Journal of Food Science and Technology (Iran)

Homepage: www.fsct.modares.ir

Scientific Research

Optimization of combined pre-process (osmosis-ultrasound) and additional drying with hot air of Pommelo fruit

Maryam Sabetghadam[1], Fathema Pourhaji[2&3], Mahdi Jalali[3*], Elham Azadfar[1]

1- Young Researchers and Elite Club, Sabzevar Branch, Islamic Azad University, Sabzevar, Iran
2- Research and Development Manager, Sepidan Shir Khorasan Company, Fariman Industrial Area, Fariman, Iran
3- Lecturer, University of Applied Science and Technology, Center of Cheshme Noshan Khorasan (Alis)

ARTICLE INFO

Article History:
Received:2023/7/25
Accepted: 2024/1/2

Keywords:

Pommelo,

Osmosis,

Ultrasound,

Drying,

Hot air

.

DOI: **10.22034/FSCT.21.148.89.**

*Corresponding Author E-Mail:
mehdijalali62@yahoo.com

ABSTRACT

Effect of osmosis dehydration, ultrasonic and edible coating as the pretreatment before drying has been studied in order to improve the flavor of the product, reduce thermal damages, decrease interstitial water and ease of transferring mass. The response surface method was used to optimize the drying conditions of Pommelo slices by osmosis-hot air. The concentration of edible coating (0-2% w/v) and the time of applying ultrasound (0-30 min) and the concentration of sucrose (40-80% w/w) were evaluated as independent variables on the amount of moisture content, absorption of solids, weight loss and productivity coefficient of Pommelo slices as dependent variables. All process variables were linearly significant for all responses (P<0.01). The comparison of the optimization results of coated and uncoated Pommelo osmotic dehydration showed that at the optimal point, the maximum amount of carboxymethyl cellulose coating and the osmotic dehydration time and the concentration of the osmotic solution in the coated sample were calculated as 2%, 21.86 minutes and 57.75%, respectively. The highest values of water reduction, weight loss and efficiency coefficient were 0.09172 (g/100g of solid matter), 0.091% and 19.478 respectively in the coated sample, and the highest absorption of solids with a value of 0.0089 (g/100g of solids) was reported in the uncoated sample. The results showed that the use of coating reduces the absorption of solid.

1. Introduction

Pommelo with its scientific name (Citrus maxima) belongs to the (Rutaceae) family and is native to Southeast Asia. pommelo is the largest fruit of the citrus family. Its color is pale green and sometimes yellow with white flesh and rarely pink and red. Its skin is very thick and sweet. The native type of East Asia has a diameter of about 15-25 cm and its weight reaches 1-2 kg. pommelo has the properties of grapefruit and is rich in vitamins A, B, C and mineral salts of phosphorus, potassium, fiber and antioxidants. The vitamin C of pommelo is several times that of oranges and can be replaced with this fruit [1, 2]. Fresh pommelo cannot be stored for more than 3 or 4 days under normal conditions, but if it is covered with plastic films at a temperature of zero degrees Celsius and a relative humidity of 93-96%, it can be stored for 7 or 8 months [3].

Methods such as canning, fermentation and freeze-drying can be mentioned to increase the storage capability. Among these methods, freeze drying produces the highest quality product, but it is one of the most expensive methods. Therefore, a simple and inexpensive method with low investment is needed that can increase the shelf life of many perishable products, and be available to all consumers far from the cultivation areas, osmotic drying is one of these methods [4]. Osmotic drying is one of the food preservation methods that can create better quality properties in the product. In the application of the osmosis process, due to the limited and short-term use of hot air flow to complete the drying process, not only the desirable characteristics of the product are maintained to a significant extent, rather, the amount of thermal energy needed to remove excess water from the product is greatly reduced [5, 6]. Osmotic dehydration is used as a pre-process for some drying methods such as hot air drying, vacuum drying, frying, canning and freezing [6].

In this research, ultrasonic treatment has been used to improve mass transfer during drying. By using ultrasonic waves, mass transfer can be increased during osmotic drying. In high concentrations of the solution, ultrasonic waves intensify the passage of water through the texture and cause a significant decrease in the drying time of the product. Naturally, in the texture of fruits and vegetables, moisture is kept by surface tension in capillary tubes. As a result, the application of ultrasound waves causes rapid expansion and contractions in the texture tissue, which is known as the sponge effect [7]. The use of ultrasonic waves increases the moisture penetration coefficient and reduces the drying time. Due to the cavitation phenomenon, ultrasonic waves cause a series of rapid contractions and expansions in the material, which is similar to squeezing and releasing a sponge and causes water to leave the solid matrix, and on the other hand, creates microchannels to facilitate mass transfer during drying by hot air [5]. Ultrasonic drying has high commercial importance; In this method, the food is less damaged and dries with a lower percentage of moisture [2]. In the study of Reshadat et al. (2023), which was conducted on the drying process of orange fruit, the results showed that the optimum point with the highest desirability index was achieved during the application of ultrasound waves for 30 minutes, the amount of brix of the osmotic solution was 45, the temperature of the drying air was 70 degrees Celsius, and the speed of the drying air was 1.07 m/s [8]. Also, the results of Daraei garmakhany and Moradi (2018) property studies with the aim of combined drying (osmosis-hot air) on the quality of yellow tree apple leaves showed that the concentration of osmotic solution, time and temperature of the osmosis process had a significant effect on the parameters of moisture content, brix, weight value after osmosis process and sensory factors of the product [9]. In this research, the effect of using coating and combined pre-treatments of osmotic and ultrasonic dehydration processes in the process of drying pommelo by hot air has been investigated.

