberry samples. The findings revealed that this pretreatment increased the loss of fruit tissue, and reduced the drying time and the cost of osmotic dehydration. Furthermore, it was found that with higher sucrose concentration, sucrose absorption and water loss in the fruit intensified. Another study reported that a higher temperature or concentration of the osmotic solution in a drying pretreatment led to increased loss of water and gain in solids of the pineapple slices (Rigi et al., 2020; Shahidi et al., 2012).

Many studies have been conducted using Response Surface Methodology (RSM) on osmotic dehydration of agricultural products (Azarpazhooh et al., 2020; Giannakourou et al., 2020; Oo et al., 2020; Rigi et al., 2020; Taghinezhad et al., 2021; Zhelyazkov et al., 2020). RSM is a statistical approach that can be used for multiobjective optimisation purposes (Rigi et al., 2020). More recently, RSM has been used to predict and optimise the various processes in the food industry, including osmotic dehydration (Grzegory et al., 2013). RSM has the potential to determine optimal parameter conditions that affect osmotic dehydration of fruits and vegetables (Rigi et al., 2020). Ghellam et al. (2021) tried to optimise the osmotic dehydration of the autumn olive using RSM to study the impact of the aspects of dehydration such as temperature (20°C–70°C), syrup concentration (30%–70%), and fruit-to-syrup ratio (1:10–2:10) on sugar gain, water loss, density, weight reduction, total colour alteration, and water activity following 10 h of osmotic dehydration. At optimal conditions (70%, 70°C, 1.8:10), the response variables were predicted at 19.21%, 59.21%, 1.22 g cm^{-3}, 32.34%, 3.65 and 0.850, and for sugar gain, water loss, density, weight reduction, total colour change, and water activity, respectively. Yıldız and Gencer (2023) investigated the impacts of osmotic dehydration before solar drying of kiwi rings by RSM. RSM obtained a successful mathematical model between the drying conditions (kiwi slice thickness, sucrose concentrations, immersion time, and solar drying time) and the responses (water loss, diameter shrinkage ratio, and colour change). Optimal drying conditions levels were determined to the sucrose concentration of 12.7% w / v, the thickness of the ring cut 4.06 mm, solar drying time 125 min, and the immersion time of 70.9 min, respectively. Bchir et al. (2021) examined the osmotic process of pomegranate seeds and optimised it using RSM. In another study, Giannakourou et al. (2020) investigated the osmotic dehydration of tomatoes in alternative sweetener solutions. RSM was used to optimise the process parameters such as the temperature and duration, osmotic treatment, composition of the osmotic solution and concentration. The results were confirmed with sensory analysis performed under the optimum conditions to evaluate organoleptic acceptance samples.

Thus far, no research has been reported on the modelling and optimisation of osmotic dehydration for apricot slices. Therefore, the present study aims to examine the concurrent impact of osmotic conditions such as concentration (sucrose-salt, respectively, with ratios of 55%-5%, 50%-10%, and 45%-15%, w/w), temperature (40°C, 50°C, and 60°C), as well as immersion time (1, 3, and 5 h) on response parameters that include water loss, solid gain, as well as weight reduction on apricot slices. Additionally, physical and nutritional properties, i.e. total sugar and vitamin C content, were investigated. RSM was also used to optimise the pretreatment of osmotic dehydration. Therefore, modelling and optimisation of osmotic dehydration were performed.

2 Materials and methods

2.1 Preparation of apricots and osmotic solutions

For the preparation, apricots (Nasiiry variety) of the same and full technological maturity level (3.4 pH) and sucrose content (commercial) were purchased from a local supermarket in Tabriz, Iran in the year 2021. The apricots were classified by size and shape to have uniformity in the raw material. The samples were cleaned and dried with paper towels. The core was then removed, and the apricots were cut before being weighed at 10 g for each sample. For the preparations of osmotic solutions, three different concentrations of sucrose-salt solutions were employed with ratios 55%-5%, 50%-10% and 45%-15% . Sodium chloride salt was bought as a commercial type with food grade which is named “NaCl”. These materials were purchased from MilaTack Company, Iran. Additionally, a temperature-controlled mixing tank was applied for the osmotic operation. For the osmotic treatment, samples were weighed and placed in an osmotic solution in dynamic conditions provided by agitation (IKA, Staufen, Germany) (150 rpm) at room temperature (24°C ± 1°C) for 4 h. The product-to-solution ratio was 1:10 (w/w). The samples were then removed from the solution to remove its excess with filter paper for almost 5 min (Yousefi et al., 2013).

2.2 Osmotic drying treatments

Osmotic conditions, i.e. solution ratio, temperatures, and immersion time, were varied. The WL/SG ratio was selected as the main criterion for the best possible osmotic treatment to produce dried apricots. The mixture of sucrose-salt ratios was varied in the 55%-5%, 50%-10% and 45%-15% for 1, 3 and 5 h, while the temperature was varied at 40°C, 50°C, and 60°C.

2.3 Response parameters

2.3.1 Vitamin C

The dry matter and moisture content were quantified using the gravimetric technique. Samples were placed in an oven (Memmert company, UF30Plus/UN30Plus, Germany) at 105°C for 24 h (AOAC, 2020). Furthermore, the vitamin C content (mg/100g) was measured in line with a method proposed by Zahoor et al. (2023).

