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Optimization of combined drying (osmotic-hot air) of aloe vera slice using response surface methodology

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ABSTRACT

The aim of this study was to produce dry aloe vera slice by osmotic-hot air drying method and to investigate the effects of this method on texture, color, shrinkage, water re-absorption ability and water activity. The studied variables included precooking time (5, 7 and 10 minutes), drying time (8, 10 and 12 hours) and drying temperature (40, 50 and 60 ° C) using the response surface method in the form of a central composite design. It was examined with six replications at the central point. The results showed that increasing the temperature to 50°C increased the hardness of the texture, but further increasing the temperature reduced the hardness. The rate of rehydration was affected by drying temperature. With increasing temperature, the rate of rehydration in the samples increased. However, changing the pre-cooking and drying process time had no effect on the amount of this parameter. None of the studied independent variables had a significant effect on water activity. Optimization results showed that pre-cooking for 10 minutes and drying at 53.93°C for 8 hours will produce products with the best characteristics.

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1- Introduction

The absence of conversion industries for processing garden products makes farmers sell their products raw and at the lowest price. Among the different processing methods, the drying process has received more attention due to the increase in temperature, reduction in weight and volume, and ease of transportation and storage of garden products. In the past, uncontrollable natural energies such as sun and wind are used, and now new controllable devices are used to dry products. The final goal of the process of drying agricultural products is to reduce waste and increase product shelf life [1]. Food drying is based on the removal of water using the heat transfer force to evaporate or sublimate water.be In all drying methods, the amount of water in the food item is reduced with the aim of reducing the water activity of the food item in order to increase the shelf life [2].

Osmotic drying is one of the types of drying methods in which a part of the water of the product is removed by immersing it in a concentrated solution and the driving force necessary for the release of water from the tissue of the food to the osmotic solution is the difference between the osmotic pressure of the hypertonic solution and can be used as a be used as an independent step or in combination with other processes [3]. dryOsmosis is one of the best processes to preserve food for a long time because it improves quality in terms of color, texture, taste, product stability, preserves nutrients and prevents microbial spoilage.to be The final quality of the product is influenced by factors such asThe treatment includes the nature and concentration of the osmosis solution, the quality of the raw materials, the ripeness of the fruits, the shape and size of the slices, the duration of the osmosis, the ratio of sample to syrup, stirring, temperature and additives. Osmotic drying for banana, jackfruit, sapota[1], mango, guava and pineapple have been used very successfully [3].

Many studies have been done in the field of drying methods of fruits and vegetables. Osmotic drying has been used as a pre-treatment method for apple processing before freeze drying and it has been found that by using this technique, sensory and textural characteristics can be improved and enzymatic browning can be prevented. Few studies have been done on drying aloe vera with methods other than the method discussed in this article. Torres et al. [4] studied the preservation of aloe vera tissue in the spray drying process. They studied the rheological behavior of mucilage as a function of concentration, temperature,pH and ionic strength were investigated. The results showed that the viscosity is dependent on the ionic strength and this dependence will increase when divalent cations are used, and the optimal conditions for using a spray dryer are the inlet temperature of 150 degrees Celsius and the atomizer speed of 27500 rpm and the inlet flow rate of 5 1/liter per hour was estimated. Sharifi et al. [5] and Hatami Bavil et al. [6] also studied other parameters of osmotic drying, such as the influence of the ratio of solution to gel, the ultrasound process. According to the review of the research done in this field, no study has been done in connection with combined

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osmosis-hot air drying of aloe vera. Therefore, this article intends to investigate the effect of pre-cooking time, drying time and temperature of aloe vera sheet in the osmosis-hot air drying method.

2- materials and methods

2-1- Preparation of aloe vera

Fresh aloe vera leaves (Aloe vera Barbadensis) were selected and purchased equally from Gonbadkavus city based on freshness, ripeness and shape. The leaves were kept in the refrigerator until drying and performing the tests. At the beginning of the work, after washing and rinsing the aloe vera, the epidermis tissue (green skin) was separated from the gel. Then the gel was cut into square sheets.