2. Materials and methods

2-1- Materials

In this study, pommelo (golden variety) was purchased from a local market in Tehran. First, the pommelo was freshly washed and peeled with a sharp stainless steel knife. Then, the pommeloes are divided into circular slices with a thickness of 10 mm, an inner diameter of 15 mm, and an outer diameter of 56 mm using a home-made slicer (MAXBLADE model, Nicer Dicer, Germany). Due to the uniformity of the pommelo slices, the diameters and thickness were controlled by calipers (model 45512, JL Company, China).

2-2- The coating

In order to cover the product before osmotic dehydration, three levels of carboxy-methyl-cellulose gum were used: zero, 1% and 2%. The coating process was done at room temperature and lasted for 30 seconds. After leaving the carboxy-methyl-cellulose gum solution, the sample was dried for 5 minutes with filter paper to remove excess gel. Finally, to dry and stabilize the coating, the sample was dried for 10 minutes at 70°C in an oven (model DIN EN6052IP20, Memmert Co., Germany) [10].

2-3- Ultrasound-osmosis dehydrating

In this research, sucrose was used as an osmotic medium. 40, 60 and 80% sucrose concentration was selected. The concentration of the desired solutions was prepared by mixing calculated amounts of sucrose (solids x %) with distilled water. The temperature of the dehydrating process during the process and in all treatments was fixed and equal to the ambient temperature (25 degrees Celsius). The ratio of fruit to osmotic medium was chosen as 1 to 10. The experiments were performed by applying moving conditions, i.e. stirring at a time interval of one revolution per hour [11].

The duration of the osmotic dehydration process was considered constant and 180 minutes. After coating and stabilizing the coating, the parts were immersed in the osmotic environment and subjected to the 25 kHz ultrasonic pre-process and 180 minutes of osmosis (without ultrasound) at time intervals of 0, 15 and 30 minutes. After the end of the dehydrating process, the pommelo fruit pieces were taken out of the osmotic environment and its surface was washed with deionized distilled water and placed on filter paper (Whatman No. 42) to absorb surface water, then the samples were weighed. An ultrasonic bath (LMS100 model, Heilscher Co., Germany) was used to apply the ultrasonic pre-process. This device is equipped with a sensor to adjust the temperature of the osmotic environment [12].

2-4- Calculation of relevant parameters and equations

Weight loss (WL), water reduction (WR), absorption of solids (SG) and efficiency coefficient (WL/SG) of pomelo slices based on weighing them in different stages (before osmotic dehydration, after osmosis and after drying in the oven) was calculated through the following relationships [3].

$$WL = \frac{(m_0 \times x_{w0}) - (m_t \times x_{wt})}{m_0} \tag{1}$$

$$SG = \frac{(m_t \times x_{st}) - (m_0 \times x_{s0})}{m_0} \tag{2}$$

$$WR = \frac{m_0 - m_t}{m_0} \times 100 \tag{3}$$

$$\Pr = \frac{WL}{SG} \tag{4}$$

m_0: initial weight of pommelo cut

m_t: Pommelo cut weight after dehydrating

x_{w0}: initial humidity of pommelo

x_{wt}: sample moisture after dehydrating

x_{s0}: the primary dry matter of pommelo is ($x_{s0} = 1 - x_{w0}$)

x_{st}: dry matter after dehydrating is ($x_{st} = 1 - x_{wt}$)

2-5- Additional drying

After obtaining the optimal conditions for ultrasound-osmosis pommelo dehydration, additional drying of the slices was done in optimal conditions. Drying process in a hot air circulation dryer equipped with an air circulation fan (model UNE 400 PA, Memmert Co., Germany) were dried until constant weight was reached. The drying process was done at 70 degrees Celsius. During drying, the weight of the samples was measured in the first hour of drying at 5-minute intervals and from the second hour onwards every 15 minutes using a digital scale with an accuracy of 0.001 (model HR 200, AND Co., Japan). Each experiment was performed in three replicates [12].

2-6- Statistical design and data analysis

In order to optimize the ultrasonic-osmosis pommelo dehydration process, the response surface methodology technique was used. In order to optimize the effect of edible coating concentration, ultrasound application time and sucrose concentration on water reduction, solids absorption, weight loss, productivity coefficient and moisture content, the response surface method was used. So that the concentration of edible coating (X1) and the time of application of ultrasound (X2) and concentration (X3) were selected as independent variables of the process, while water reduction (Y1), absorption of solids (Y2), weight loss (Y3), productivity coefficient (Y4) were evaluated as responses. For the statistical analysis of the Box-Benken design including 20 experiments with 8 replications at the central points, the actual values of the independent variables used in this process are shown in Table (1). Design Expert statistical software version 7 was used for statistical analysis of data. The experimental data were fitted with the help of a quadratic polynomial model; This model is as follows:

$$Y_k = \beta_{k0} + \Sigma^3_{i=1} \beta_{ki} x_i + \Sigma^3_{i=1} \beta_{kii} x_i^2 + \Sigma^2_{i=1}\Sigma^3_{j=i+1}\beta_{kij} x_i x_j + \varepsilon_k \quad (5)$$

In this equation, β_{kn} are the constant coefficients of the model and X_i are the independent variables used in the optimization process. The assessment of the best model was confirmed by examining the lack of fit test. So that the model that made the lack of fit test insignificant was selected as the best model. With 8 repetitions at the central point, the total number of tests required according to the formula, N=2K(K-1)+nc 20 tests were obtained.