2.3.2 Sugar

The total sugar (%) was measured using the Fehling test (Ahmmed et al., 2015). For this test, 20 mL of the defecated extract, 10 mL of Fehling I solution and 10 mL of Fehling II solution were mixed in an Erlenmeyer flask (300 mL). The vessel was heated for 2 min. After cooling the flask, 15 mL H_2SO_4 and 20 mL of KI solution were added. Then titration was done in the presence of starch (1%) with 0.1 N $Na_2S_2O_3$.

Additionally, salt values (%) were estimated by determining the NaCl content in osmotically dehydrated samples by AOAC (2020). All measurements were conducted with triplication.

2.3.3 WR, SG, and WL

Following individual contact times, fresh and dried apricots were placed in an oven at a temperature of 105 °C until stable weight was achieved (24 h) for the measurement of moisture content and solid content in accordance with the approach of the Association of Official Analytical Chemists (AOAC, 2020). Afterwards, water ratio (WR), solid gain (SG), and water loss (WL) were quantified for all situations at various time periods, t, using the Equation 1, 2 and 3 (Singh et al., 2022). The weight of the samples was measured by a digital balance (Sartorius, Göttingen, Germany).

$$WL\ (\%) = \frac{(w_i \,.\, X_i - w_f \,.\, X_f)}{w_i} \times 100 \quad (1)$$

$$SG\ (\%) = \frac{(w_f \,.\, X_{sf} - w_i \,.\, X_{si})}{w_i} \times 100 \quad (2)$$

$$WR\ (\%) = WL(\%) - SG(\%) \quad (3)$$

Here, W_i is the initial matter content before osmotic dehydration (g), X_i is the moisture content of the sample before osmotic dehydration (g sample / g water); W_f is the matter content after osmotic dehydration (g); X_f is the moisture content of the sample after osmotic dehydration (g sample / g water). X_{sf} is dry matter content after osmotic dehydration (g sample / g dry sample); X_{si} is dry matter content before osmotic dehydration (g sample / g dry sample).

2.4 Response Surface Methodology (RSM)

All experiments (statistical, modelling, and optimisation) were conducted in a "Historical data" design with triplicates by Design Expert 10 software (Minneapolis, Statease Inc, USA). The independent (temperature and time) and dependent (solid gain, water loss, water ratio, salt, sugar, vitamin C) variables of this research were revealed in Table 1. All analyses were performed separately for each concentration of solutions (55-5, 50-10 and 45-15). Although importation of sucrose (55%, 50%, 45%) and salt (5%, 10%, 15%) as independent variables was made, no correlation or mathematical equation was found between these independent variables and response variables. Therefore, RSM analysis was conducted in 3 different groups (three solutions). In the RSM, many variables affect the desired level, and the goal is to predict and optimise the response. Optimal values were obtained by the solution of regression relation (Jain et al., 2011):

$$y_k = \beta_0 + \sum_{j=1}^{k} \beta_j x_j + \sum_{j=1}^{k} \beta_{jj} x_j^{\ 2} + \sum_{i<j}\sum^{k} \beta_{ij} x_i x_j \quad (4)$$

Where y_k shows the predicted response, $\beta_0, \beta_j, \beta_{jj}$ and β_{ij} are a constant, linear coefficient, quadratic coefficient, and mutual coefficient, respectively, and X_i and X_j are independent parameters. The statistical significance of the independent variables for the response variables was investigated at a 95% confidence level ($P < 0.05$). Only the variables that significantly affected the response variable were used in the proposed regression equation. Response surface plots were drawn for all significant responses as a function of two independent variables. Finally, the optimal point of the process according to the boundary conditions and objective functions according to Table 1 was obtained. According to different studies on osmotic dehydration of fruits and vegetables, this study aimed to maximise WL, WR, salt, sugar and vitamin C and minimise SG parameters (Rigi et al., 2020).

3 Results and discussion

The osmosis dehydration involves the immersion of fruits in a hypertonic solution leading to loss of water through the cell membrane of the fruit, flowing along the cell-to-cell space prior to dissolving in the liquid. Submersion osmotic drying in condensed solutions was applied for fractional water removal from the tissue of a plant. This section presents the results and discussion on various osmotic solution concentrations (sucrose-salt 55%-5%, 50%-10% and 45%-15%) used in the apricot drying treatment to obtain the optimisation conditions and best drying model. The temperatures also varied at 40°C, 50°C, and 60°C for three different treatment times (1, 3, and 5 h). Moreover, response parameters included SG, WL, WR, salt, sugar. In this study, osmotic dehydration was applied with different concentrations as a pretreatment to investigate the quality of dried apricots and achieve the best osmotic pretreatment for the production of dried apricot.