2-2- pre-cooking aloe vera

The aloe vera gel obtained from the previous step was poured into boiling water for a specified period of time (according to the treatments specified in Table 1) and allowed to remove the unpleasant taste of aloe vera completely.

2-3- Osmotic water extraction using sugar solution

To perform osmotic pretreatment, from the method optimized by Sharifi et al]5[used. In this way, the samples are placed in the osmotic solution prepared from sugar at a temperature of 30 degrees Celsius with a Brix of 31 and a sample to solution ratio of 1 to 5.7 for a certain period of time until the stage of losing moisture and absorbing the dissolved solids completely. be passed

2-4- drying using hot air

Aloe vera sheets dehydrated by osmosis method were placed in a hot air dryer until reaching the desired texture and moisture content. Drying time (8 to 12 hours) and drying temperature (40 to 60 °C) were considered as variables (Table 1).

Table 1- Experimental treatments determined by design expert

treatment	Precooking time (min)	Temperature)	Time (h)
1	10	40	12
2	7.5	60	10
3	10	40	8
4	5	40	12
5	10	50	10
6	7.5	50	10
7	7.5	50	8
8	7.5	40	10

9	7.5	50	10
10	10	60	12
11	7.5	50	10
12	5	60	12
13	5	40	8
14	5	60	12
15	5	40	8
16	7.5	50	10
17	7.5	50	10
18	7.5	50	12
19	10	60	8
20	5	60	8

5-2- Evaluation of water reabsorption

In order to check the water absorption ability of the samples, immersion method in distilled water was used. One gram of dry samples was immersed in 100 ml of distilled water at a temperature of 100 at specific time intervals. The samples were removed from the distilled water and after removing the surface moisture, they were weighed with filter paper. For this purpose, initially, the times were considered short because the absorption rate is high. This process continued until the weight change of the samples was minimized and almost fixed. This point was considered the final point and the percentage of absorbed water, the maximum ability of the substance to absorb water [7]. The following equation was used to calculate the amount of water reabsorption:

$$\text{Water reabsorption rate}=\frac{Wr\,Wr}{Wd\,Wd} \quad \text{relationship (1)}$$

where Wr and Wd are the weight of the dried sample after water absorption and before that, respectively.

6-2- Evaluation of water activity

Aw meter (Novasina) was used to measure water activity. The sample was placed inside the special screen of the device and after 10 minutes, the amount of blue activity was determined on the screen of the device [8].

2-7- Humidity measurement

To measure the humidity, the plate was placed in the oven at 105 degrees Celsius for 30 minutes and weighed after reaching a constant weight. 2 grams of the sample was transferred to a plate and placed in an oven at 105 degrees Celsius for almost 3 hours. After reaching a constant weight and cooling, the sample was weighed and the moisture content was calculated according to the following formula [9].

$$\text{Moisture percentage} = \frac{M1-M2}{M0}\frac{M1-M2}{M0} \times 100$$ relationship (2)

In this regard: M_1 Weight of container and sample before drying, M_2 Weight of container and sample after drying and M_0 It is the weight of the sample.

8-2- Determining volume and shrinkage

The volume was measured by pycnometric method [10]. For this purpose, the weight of the empty pycnometer (In_p(and filled with fluid of specific density)In_{pf}) will be recorded.Then the pycnometer is completely emptied and dried and aloe vera pieces are poured into it and weighed again (w_{ps}). In the next step, the pycnometer containing aloe vera and fluid is weighed (w_{pfs}). Finally, the volume is calculated from the following relationship:

$$Vs = \frac{(Wpf - Wp) - (Wpfs - Wps)}{pF}$$ relationship (3)

In order to measure the shrinkage, the initial volume of the samples and the final volume of the sample obtained using the liquid displacement method are placed in the following relationship and the amount of shrinkage is calculated:

$$S = \left(1 - \frac{V_t}{V_0}\right) * 100$$ relationship (4)

In this regard: S percentage of shrinkage, V_t V_t Sample volume after drying and V_0 V_0 It is the initial volume of the sample.