Table 1 Independent variables of Pommelo's ultrasound-osmosis dehydration process

Variables	Actual values		
	-1	0	+1
Concentration of edible coating (% w/v) (X1)	0	1	2
Ultrasound application time (minutes) (X2)	0	15	30
Sucrose concentration (% w/w) (X3)	40	60	80

In order to determine the significance of the parameters and as a result of the proposed model for measuring water reduction, absorption of solid materials, the analysis of variance table is used, which are given in table (2). P values below 0.05 for each parameter indicate its significance at the confidence level of 0.95. Also, P values related to the lack of fit greater than 0.05 indicate that the error related to the model is not significant, and therefore the remaining major part is related to the pure error. As can be seen, for each answer, at least four variables are directly influential (Table 2). The coefficient of determination (R^2) values for all four responses are listed in Table (2). The large values of the adjusted coefficient of determination and its closeness to the coefficient of determination determine the validity of the proposed model. The closer (R^2) is to 1, the stronger the model is and the better it can predict the answer. Also, the values related to the predicted coefficient of determination are above 0.94, which indicates the validity of the model for the data that are not included in the model.

Table 2 Analysis of variance for all responses

	R-Squared	Adjusted R-Squared	Predicted R-Squared
Y1	0.9927	0.9861	0.9723
Y2	0.9928	0.9863	0.9397
Y3	0.9838	0.9692	0.9351
Y4	0.9949	0.903	0.9675

3. Results and Discussion

3-1- Water reduction changes

The results of the analysis of variance of the central composite response surface model showed that linear ($P<0.0001$) and quadratic effects ($P<0.05$) had a significant effect on the reduction of pommelo water during osmotic dehydration. Examining the F values showed that among the linear effects of the response surface model, it had the greatest effect on the reduction of coated pommelo juice. Among the second-order effects and mutual effects, parameters A2 and BC have the most effect, so that with the increase in the time of ultrasound pretreatment, the amount of water reduction changes, a downward trend, but with a decrease in the concentration of sucrose, it first showed a decrease and then an increasing trend. Figure (1), three-dimensional diagram and contour, shows the simultaneous effect of dehydrating time and coverage percentage on pommelo water reduction during osmotic dehydrating. The results showed that increasing the coverage percentage of carboxymethyl cellulose increased the water reduction parameter. Also, in relation to the effect of water extraction time on the process of water reduction, an upward trend was observed from 0 to 30 minutes. In osmotic dehydration, sugary and acidic substances from the absorbed solution soften the tissue and water absorption increases and with the increase of ultrasound time, the amount of water absorption increases, or in other words, water excretion decreases [13].

Eshraghi et al. (2014) investigated the effect of ultrasound pretreatment on the drying of kiwifruit leaves and concluded that the increase in water absorption with increasing ultrasound time can be attributed to the effect of ultrasound time on the formation of more microscopy channels and as a result the difference in osmotic pressure between the sample and distilled water, which leads to the absorption of water and the reduction of solids [13], these results are consistent with the observations of Fernandes et al. By studying the changes in cell structure, these researchers came to the conclusion that fruit loses water during osmotic pretreatment and absorbs water during ultrasound pretreatment [14]. Taiwo et al. (2003) tested the effect of ultrasound on strawberries subjected to osmosis, and the result indicated that ultrasound improved mass transfer [15].

Figure (1) also shows the effect of increasing the concentration of the osmotic solution and the coating on the changes in pommelo water reduction during osmotic dehydration. Accordingly, the increase in the concentration and coating caused the water to decrease.

Increasing the concentration of the solution, which increases the osmotic pressure outside the samples and causes swelling in the cell membrane. As a result, it causes more water to escape from the sample into the product, and also the amount of water outflow in the coated samples is higher than in the uncoated samples, and the use of edible coating can increase the efficiency of osmotic water removal [16].

Jalaee et al. (2011) conducted dehydration in apple samples and concluded that the maximum reduction of water in coated with a concentration of 2% coating and a dehydration time of 180 minutes was observed that the amount of water released in coated samples is higher than in uncoated samples and the use of edible coating can increase the efficiency of osmotic water extraction [17]. Dehghannya et al. (2006) and García et al. (2010), investigating the effect of chitosan and carboxymethyl cellulose coating on papaya and apple fruit mass transfer during osmotic dehydration, showed that the amount of water released in coated samples compared to There are more uncoated samples and the use of edible coating can increase the efficiency of osmotic dehydration [18, 19]. The following prediction equation for the amount of water reduction was obtained by fitting the data.

)6 $(Y1 = +0.089 + 1.874\,A + 5.006\,B + 0.012\,C + 0.010\,AB - 0.003\,AC + 4.656\,BC + 2.321\,A^2 - 0.010\,B^2 - 5.351\,C^2$

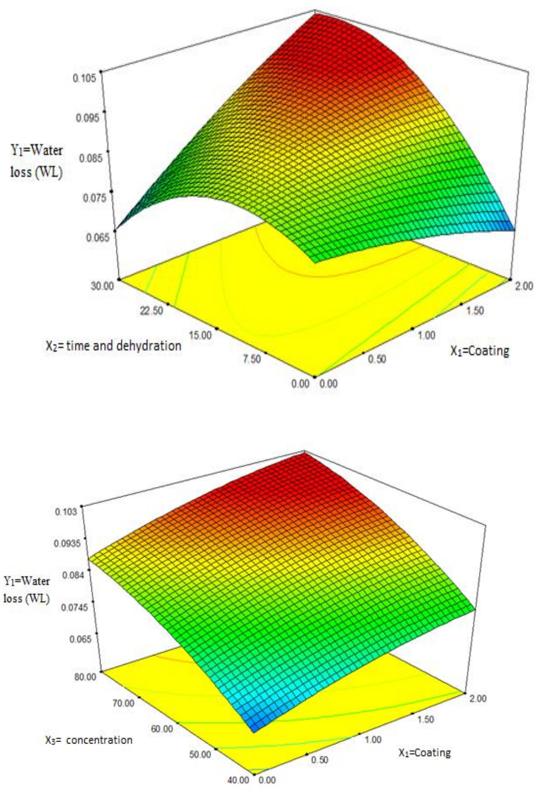


Fig 1 Response surface diagrams for water loss and the influence of independent variables

3-2- Changes in absorption of solid materials

The results of the analysis of variance of the central composite response surface model showed that the linear (P<0.0001) and quadratic (P<0.05) effects had a significant effect on the absorption of pommelo fruit solids (Table 3). Among the second-order effects and mutual effects, B^2 and AC parameters had the greatest effect, so that with the increase in the concentration of the edible coating and the decrease in the concentration of sucrose, the amount of changes in the absorption of solids showed a linear downward trend. Figure (2), the three-dimensional diagram and contour, shows the simultaneous effect of dewatering time and coating on the absorption of pommelo solids during osmotic dehydrating. The results showed that the increase in water extraction time from 0 to 30 (minutes) caused an increase in the absorption parameter of solids. Also, the results showed that the increase of carboxymethylcellulose from 0 to 2% (w/v) caused a decrease in the absorption parameter of solids.