Table 1 Boundary conditions of independent and dependent variables for modelling and target for optimisation of the selected model by RSM

Variable	Category	Target	Min	Max
Temperature (°C)	Input (independent)	In the range	40	60
Time (h)	Input (independent)	In the range	1	5
Solid gain (%)	Output (dependent)	minimum	0.5	12.4
Water loss (%)	Output (dependent)	maximum	15.2	49
Water ratio (%)	Output (dependent)	maximum	13.4	49.8
Salt (%)	Output (dependent)	maximum	0.07	0.7
Sugar (%)	Output (dependent)	maximum	9	13.5
Vitamin C (mg/100g)	Output (dependent)	maximum	4	11

3.1 SG, WL and WR

Table 2 shows the effect of temperature and time variables with different concentrations of osmotic solution (sucrose-salt solution in a ratio of 55-5, 50-10 and 45-15, respectively) on the amount of SG, WL and WR with the best-fitted model. The results show that the effect of temperature and time on the SG, WL and WR during the linear or quadratic equation is significant ($P < 0.05$). The positive sign of the regression coefficients means the direct effect of the independent variables on the response variables. In contrast, the negative sign of the model indicates the indirect impact of independent variables on the response variables (Chen et al., 2008). It should be noted that only the coefficients that had a significant effect ($P < 0.05$) on the values of SG, WL and WR were shown in the equation.

Figures 1, 2 and 3 show the interaction of temperature and treatment time on the amounts of SG, WL and WR at different concentrations of osmotic solution. According to Figure 1, the highest and lowest SG values were obtained at 60°C for 5 h and at 40°C for 1 h, respectively. From these Figures, it can be seen that the amount of SG increased with increasing temperature and time. These findings were consistent with the results of Sharifi et al. (2020), who worked on aloe vera gel. As shown in Figure 2, the maximum and minimum values of WL were 49% and 15.2%, respectively. The WL value increased as the air temperature remained constant and the treatment time increased. According to Figure 3, the WR value increased with increasing temperature and treatment time. The highest WL and WR were achieved at 60°C, and the highest WL and WR were also obtained at 5 h of drying time.

Table 2 Fitting the effect of different levels of temperature and time on the solid gain (SG (%)), water loss (WL (%)) and water ratio (WR (%))

Treatment (sucrose (%)- salt (%))	Final equation in terms of actual factors	R^2	C.V. (%)
45-15	$SG=-4.85+0.12\times A+0.48\times B$	0.82	8.27
50-10	$SG=-7.53+0.21\times A+0.66\times B$	0.87	9.88
55-5	$SG=-11.60+0.28\times A+0.87\times B$	0.92	9.49
45-15	$WL=26.09-0.35\times A+0.99\times B+0.26\times A\times B-1.48611\times B^2$	0.92	9.83
50-10	$WL=-8.72+0.41\times A+12.97\times B-1.29\times B^2$	0.86	11.77
55-5	$WL=121.47-4.43\times A+5.56\times B+0.045\times A^2$	0.85	10.95
45-15	$WR=11.47-0.14\times A+4.24\times B+0.22\times A\times B-1.69\times B^2$	0.94	9.13
50-10	$WR=-14.20+0.40\times A+13.94\times B-1.36\times B^2$	0.87	13.62
55-5	$WR=-5.18+0.38\times A+5.08\times B$	0.91	9.4

Note: Amount of SG, WL and WR under different concentrations of osmotic solution SG = solid gain (%); WL = water loss (%); WR = water ratio (%); A = temperature (°C); B = time (h)

These results are in agreement with the reported findings by Falade et al. (2007) and İspir and Toğrul (2009), who studied watermelon and apricot, respectively. All in all, from the perspective of technology and the content of WL and WR, the findings revealed that osmotic dehydration at 60°C or 5 h yielded the best temperature or time condition for osmotic apricot drying.