9-2- Determining texture characteristics

Determining tissue characteristics according to the proposal of the manufacturer of the tissue measuring device (Microstable System,UK) was done with tissue profile analysis (TPA) test. For this purpose, a cylindrical probe with a diameter of 20 mm was used. The probe started moving from 10 mm above the surface of the sample and the speed during the test was 5 mm/s. Two cycles of the compression curve were obtained according to Figure 1 and parameters such as stiffness, adhesion, cohesion and chewability were extracted from it.

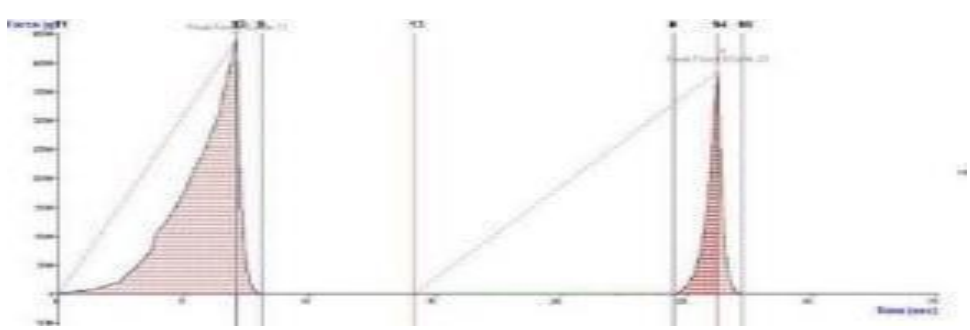

Figure 1- Sample typical force-time diagram for texture profile analysis (TPA) test

2-10- Color

The color of the dried samples was evaluated with the help of Imag J software. Photography was done in a room equipped with LED lamps. The conditions of photography were provided in such a way that disturbing ambient lights do not interfere with color evaluation. The photo of the samples was transferred to the software and the parameters L* (brightness), b* (yellow-blue) and a* (red-green) were extracted from it [11].

2-11- Sensory evaluation

The comparison of different treatments in order to measure the desired sensory characteristics was carried out by ten trained evaluators and they were asked to rate the samples in terms of color, smell, appearance, taste, texture and overall acceptance with the 5-point hedonic method (5 excellent points and 1 point very bad) [12].

3- Results and discussion

3-1- Water reabsorption changes

The ability to absorb water is a quality indicator for dry food, so those foods that are dried under optimal conditions are less damaged and absorb water faster. As shown in Figure 2, the amount of moisture reabsorption was affected by the drying temperature ($p<0.05$). So that with the increase in temperature, the amount of moisture reabsorption in the samples increased, while changing the time of pre-cooking and drying did not affect the amount of this parameter. Increasing pre-cooking time and drying time at low temperatures slightly increased moisture reabsorption ($p<0.05$).