Eshraghi et al. (2014) during the study of the effect of ultrasound pretreatment on the drying of kiwifruit sheets also concluded that, the reduction of solids with increasing the ultrasonication time can be considered due to the effect of the ultrasonication time on the formation of microscopic channels and as a result the difference in osmotic pressure, which leads to the absorption of water and the reduction of solids [13], this result is consistent with the results of Fernandes et al. (2008) in investigating the effect of ultrasound pretreatment on the cell structure of cantaloupe [14]. Shukla and Sink (2007) investigated the osmotic drying of cauliflower, white button mushroom and green peas. The results showed that in the first 4 hours, the rate of water loss and absorption of solids in all samples increased and then gradually decreased until reaching the equilibrium level [20]. Also, Raul Walk (1994) reported that usually in most osmotic drying conditions, the highest amount of mass transfer in the direction of water loss occurs in the first 2 hours and absorption of solids occurs in the first 50 minutes [21].

Figure (2) shows the effect of increasing the concentration of the osmotic solution and the coating on changes in the absorption of pommelo solids during osmotic dehydration. Accordingly, increasing the concentration increased the absorption of solids and the coating decreased the absorption of solids. The research results of the researchers have reported the effect of food coating on increasing the amount of water loss and reducing the amount of absorption of solids [22]. The following predictive equation for the amount of water loss was obtained by fitting the data.

$$Y2 = +5.109 + 1.116\,A + 1.877\,B + 4.212\,C - 1.584\,AB + 1.298\,AC - 1.873\,BC - 1.483\,A^2 + 3.318\,B^2 + 5.070\,C^2 \quad (7)$$

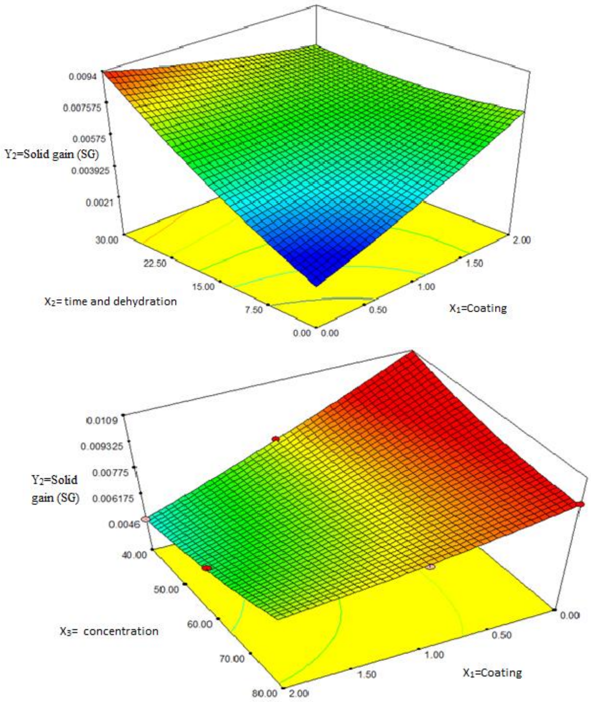


Fig 2 Response surface diagrams for adsorption of solids and the influence of independent variables

3-3- Weight loss changes

The results of the analysis of variance of the central composite response surface model showed that the linear (P<0.0001) and quadratic (P<0.05) effects had a significant effect on the pommelo fruit weight loss index (Table 4). Among the second-order effects, the A^2 coefficient and the AC and BC coefficients showed the greatest effect in the mutual effects, so that in the interaction effect of BC, with the increase of the independent variables, the time of ultrasound pretreatment and the concentration of sucrose, the amount of weight loss linearly increased. Figure (3), three-dimensional diagram and contour, shows the simultaneous effect of dehydrating time and coating on pommelo weight loss during osmotic dehydrating, which can be concluded by increasing the dehydrating time from 0 to 30 (minutes), it caused an increase in the weight loss parameter. Also, the results showed that with the increase of carboxymethyl cellulose from 0 to 2% (w/v), it caused an increase in weight loss.

Rodrigues et al. (2008) confirmed the results of this research in investigating the effect of osmotic dehydrating with the help of ultrasound on the sapota structure [23]. Sabahi (2013) investigated the effect of ultrasound treatments on the osmotic dehydration process of celery and concluded that with increasing ultrasound time, the amount of weight loss decreases [24]. Maskooki et al. (2007) during grape drying using osmotic solution and alkaline pre-treatment simultaneously with ultrasonic waves announced that the weight loss of grapes caused by grape drying and turning into raisin during the drying time is significantly different from the control sample in the samples treated with ultrasound waves and it seems that the weight loss during drying increases with the increase in the time of ultrasound application. But in this research, probably due to the use of ultrasound waves separately without combining with osmotic dehydration, it causes water absorption and the sample absorbs more water than it loses, therefore the weight loss decreases [5].