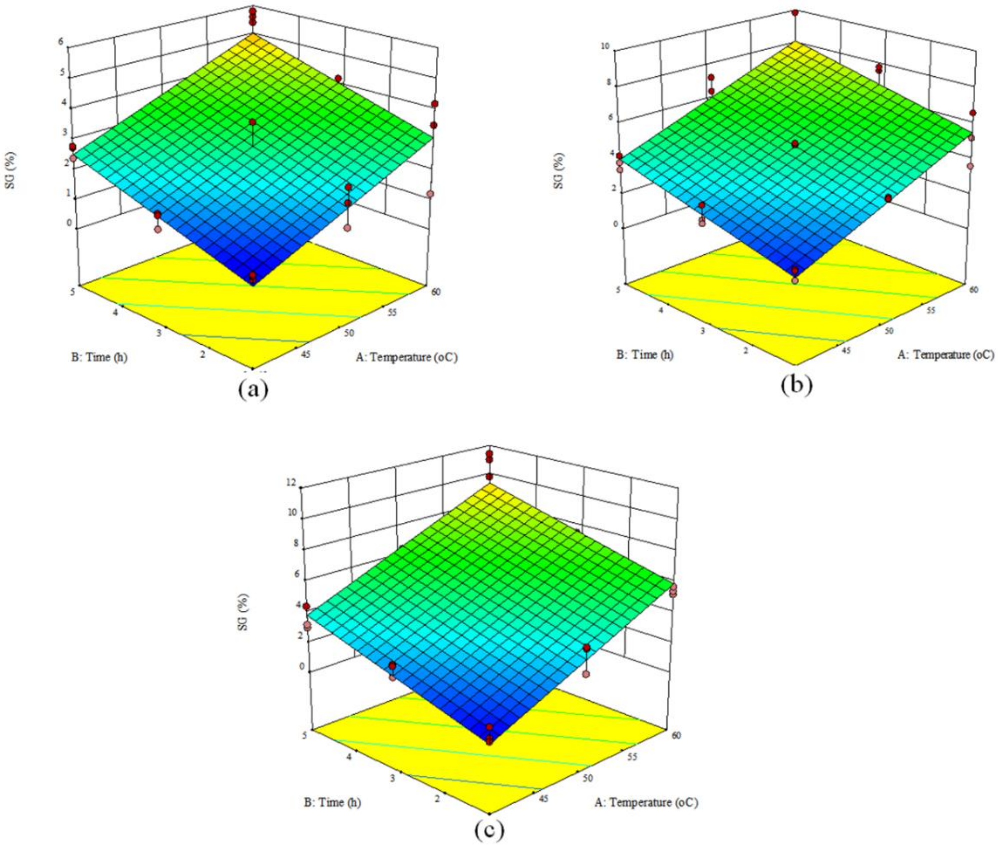


Figure 1 Effect of the interaction of temperature and treatment time on solid gain (SG%) value under sucrose-salt solution in the ratio of a) 45-15, b) 50-10 and c) 55-5

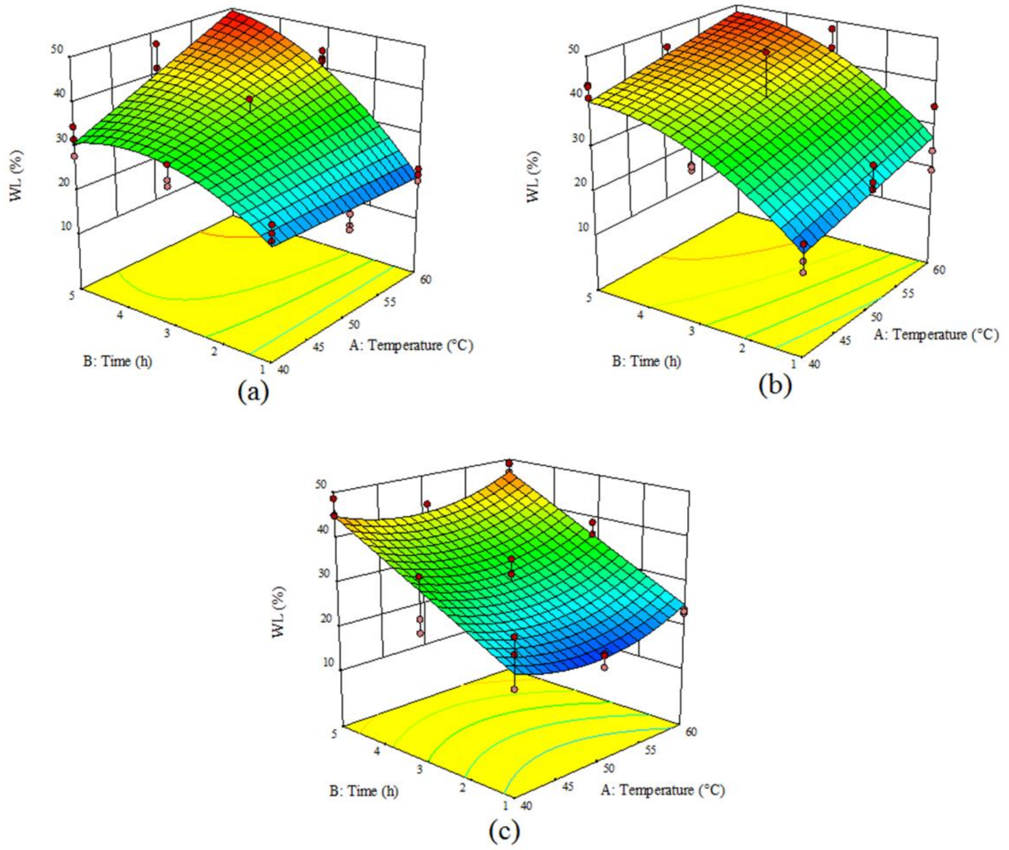


Figure 2 Effect of the interaction of temperature and treatment time on water loss (WL%) value under sucrose-salt solution in the ratio of a) 45-15, b) 50-10 and c) 55-5