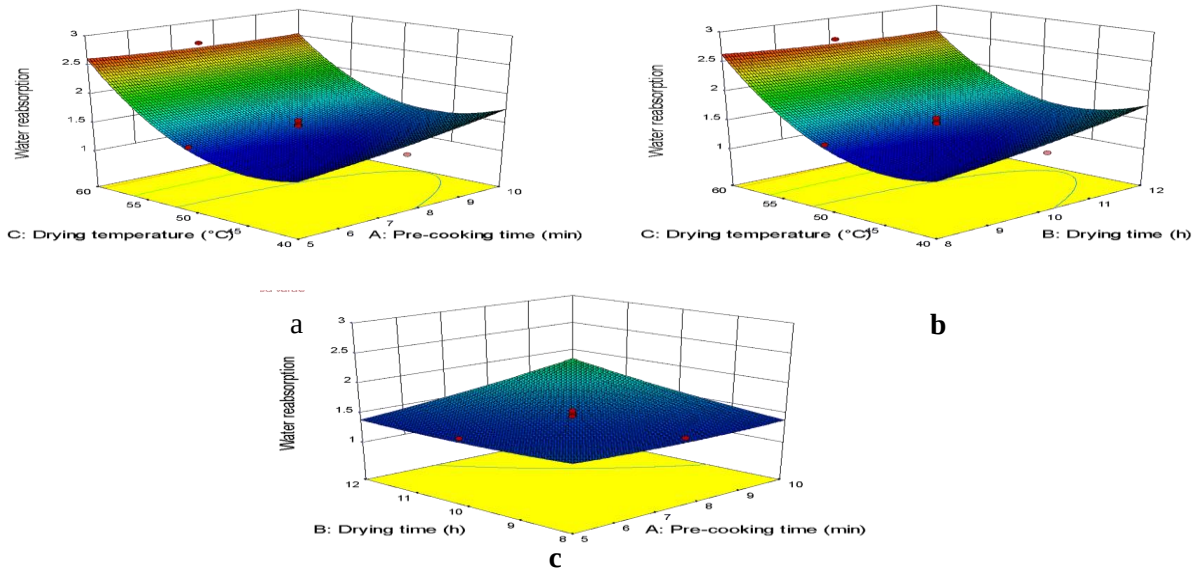

Figure 2- Effect of a) drying temperature and pre-cooking time, b) drying temperature and time, and c) pre-cooking time and drying time on water reabsorption

Osmotic pretreatment has increased the water reabsorption of the samples due to the reduction of drying time and as a result less damage to the food structure. During drying, irreparable changes such as texture changes, migration of soluble substances and volatile substances are created in the product. Heat reduces the elasticity of the cell wall and as a result the water holding capacity of the dried product decreases. Fruits and vegetables have a large amount of air in the intracellular space, which can escape during the evaporation of moisture and due to shrinkage. All these factors affect the internal porosity of the product [13]. Increasing the amount of reabsorption indicates the better quality of the product during drying and less damage to the tissue of the slices. It is a fruit. Feng and Tang [14] stated that the rehydration characteristics of dried products indicate its physical and chemical changes during the drying process and can be affected by processing conditions, pretreatment and composition of the sample. The reduction of water reabsorption in onions dried by combined osmosis-hot air method compared to samples dried by hot air method was also reported by Patil et al [15]. The amount of water reabsorption in osmosis onion samples was lower than that of non-osmosis samples due to salt preventing the penetration of water. In contrast to the study of Ayoubi and Belordi [16], it showed that the water reabsorption power in dried onion sheets with the presence of sucrose in the solution Osmosis is increased.

2-3- Changes in water activity

Water activity is an important parameter during the storage period of powders and dry materials. Low water activity because it reduces the water available to microorganisms (free water) for biochemical reactions, thus increasing the shelf life [17]. Water activity is temperature dependent. The change in temperature due to the change in the bound water, dissociation of water and the solubility of substances dissolved in it causes a change in water activity [18]. The decrease in water activity with the increase in temperature, on the one hand, can be attributed to the decrease in moisture content of the samples at higher temperatures, because the structure is more porous, and this accelerates the decrease in moisture content at higher temperatures. They are reduced, which has an effect on the reduction of water activity [19]. None of the independent variables studied had a significant effect on the water activity of the product, and only the second power of the drying process temperature had a significant effect on this feature ($p<0.05$). As the temperature increased to 50 degrees Celsius, water activity decreased

(Figure 3). The amount of this characteristic increased slightly with the increase of pre-cooking and drying time and then decreased ($p<0.05$).