Figure (3) shows the effect of increasing the concentration of osmotic solution and coating on changes in weight loss of pommelo during osmotic dehydrating, therefore, increasing the concentration and coating caused a decrease in water. Osmotic dehydration reduces the weight of pommelo. Dehydration pommelo at the highest concentration has the greatest weight loss. The results show that dehydration was more intense at the beginning of this process. The rate of weight loss in the first hour was the highest, which is due to the presence of a greater driving force at the start of osmotic dehydration. Driving force means the greater difference in osmotic pressure between surrounding hypertonic solutions and plant tissue [25]. The following prediction equation was obtained for the weight loss value of the data fit.

$$Y3 = +0.079 + 7.291\,A + 2.176\,B + 0.011\,C + 0.013\,AB + 1.915\,AC + 3.426\,BC + 2.201\,A^2 - 0.012\,B^2 - 1.084\,C^2 \quad (8)$$

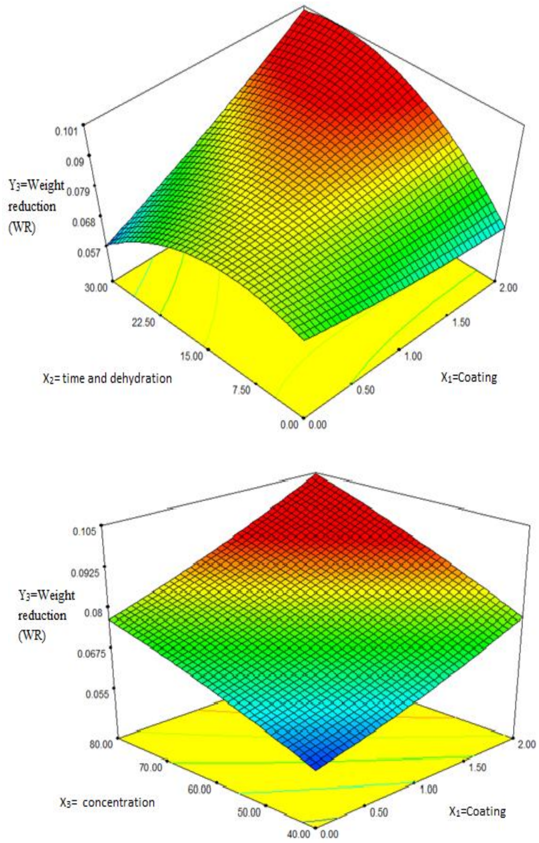


Fig 3 Response surface diagrams for weight loss and the influence of independent variables

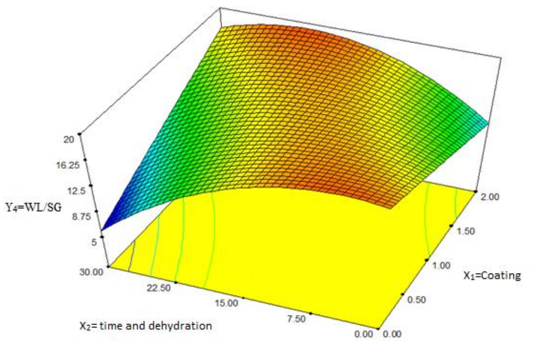
3-4- Efficiency coefficient

The results of the analysis of variance of the central composite response surface model showed that the linear (P<0.0001) and quadratic (P<0.05) effects had a significant effect on the efficiency coefficient of pommelo fruit during osmotic dehydration. Examining the (F) values showed that among the linear effects of the response level model, the F value had the greatest effect on the pommelo efficiency coefficient. Examining the coefficients of the presented model shows that among the quadratic effects, the A^2 coefficient and the AB and BC coefficients showed the greatest effect in the interaction effects, so that the interaction effect of AB exerted a double effect was applied in the model, so that with increasing values Independent variables such as the concentration of edible coating and the time of application of ultrasound pretreatment, the index of efficiency coefficient increased at first and then decreased.

Figure (4), a three-dimensional diagram and contour, shows the simultaneous effect of dehydrating time and coating on the efficiency coefficient of pommelo during osmotic dehydrating. The results showed that the increase in water extraction time from 0 to 30 (minutes) caused an increase in the efficiency coefficient parameter. Also, the results showed that the increase of carboxymethylcellulose from 0 to 2% (w/v) caused an increase in efficiency coefficient. Increasing the contact time increases the amount of water removed from the sample and enters the product and also increases the osmotic factor into the tissue. Azizi Khasal et al. (2013) orange dehydration, Seraji et al. (2012) cucurbit dehydration, and Emam-Djomeh and Aladdini (2005) the process of dehydration on kiwi, which showed that increasing the WL/SG ratio is soluble with increasing extraction time [26, 27, 28].

Figure (4) shows the effect of increasing the concentration of the osmotic solution and the coating on the changes in the efficiency coefficient of pommelo during osmotic dehydration. Accordingly, the increase in the concentration and coating caused an increase in the efficiency coefficient. The effect of coating concentration and solution concentration on WL/SG ratio during osmotic pommelo dehydration is shown. The ratio of WL/SG in uncoated and coated samples shows that under the same conditions, WL/SG is more than uncoated samples. The experimental results show that the coating reduces the absorption of solids without having a great effect on water removal compared to the samples without coating. The change in WL/SG of coating samples depends on the chemical capability or propulsion of water and solution mass transfer between the sample and the osmotic solution. In addition, the molecular structure of the coating material also affects the W L/SG ratio. An increase in the concentration of the osmotic solution increases both components, so it can be said that with an increase in the concentration of the osmotic solution, the osmotic pressure and the concentration difference between the pommelo slices and the osmotic solution increase. The researchers declared the osmotic pressure difference as the driving force for mass transfer to remove moisture and the concentration difference as the propulsion for mass transfer to absorb the osmotic agent [26, 28]. Dehghannya et al. (2006) investigated the water loss, absorption of solids and efficiency coefficient of apples coated and not coated by carboxymethylcellulose and they concluded that apples coated with carboxymethyl-cellulose lost more water and absorbed less solids. Also, they had a higher efficiency coefficient compared to uncoated samples [18]. The following predictive equation was obtained for the value of the efficiency coefficient of data fitting.