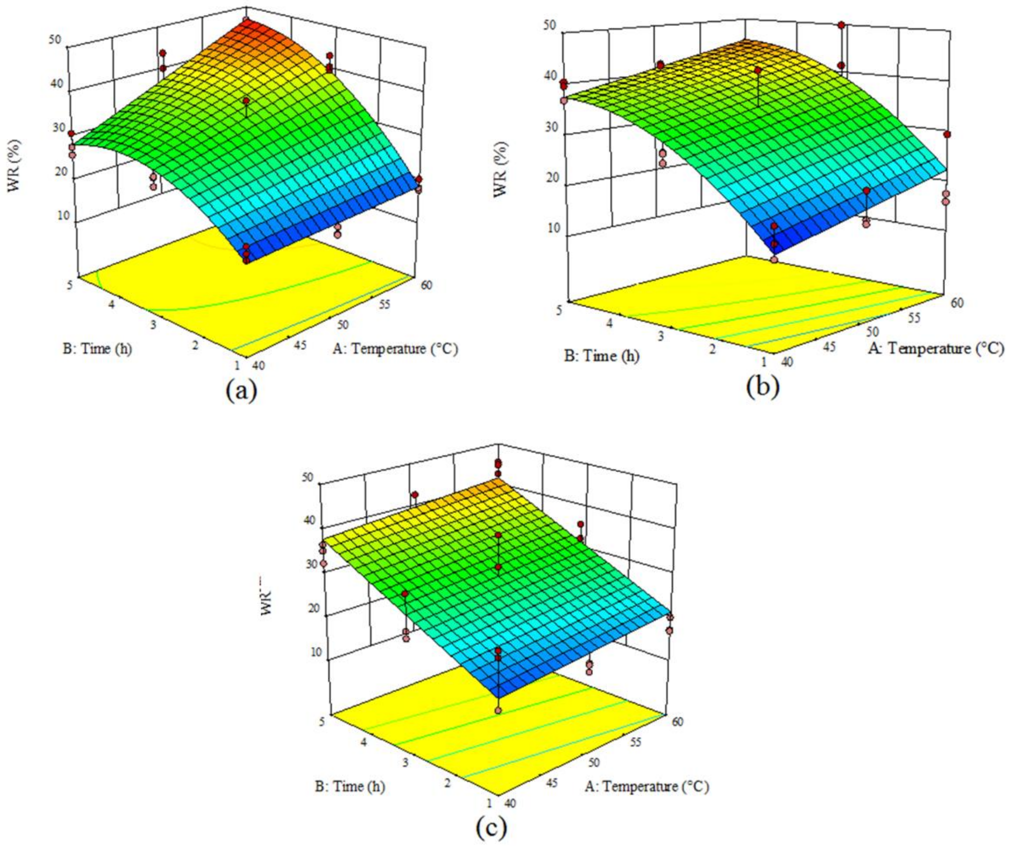


Figure 3 Effect of the interaction of temperature and treatment time on the value of the water ratio (WR%) in different solutions with the ratio of a) 45-15, b) 50-10 and c) 55-5**.**

These results follow fundamental osmotic treatment theories, where the pressure gradient and the driving force for mass transfer are strongly related to temperature and immersion duration time (Mercali et al., 2012). The increase in temperature and immersion duration time has shown a slight increase in WL and WR (Mercali et al., 2012).

3.1.1 Salt and sugar

Table 3 lists the results of the modelling of the amounts of salt and sugar at various temperatures and times in different concentrations of osmotic solution. The R^2 value was obtained higher than 0.81. The results revealed the significant effects of the two main parameters (temperature and time) on the salt and sugar values of the dried samples ($P<0.05$). Moreover, the reciprocal effects of temperature and time were not significant on the sugar value of the dried slices. The lowest-highest sugar and salt values were 13.5%-9% and 0.7%-0.07%, respectively. The highest sugar and salt value was observed in a solution 55-5, temperature 60°C, time 5 h and solution 45-15, temperature 40°C, time 1 h, respectively; while the lowest sugar and salt value was achieved at the solution of 45-15, temperature 40°C, 1 h and solution 55-5, temperature 40°C, time 1 h, respectively. Also, the highest total sugar and salt values were obtained for 5 h. Overall, from the perspective of technology and sugar content, the findings revealed that 5 h was the best time period to dry apricots in osmosis. It was also found that between the three different osmotic solutions shown in Table 3, solution 55-5 yielded the highest total sugar amount. In contrast, the highest amount of salt was yielded by solution 45-15. Furthermore, Yadav and Singh (2014) found that sucrose solutions led to an increase in the loss of water compared to salt at a similar concentration. Furthermore, the findings also suggested that a fractional substitute for sucrose by salt in the solutions resulted in higher water loss compared to 100% solution of sucrose (Yadav and Singh, 2014). This eventually decreased the activity of water and increased the pressure of osmotic dehydration in concentrated aqueous solutions (Jayaraman et al., 1990).

Furthermore, the study by Ghellam et al. (2021) on osmotic dehydration of autumn olive berries supports the findings presented in Table 3 on the effect of temperature and time on the sugar and salt values in dried apricots. That study also employed osmotic processing to alter the composition of fruits, identifying temperature and time as significant factors in determining the properties of the final product. The study found that the concentration and temperature were the most important factors in determining the loss of water, sugar gain, weight reduction, density, water activity, and total colour change in the fruit after osmotic dehydration. The study by Ghellam et al. (2021) suggests that osmotic processing can be used to alter the composition of fruits, and that temperature and time are important factors to consider when optimising the process.

Table 3 Fitting the effect of different levels of air temperature and treatment time on the amount of salt and sugar at different concentrations of osmotic solution

Treatment (sucrose (%)- salt (%))	Final equation in terms of actual factors	R^2	C.V. (%)
45-15	$Salt=-0.61+0.03\times A+0.10\times B-2.72E-004\times A^2$	0.99	3.83
50-10	$Salt=0.03\times A+0.10\times B+6.25E-004\times A\times B-2.56E-4\times A^2-0.01\times B^2$	0.99	5.01
55-5	$Salt=-1.02E-3+8.89E-4\times A+0.045\times B$	0.96	8.64
45-15	$Sugar=7.125+0.06\times A+0.25\times B$	0.84	6.86
50-10	$Sugar=8.98+0.04\times A+0.18\times B$	0.81	3.91
55-5	$Sugar=8.34+0.04\times A+0.38\times B$	0.86	5.46