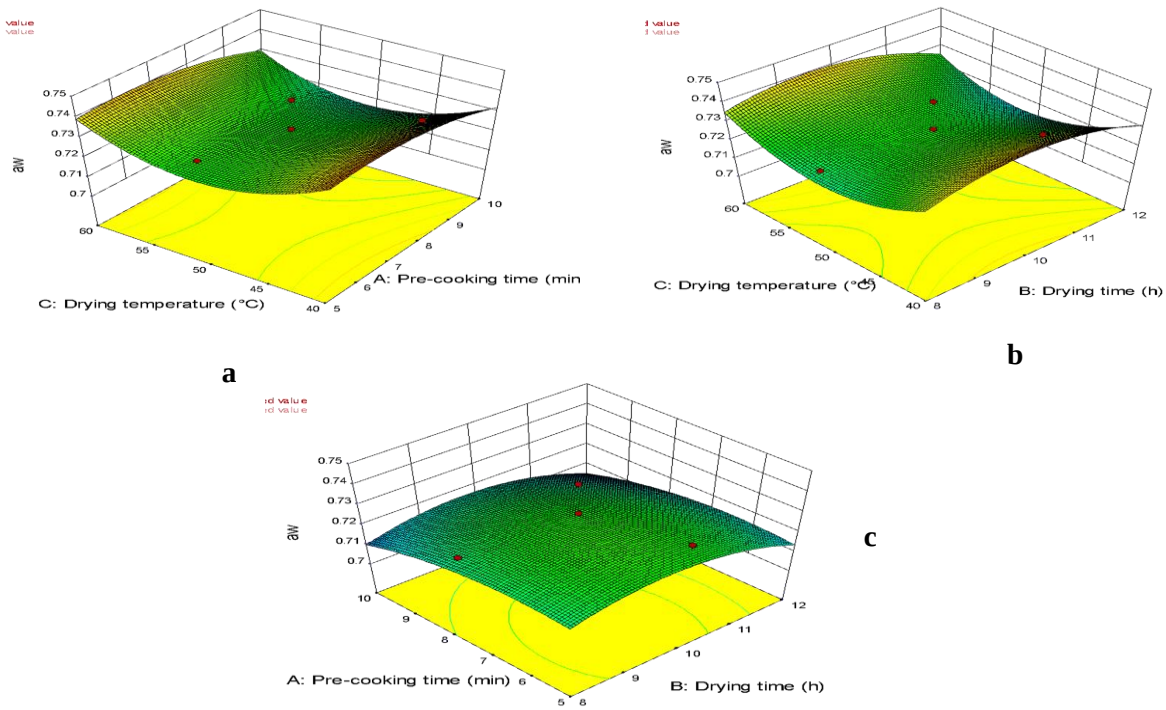

Figure 3- The effect of a) drying temperature and pre-cooking time, b) drying temperature and time and c) pre-cooking time and drying time on water activity

4- Pourmehdi et al. [20] reported similar results in the optimization of potato puree powder production by floor drying method.

3-3- Wrinkling changes

Tissue shrinkage is an indicator that directly affects the amount of water reabsorption by the product. If the amount of cell destruction is low, water reabsorption will be very high [21]. According to the table, a quadratic polynomial model was proposed to predict the effect of process conditions on the shrinkage of samples. According to the results of the statistical analysis, the use of different temperatures in drying caused a change in the shrinkage of the samples ($p<0.05$). Meanwhile, the preliminary cooking time and the drying process time did not affect the amount of this feature. As can be seen in the figure,

increasing the temperature first increased and then decreased the shrinkage of the samples (Figure 4). Meanwhile, no significant change was observed in the amount of shrinkage of the sample with the change of pre-baking time and drying process time ($p<0.05$).