$$Y4 = +17.422 + 1.115\,A - 1.550\,B - 0.710\,C + 4.540\,AB - 3.341\,AC + 1.676\,BC + 0.047\,A^2 - 4.242\,B^2 - 2.564\,C^2 \quad (9)$$



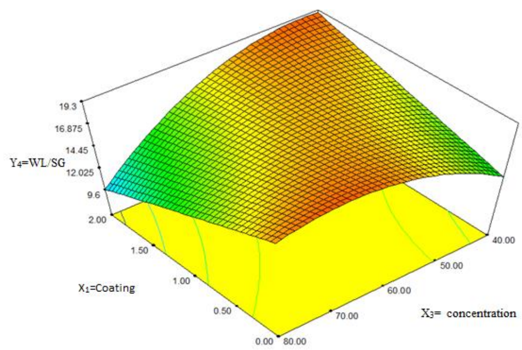


Fig 4 Response surface diagrams for efficiency coefficient and the influence of independent variables

3-5- Optimizing the osmotic dehydration process

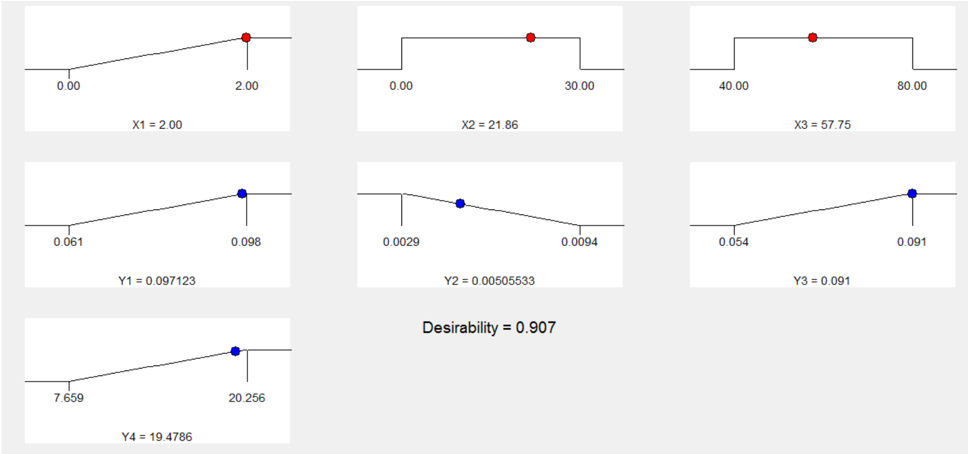
According to the tests and analyzes performed at the end, the optimal points of the pommelo osmotic dehydration process should be determined. The optimal point is the point where the process of pommelo osmotic dehydration is in ideal conditions and almost all the investigated factors are in favorable conditions. The optimal points for the concentration of the edible coating, the time of ultrasound pretreatment and the concentration of the osmotic solution (sucrose) in the coated sample were 2%, 21.86 minutes and 57.75%, respectively. Finally, the values of dependent variables for water reduction, absorption of solid materials, weight loss and efficiency coefficient for the coated samples are respectively 0.09172 (g/100g of solids), 0.005055 (g/100g of solid matter), 0.091% and 19.478 were reported.

Table 3 Comparison of independent variables in optimal conditions (covered sample - non-covered sample)

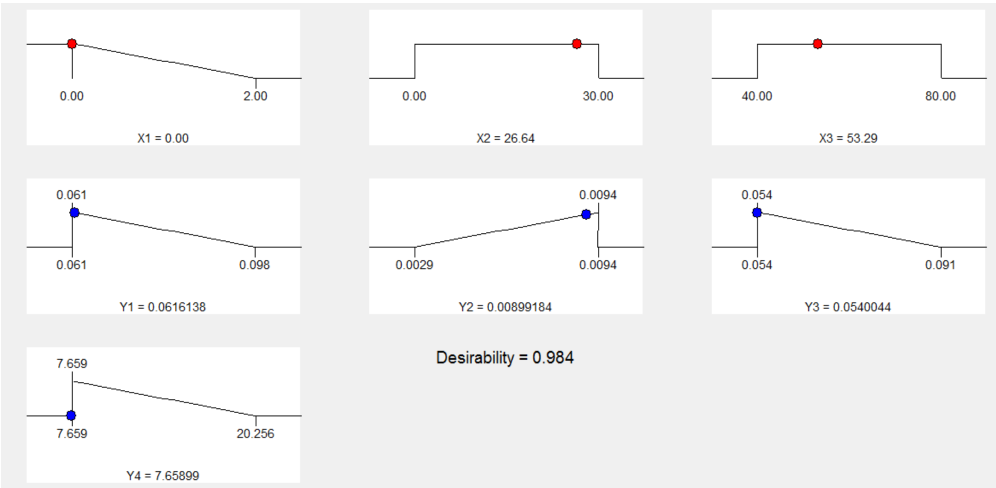
Variables	Actual values	
	Without cover	Covered
Concentration of edible coating (% w/v) (X1)	2	0
Ultrasound application time (minutes) (X2)	21.86	26.64
Sucrose concentration (% w/w) (X3)	57.75	53.29

Table 4 Comparison of osmotic-ultrasonic dewatering of Pommelo in optimal conditions (covered-uncovered sample)

Sample type	Water reduction	Adsorption of solids	Weight loss	Efficiency coefficient
Covered	0.0917	0.0050	0.091	19.47
Without cover	0.0616138	0.00899	0.0540044	7.5999



(A)



(B)

Fig 5 Optimizing the drying of coated (A) and uncovered (B) Pommelo by the dehydration process