Note: A = temperature (°C); B = time (h)

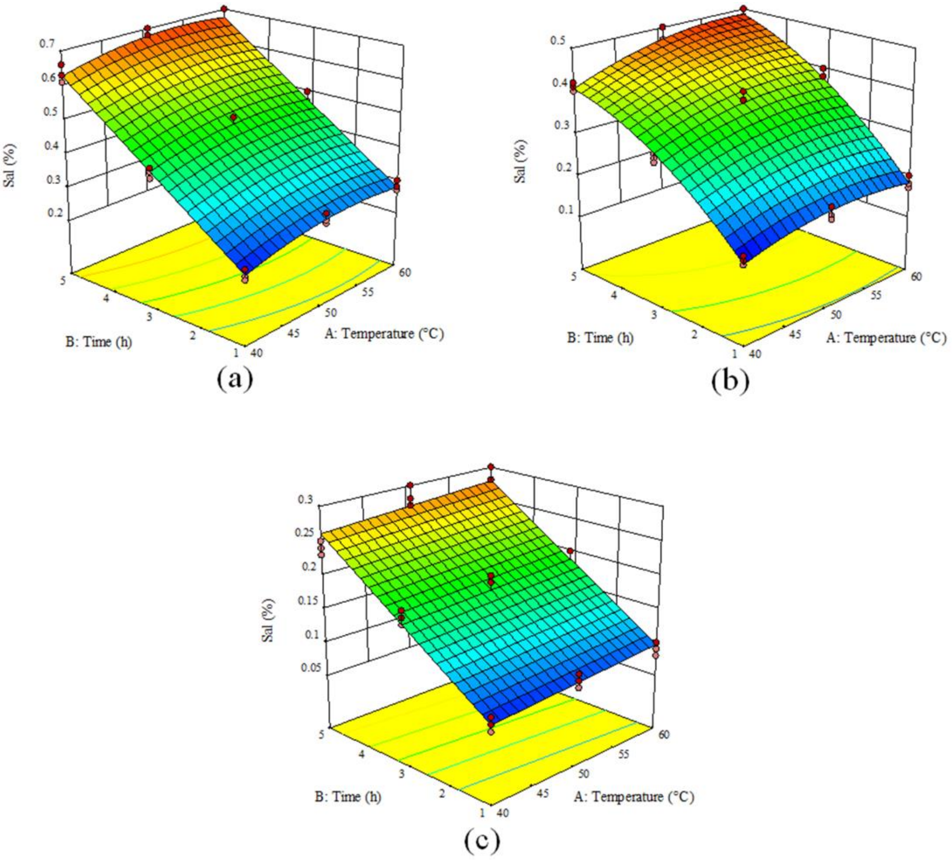


Figure 4 Effect of the interaction of temperature and treatment time on the amount of salt (salt (%)) in different solutions with the ratio of a) 45-15 b) 50-10 c) 55-5.

Figures 4 and 5 depict the reciprocal effects of parameters (temperature and time) on the effective sugar and salt value of dried samples. Increase in temperature and time improved the sugar (linearly) and salt values of the samples. The rise in temperature or time enhanced the heat energy. This phenomenon can increase the activity of water molecules and accelerate evaporation (Prinzivalli et al., 2006). Therefore, increasing the temperature and time can increase the sugar or salt amounts. Similar results were reported by

Prinzivalli et al. (2006) and Van Buggenhout et al. (2008).