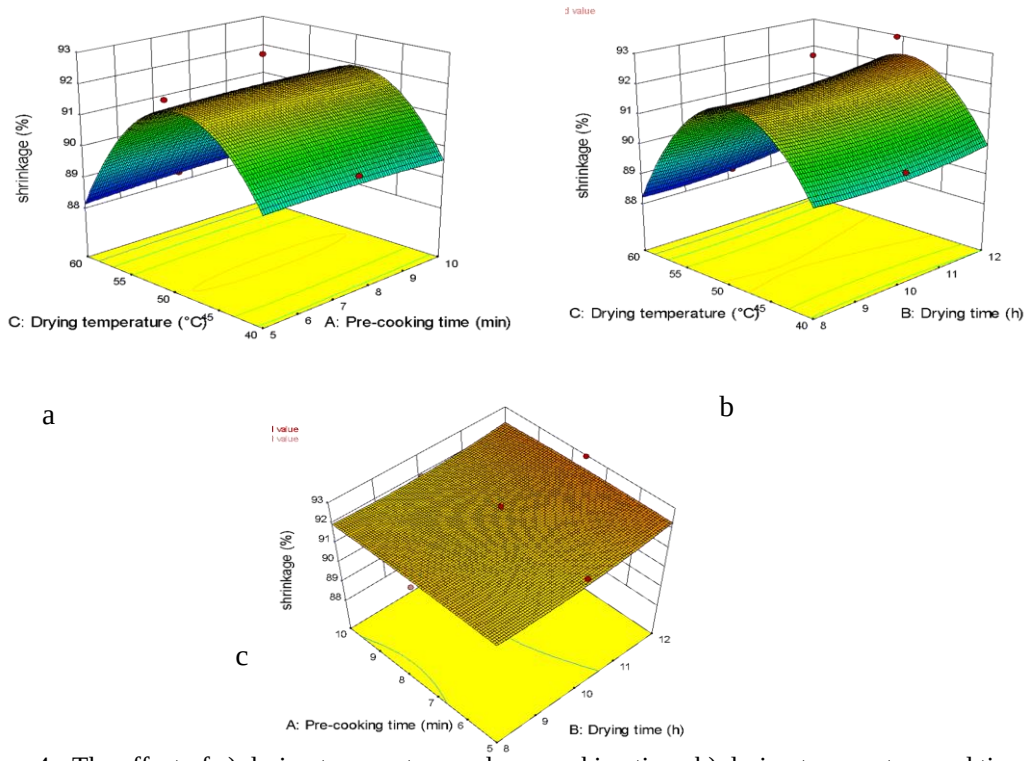

Figure 4 - The effect of a) drying temperature and pre-cooking time, b) drying temperature and time and c) pre-cooking time and drying time on shrinkage

In fact, shrinkage occurs with the increase in surface temperature and the migration of dissolved solids to the surface of the sample and its evaporation. This happens as a result of physical and chemical changes on the surface, and after that the tissue is destroyed and moisture is transferred outside with the increase in temperature and the formation of an open structure. Another reason for wrinkling is the destruction of the tissue in such a way that the cell wall is destroyed and the resistance to moisture in the sample decreases and more water is lost [22]. Shrinkage is related to the amount of separated moisture, which decreases in the final stages of drying. Shrinkage of products during drying has an effect on moisture diffusion and thermal conductivity, especially in the final stages. The drying ratio also increases with increasing porosity. The severity of wrinkling depends on the type of product. Also, drying conditions have a great impact on structural changes. The fruit and vegetable tissue contains a large amount of air bubbles in the intercellular spaces. Evaporation of moisture also causes the product to wrinkle because

intercellular water is regularly separated during drying and air replaces it. As a result, the tissue is not able to maintain the structural network, so that the structure of the outer shell of the cell collapses and wrinkling occurs [23]. Shrinkage and porosity for many varieties of food products have been mainly as a function of moisture content.

The amount of shrinkage in all the pre-processed treatments is less than the shrinkage in the control sample. Evaporation of water and heating causes tension in the cellular structure of food, which itself causes changes in the microstructure, such as the formation of pores and wrinkles. The expansion of pores and shrinkage depends on changes in moisture transfer mechanisms and external pressure [24]. This report is consistent with the results of Nito et al. [25], who believe that the reason for the increase in wrinkling is the removal of water and the decrease in the absorption of soluble solids.

According to other researches, fruits that have a structure with less shriveling have a higher water absorption capacity at the time of regeneration [22]. Also, the study of optimization of combined drying (osmosis-hot air) of apple tree leaves using the response surface method, similar results were obtained [26]. The effect of osmosis drying has been studied as a pre-process of cabbage drying, and it was found that osmosis samples were less damaged and less wrinkled during additional drying [27].

3-4- Tissue evaluation

The texture of food and agricultural products, as one of the most important quality characteristics of the product, plays an important role in the overall acceptance of consumers and buyers of agricultural products. According to the definition, tissue hardness is the maximum force required during a compression test and the force necessary to cause initial rupture and failure in the tissue, and both of these parameters can be determined during a compression test. According to the results of the statistical analysis, it can be stated that only the drying temperature and its second power significantly changed the hardness of the product ($p<0.05$). As can be seen in the figure, increasing the temperature up to 50 degrees Celsius increased the hardness of the tissue, but increasing the temperature further decreased the hardness of the samples (Figure 5). The hardness of the samples decreased slightly and then increased with increasing pre-baking time ($p<0.05$). Increasing the drying time also increased the hardness of the sample ($p<0.05$).