4.Conclusion

The quality of the food product depends on the amount of physical and biochemical changes that occur during the drying process. Temperature, time and water activity during the drying process affect the quality of the final product. The osmotic dehydration process can be used as a pre-process for subsequent processes such as drying or freezing. Also, applying ultrasound pretreatment as a pretreatment before drying, in addition to reducing drying time, has high commercial importance. In this method, compared to the case where conventional dryers are used (in the same temperature conditions), food products are dried with a lower percentage of moisture. In this research, the response surface method was used to determine the optimal conditions of the variables of the drying process of pommelo fruit slices with the aim of maximizing water reduction, weight loss and efficiency coefficient and minimizing the absorption of solid materials. For uncoated pommelo fruit samples, the optimal points for four dependent variables of water reduction, absorption of solid materials, weight loss and efficiency coefficient, respectively 0.06161 (g/ 100g of solid matter), 0.00899 (g/in 100g of solid matter), 0.054% and 7.599 were obtained.

5. References

[1] Mozaffarian, V. 2009. A dictionary of Iranin plant, Names; Latin, English, Persian. Farhang Moaser Publishers, ISBN: 9789645545404. [In Persian].

[2] Sun, L., Zhang, H., and Zhuang, Y. 2012. Preparation of free, soluble conjugate, and insoluble-bound phenolic compounds from peels of rambutan (Nephelium lappaceum) and evaluation of antioxidant activities in vitro. *Journal of Food Science*, 77(2): 198-204.

[3] AOAC. 2005. Official methods of analysis, 18th edn. Association of Official Analytical Chemists, Washington, DC.

[4] Bolin, H.R., Huxsoll, C.C., Jackson, R., and Ng, K.C. 1983. Effect of osmotic agents and concentration on fruit quality. *Journal of Food Science*, 48(1): 202-205.

[5] Maskooki, A., Mortazavi, A., and Maskooki, A. 2007. Effects of combined caustic soda and ultrasound on reducing the drying time of grapes in raisin production. *Iranian Journal of Nutrition Sciences & Food Technology*, 2(1): 1-10. [In Persian].

[6] Moini, S., and Javaheri, M. 2004. An investigation on usage of osmotic method for drying kilka. *Iranian Journal of Agriculture Science*, 35(4): 901-909. [In Persian].

[7] Hahn, F., and Sanchez, S. 2000. Carrot volume evaluation using imaging algorithms. *Journal of Agricultural Engineering Research*, 75(3): 243-249.

[8] Reshadat, R., Khoshtaghaza, M.H., and Hamidy, Z. 2023. Optimization of Orange fruit drying in hot air dryer with combined pretreatment of osmotic dehydration and ultrasonic waves. *Journal of Researches in Mechanics of Agricultural Machinery*, 12(2): 115-126. [In Persian].

[9] Daraei garmakhany, A., and Moradi, M. 2018. Response Surface Optimization of Combination Drying (Osmotic-Hot Air Drying) of Apple Fruit Slices. *Iranian Journal of Nutrition Sciences & Food Technology*, 13(3): 103-114. [In Persian].

[10] Seraji, A., Ghanbarzadeh, B., Sowti Khiabani, M., and Movahhed, S. 2012. The study of carboxymethyl cellulose-ascorbic acid based edible coating and osmotic dehydration on cucurbit drying. *Iranian Food Science and Technology Research Journal*, 8(2): 209-218. [In Persian].

[11] Yadav, A.K., and Singh, S.V. 2014. Osmotic dehydration of fruits and vegetables: a review. *Journal of Food Science and Technology*, 51(9): 1654-1673.

[12] Seiiedlou, S., Ghasemzadeh, H.R., Hamdami, N., Talati, F., and Moghaddam, M. 2010. Convective drying of apple: mathematical modeling and determination of some quality parameters. *International Journal of Agriculture and Biology*, 12: 171-178.

[13] Eshraghi, E., Kashani-Nejad, M., Maghsoudlou, Y., Beiraghi-Toosi, S., and Alami, M. 2014. Studying the effect of osmosis-ultrasound compound pre-treatment on drying kiwi fruit sheets. *Iranian Food Science and Technology Research Journal*, 9(4): 323-329. [In Persian].

[14] Fernandes, F.A.N., Gallão, M.I., and Rodrigues, S. 2008. Effect of osmotic dehydration and ultrasound pre-treatment on cell structure: Melon dehydration. *LWT - Food Science and Technology*, 41(4): 604-610.

[15] Taiwo, K.A., Eshtiaghi, M.N., Ade-Omowaye, B.I.O., and Knorr, D. 2003. Osmotic dehydration of strawberry halves: influence of osmotic agents and pretreatment methods on mass transfer and product characteristics. *Interrnational Journal of Food Science & Technology*, 38(6): 693-707.

[16] Kowalska, H., Marzec, A., Domian, E., Kowalska, J., Ciurzyńska, A., and Galus, S. 2021. Edible coatings as osmotic dehydration pretreatment in nutrient-enhanced fruit or vegetable snacks development: A review. *Comprehensive Reviews in Food Science and Food Safety*, 20(6): 5641-5674.

[17] Jalaee, F., Fazeli, A., Fatemian, H., and Tavakolipour, H. 2011. Mass transfer coefficient and the characteristics of coated apples in osmotic dehydrating. *Food and Bioproducts Processing*, 89(4): 367-374.

[18] Dehghannya, J., Emam-Djomeh, Z., Sotudeh-Gharebagh, R., and Ngadi, M. 2006. Osmotic dehydration of apple slices with carboxy-methyl cellulose coating. *Drying Technology*, 24(1): 45-50.

[19] García, M., Díaz, R., Martínez, Y., and Casariego, A. 2010. Effects of chitosan coating on mass transfer during osmotic dehydration of papaya. *Food Research International*, 43(6): 1656-1660.