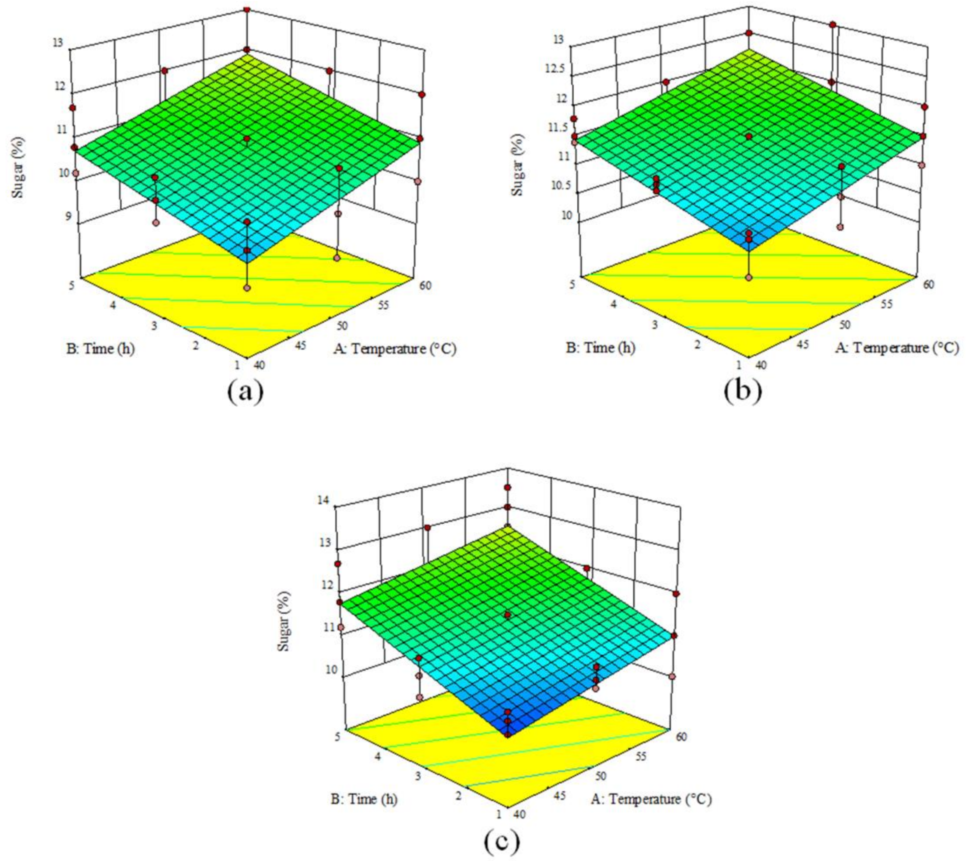


Figure 5 Effects of the interaction of temperature and treatment time on the amount of sugar in different solutions with the ratio of a) 45-15 b) 50-10 c) 55-5

3.1.2 Vitamin C

Table 4 presents the results of the modelling for the vitamin C content of the apricot products after osmotic dehydration. The linear effects of the immersion time and temperature on the vitamin C content were found to be significant ($P<0.05$). Furthermore, the second-order effects of temperature on vitamin C were also significant ($P<0.05$).

Figure 6 illustrates the impact of different temperatures and immersion times under three osmotic solutions on the vitamin C content of the apricot products. The results showed that the vitamin C content increased significantly ($P<0.05$) with increasing temperatures and longer immersion times except for 45-15 treatment. There was a significant difference ($P<0.05$) in the vitamin C content for each solution. Among the three solutions, the highest vitamin C content of 11 mg/100g was obtained for solution 55-5, while the lowest vitamin C content of 4 mg/100g was observed in solution 45-15.

These findings suggest that osmotic dehydration can affect the vitamin C content of apricot products. The reduction in vitamin C content may be due to thermal degradation and/or leaching of vitamin C into the osmotic solution during the process. Therefore, it is important to carefully control osmotic dehydration conditions to minimise the loss of vitamin C and other important nutrients.

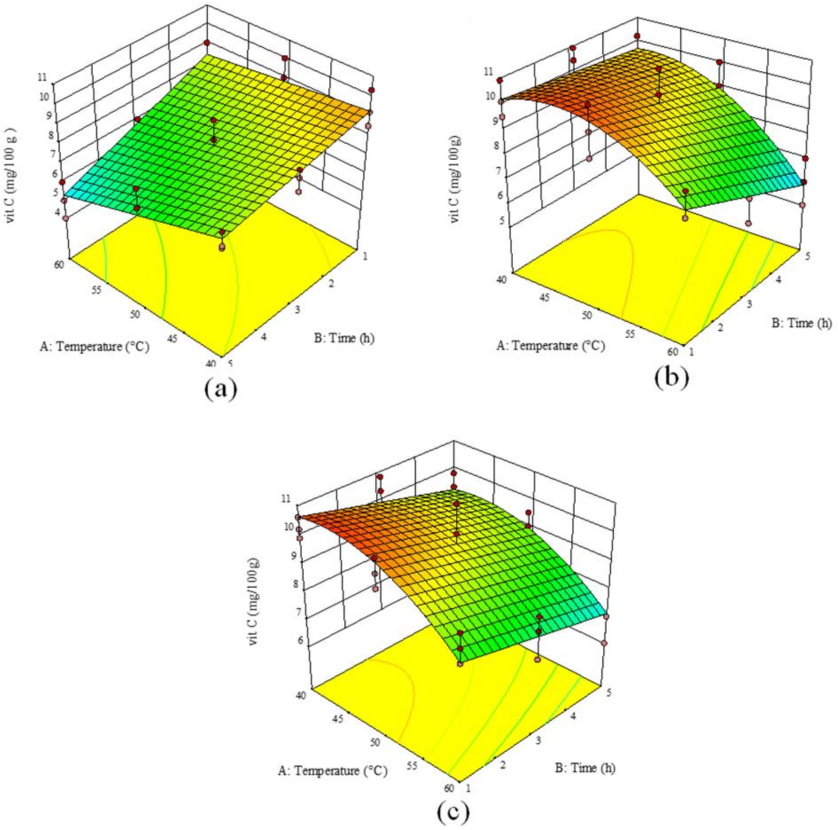
Devic et al. (2010) explained that the lower vitamin C content could be attributed to two reasons. The first reason is associated with the effect of vitamin C extraction into an osmotic solution with fruit water. The second reason is associated with the exposure of vitamin C to air and oxygen, which results in oxidation and a decrease in the amount of vitamin C. Furthermore, Devic et al. (2010) found that changes in antioxidant components differed according to the nature of molecules and decreased according to temperature, with few differences observed between cultivars. This supports the findings presented in Table

4 of the modelling results for the vitamin C content of apricot products after osmotic dehydration, which found that the linear effects of immersion time and temperature on vitamin C content were significant ($P<0.05$). These findings suggest that, as with the antioxidant components of apples, the reduction in vitamin C content observed in apricot products may be due to thermal degradation and/or leaching into the osmotic solution during the osmotic dehydration process. Therefore, controlling osmotic dehydration conditions is important to minimise the loss of vitamin C and other important nutrients. Note that the highest vitamin C content was shown at a temperature of 40°C and 1 h of immersion (Figure 6). Regarding nutritional vitamin C protection, the temperature of 50°C and 1h were more appropriate.