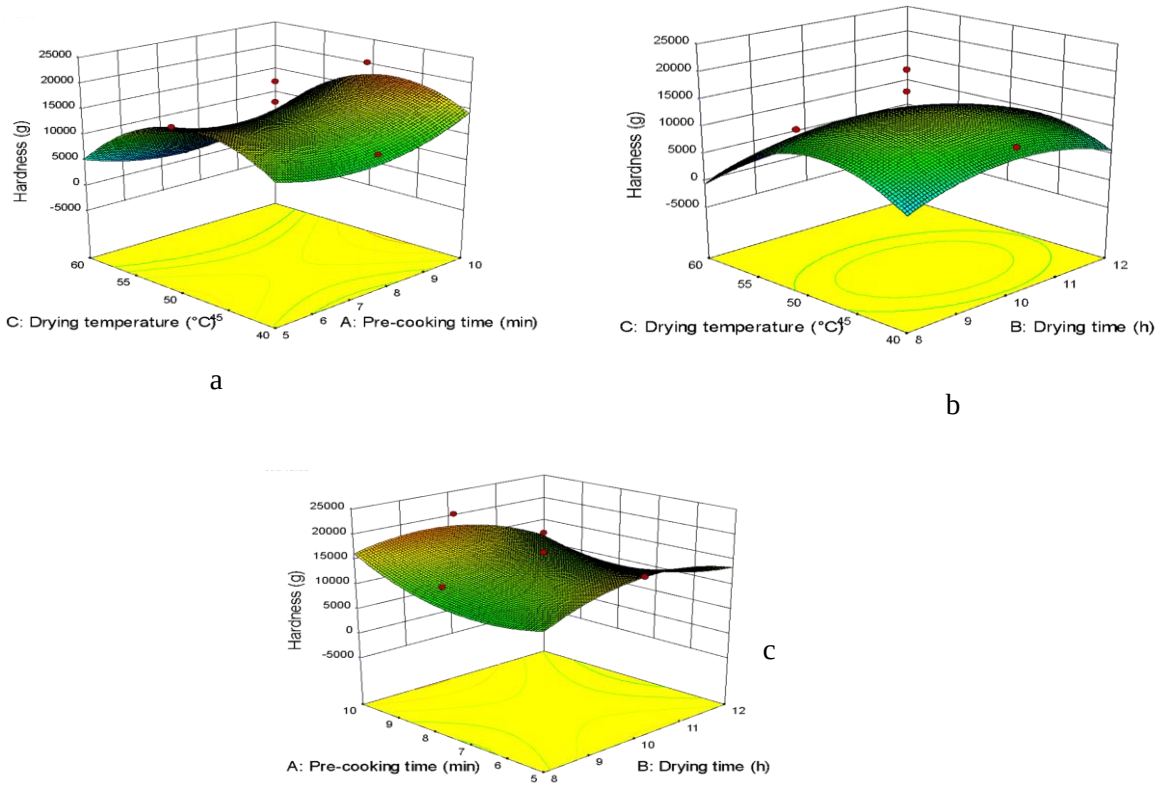

Figure 5 - The effect of a) drying temperature and pre-cooking time, b) drying temperature and time and c) pre-cooking time and drying time on hardness

The texture behavior is largely dependent on the food structure, chemical and biophysical properties of the product [28]. By increasing the drying temperature, the rate of moisture removal from the samples increases and the surface hardness increases. The phenomenon of surface hardening of the samples increases with the increase in temperature and causes the surface of the dry samples to harden, and as a result, the failure force of the samples increases. On the other hand, the sucrose present in the pre-treatment process reduces the amount of failure force. The reason for this is that by using sucrose and increasing its concentration in the pretreatment, the amount of porosity in the samples increases and the amount of porosity in the dried samples increases. The reason for the increase in porosity can be due to the exit of more moisture than the absorption of solid materials, and since sugar cannot enter the fine channels of the product, this causes more porosity. On the other hand, with the increase in concentration, the amount of calcium loss and withdrawal from the samples increased and this can cause the texture to become softer. Similar results have been reported in drying layers of mango [29], pear [23] and apple [30].