[20] Shukla, B.D., and Singh, S.P. 2007. Osmo-convective drying of cauliflower, mushroom and greenpea. *Journal of Food Engineering*, 80(2): 741-747.

[21] Raoult-Wack, A.L. 1994. Recent advances in the osmotic dehydration of foods. *Trends in Food Science & Technology*, 5(8): 255-260.

[22] Wongphan, P., Panrong, T., and Harnkarnsujarit, N. 2022. Effect of different modified starches on physical, morphological, thermomechanical, barrier and biodegradation properties of cassava starch and polybutylene adipate terephthalate blend film. *Food Packaging and Shelf Life*, 32: 100844.

[23] Rodrigues, S., Gomes, M.C.F., Gallão, M.I., and Fernandes, F.A.N. 2008. Effect of ultrasound-assisted osmotic dehydration on cell structure of sapotas. *Journal of the Science of Food and Agriculture*, 89(4): 665-670.

[24] Sabahi, S. 2013. Study the effect of ultrasound & microwave methods on osmotic dehydration of celery. Thesis on Food Science and Technology "M.Sc.". Faculty of Agricultural Engineering - Food Science and Technology. Islamic Azad University Sabzevar Branch. [In Persian].

[25] Rastogi, N.K., and Raghavarao, K.S.M.S. 2004. Mass transfer during osmotic dehydration of pineapple: considering Fickian diffusion in cubical configuration. *LWT - Food Science and Technology*, 37(1): 43-47.

[26] Azizi Khasal, M., bassiri, A., and Maghsoudlou, Y., 2013. Optimization of combined process of osmotic dehydration in discontinuous reduced pressure-hot air drying of orange slices using response surface method. *Food Technology & Nutrition*, 10(3): 63-72. [In Persian].

[27] Seraji, A., Ghanbarzadeh, B., Sowti Khiabani, M., and Movahhed, S. 2012. The study of carboxymethyl cellulose-ascorbic acid based edible coating and osmotic dehydration on cucurbit drying. *Iranian Food Science and Technology Research Journal*, 8(2): 209-218. [In Persian].

[28] Emam-Djomeh, Z., and Aladdini, B. 2005. Improving the quality indicators of dried kiwi and its formulation using pre-process osmosis. *Iranian Journal of Agriculture Science*, 36(6): 1421-1427. [In Persian].

مجله علوم و صنایع غذایی ایران

سایت مجله: www.fsct.modares.ac.ir

مقاله علمی_پژوهشی

بهینه‌سازی پیش فرآیند ترکیبی (اسمز-فراصوت) و خشک کردن تکمیلی با هوای داغ میوه پوملو

مریم ثابت قدم[۱]، فاطمه پورحاجی[۲و۳]، مهدی جلالی[۳]*، الهام آزادفر[۱]

۱- باشگاه پژوهشگران جوان و نخبگان، واحد سبزوار، دانشگاه آزاد اسلامی، سبزوار، ایران

۲- مدیر تحقیق و توسعه، شرکت سپیدان شیر خراسان، شهرک صنعتی فریمان، فریمان، ایران

۳- مدرس، دانشگاه جامع علمی- کاربردی، مرکز چشمه نوشان خراسان (عالیس)

اطلاعات مقاله

تاریخ های مقاله :

تاریخ دریافت: ۱٤۰۲/۵/۳

تاریخ پذیرش: ۱٤۰۲/۱۰/۱۲

کلمات کلیدی:

پوملو،

روش اسمزی،

فراصوت،

خشک کردن،

هوای داغ

DOI: 10.22034/FSCT.21.148.89.

مسئول مکاتبات: *

mehdijalali62@yahoo.com

چکیده

در این مطالعه، اثر استفاده از آبگیری اسمزی، فراصوت و پوشش خوراکی به عنوان پیش تیمار قبل از فرآیند خشک کردن جهت بهبود طعم محصول، کاهش صدمات حرارتی، کاهش آب بافتی و سهولت انتقال جرم مورد بررسی قرار گرفت. روش سطح پاسخ برای بهینه‌سازی شرایط خشک کردن برش‌های میوه پوملو توسط اسمز-هوای داغ مورد استفاده قرار گرفت. غلظت پوشش خوراکی (۲-۰ ٪ وزنی/حجمی)، زمان اعمال فراصوت (۳۰-۰ دقیقه) و غلظت ساکارز (۸۰-٤۰ ٪ وزنی/وزنی) به عنوان متغیرهای مستقل بر میزان رطوبت، جذب مواد جامد، افت وزن و ضریب بهره‌وری میوه پوملو به عنوان متغیرهای وابسته مورد ارزیابی قرار گرفت. تمام متغیرهای فرایند به صورت خطی برای تمام پاسخ‌ها معنی‌دار بودند (P<۰/۰۱). مقایسه نتایج بهینه‌سازی فرایند آبگیری اسمزی پوملو پوشش یافته و بدون پوشش نشان داد که در نقطه بهینه، بیشترین مقدار پوشش کربوکسی‌متیل‌سلولز و زمان آبگیری اسمزی و غلظت محلول اسمزی در نمونه پوشش یافته به ترتیب ۲ درصد، ۲۱/۸٦ دقیقه و ۵۷/۷۵ درصد محاسبه شد. بیشترین مقادیر کاهش آب، افت وزن و ضریب بهره‌وری به ترتیب ۰/۰۹۱۷۲ (گرم/در ۱۰۰گرم ماده جامد)، ۰/۰۹۱ درصد و ۱۹/٤۷۸ در نمونه پوشش یافته و بیشترین جذب مواد جامد با مقدار ۰/۰۰۸۹ (گرم/در ۱۰۰گرم ماده جامد) در نمونه بدون پوشش گزارش شد. نتایج نشان داد استفاده از پوشش باعث کاهش جذب مواد جامد می- گردد.