Table 4 Fitting the effect of different levels of air temperature and treatment time on the amount of vitamin C at different concentrations of osmotic solution

Treatment (sucrose (%)- salt (%))	Final equation in terms of actual factors	R^2	C.V. (%)
45-15	$VitC=10.44-0.021\times A+0.58\times B-0.02\times A\times B$	0.83	9.86
50-10	$VitC=-14.41+1.08\times A+0.84\times B-0.02\times A\times B-0.01\times A^2$	0.88	9.27
55-5	$VitC=-3.78+0.68\times A-0.35\times B-7.89E-003\times A^2$	0.88	7.07

Note: A = temperature (°C); B = time (h)



(a) (b) (c)

Figure 6 Effects of the interaction of temperature and treatment time on the amount of vitamin C in different solutions with the ratio of a) 45-15 b) 50-10 c) 55-5

3.2 Optimisation

The numerical optimisation of the osmotic dehydration of apricot slices was performed using the desirability function technique for the developed models. The main constraints criteria were maximisation of WL, WR, salt, sugar, and vitamin C content, and minimisation of SG of the dehydrated product (Haque et al., 2020). However, independent variables such as temperature and time restored were set in the experimental range for optimisation, and time restored was set in the experimental range to optimise process variables.

RSM identified the optimal dehydration conditions as an immersion time of 5 h and a temperature of 59°C. The corresponding response variables for the solutions 55-5, 50-10, and 45-15 are as follows: SG values of

2.325%, 1.46%, and 0.206%; WL of 45.449%, 48.269%, and 49.314%; WR of 41.347%, 45.480%, and 46.8%; salt contents of 0.277%, 0.487%, and 0.675%; sugar contents of 12.465%, 12.211%, and 11.882%; and vitamin C levels of 7.556, 5.915, and 5.314 mg/100 g. The three data sets correspond to the solutions 55-5, 50-10, and 45-15, respectively. The optimisation outcomes revealed that the best treatment was administered by solution 45-15 (45% sucrose and 15% sodium chloride) in terms of the amount of SG, WL, WR and salt. While in terms of the amount of sugar and vitamin C, a solution of 55-5 was more appropriate. These findings were in agreement with those of Prinzivalli et al. (2006), Van Buggenhout et al. (2008) and Garcia-Nogueira et al. (2010).

The study of strawberry osmotic dehydration by Prinzivalli et al. (2006), for example, showed that longer immersion times in sucrose solutions resulted in loss of texture and tissue breakdown. The breakdown was attributed to a sugar peripheral layer formation causing anaerobic conditions and accelerated ripening of the fruit. The findings of that study support the optimisation of osmotic dehydration of apricot slices in the present study, where the use of sucrose and sodium chloride solutions at specific concentrations and processing times was found to improve water loss, salt, sugar and vitamin C content.

Furthermore, Garcia-Nogueira et al. (2010) investigated the use of ultrasound-assisted osmotic dehydration as a pretreatment for drying strawberries. Different concentrations of sucrose solutions were used to determine their effect on drying time, water loss and gain in soluble solids. The results showed that a higher sucrose concentration resulted in greater water loss, but the optimal pretreatment time and concentration to reduce drying time were 30 minutes with a 50% sucrose solution. The combination of osmotic dehydration with ultrasound energy was found to be effective in reducing processing time and increasing water diffusivity.

4 Conclusions

In the present study, osmotic dehydration was employed to partially eliminate water by immersing apricots in an osmotic aqueous solution. The findings of this study revealed that the concentration of the osmotic solution, the temperature (50°C and 60°C) and duration time (1, 3, and 5 hours) had a significant impact ($P<0.05$) on the osmotic drying process of apricots. Solution 50-10 (50% sucrose and 10% sodium chloride) treated for 5 h at 60°C was found to be the best treatment. It has the lowest SG/WL ratio, thus providing better dried apricots as compared to other treatments. The lowest *SG* and the highest *WL* were obtained for solution (55%-5%). The highest and lowest Vitamin C content was provided by osmotic solution 55-5 (11mg/100g) and 45%-15% (4 mg/100g), respectively. Optimisation showed that in terms of the amount of SG, WL, WR and salt, the best treatment was solution 45-15 (45% sucrose and 15% sodium chloride) with temperature 58.277°C and time 5 h, resulting in SG 2.325%, WL 45.449%, WR 41.347%, salt 0.277%.

One limitation of the present study is that it only focused on a specific range of concentrations, temperatures and immersion times in the osmotic solution, which may not reflect ideal conditions for all circumstances. Having said that, this study has provided valuable insights into the osmotic drying of apricots, highlighting the significant influence of various factors on the process. These findings contribute to the knowledge within the field and offer potential applications in the food industry to improve product quality and shelf life. The potential application of osmotic dehydration in the food sector, particularly its impact on shelf life and customer acceptance of dried products, can then be investigated on an industrial scale.

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