Adhesion results showed that none of the independent variables studied in this test, as well as their mutual effects, had any effect on tissue adhesion ($p<0.05$).

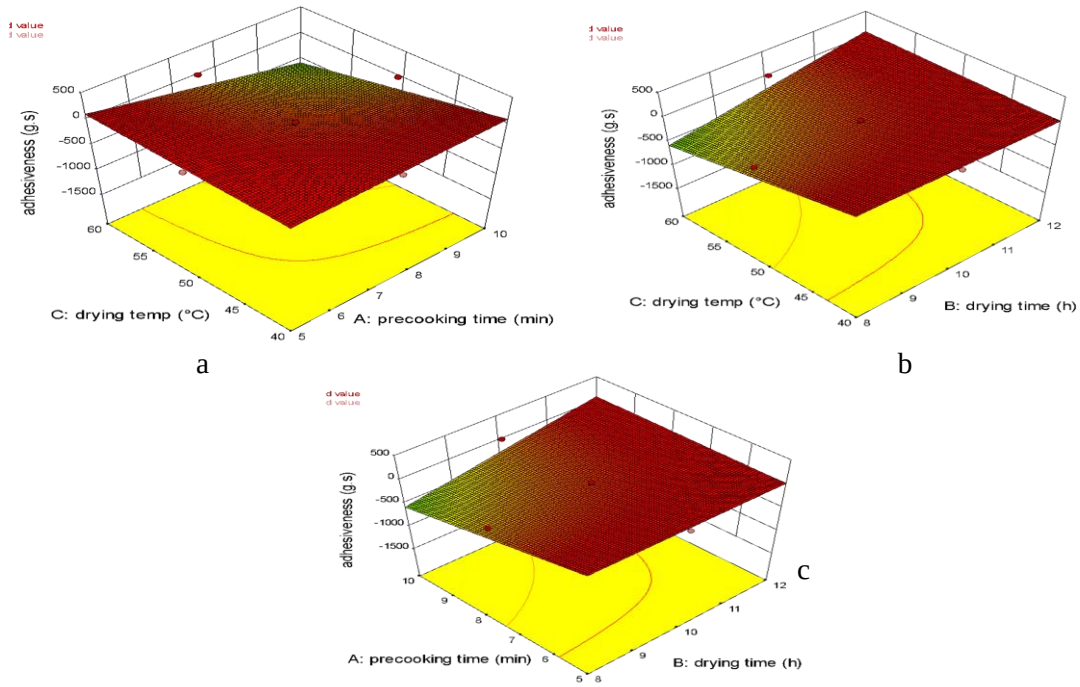

Figure 6 - The effect of a) drying temperature and pre-baking time, b) drying temperature and time, and c) pre-cooking time and drying time on adhesiveness

The trend of changes in adhesion (Figure 6) showed that the amount of adhesion decreased with the decrease of moisture content. This means that the work required to overcome the tensile force between the surface of the probe and the samples decreases with decreasing humidity. The reason for this can be seen in the reduction of surface adhesion because the adhesion is significantly dependent on the surface moisture of the sample [31] and it decreases with the drying of the surface layers of the sample during drying. The process of reducing adhesion with decreasing humidity at different temperatures is such that their final adhesion does not show any difference and the effect of drying air temperature on adhesion is not significant.

Figure 7 shows the effect of variables on coherence. The analysis of the obtained results shows that the studied parameters had no significant effect on the integrity of the samples ($p<0.05$)**.** Temperature changes did not have a significant effect on the cohesion characteristics, which can be attributed to the low humidity gradient of the samples at this drying air speed due to having different temperatures. In other words, the factor affecting the cohesion is the moisture content, if the samples have

a uniform moisture content (low moisture gradient), their cohesion does not show any difference compared to each other. Similar results have been reported by Vares et al. [4] for this feature during drying of figs and pears [30] that temperature changes have a significant effect on this feature, but the effect of drying air speed changes was significant.

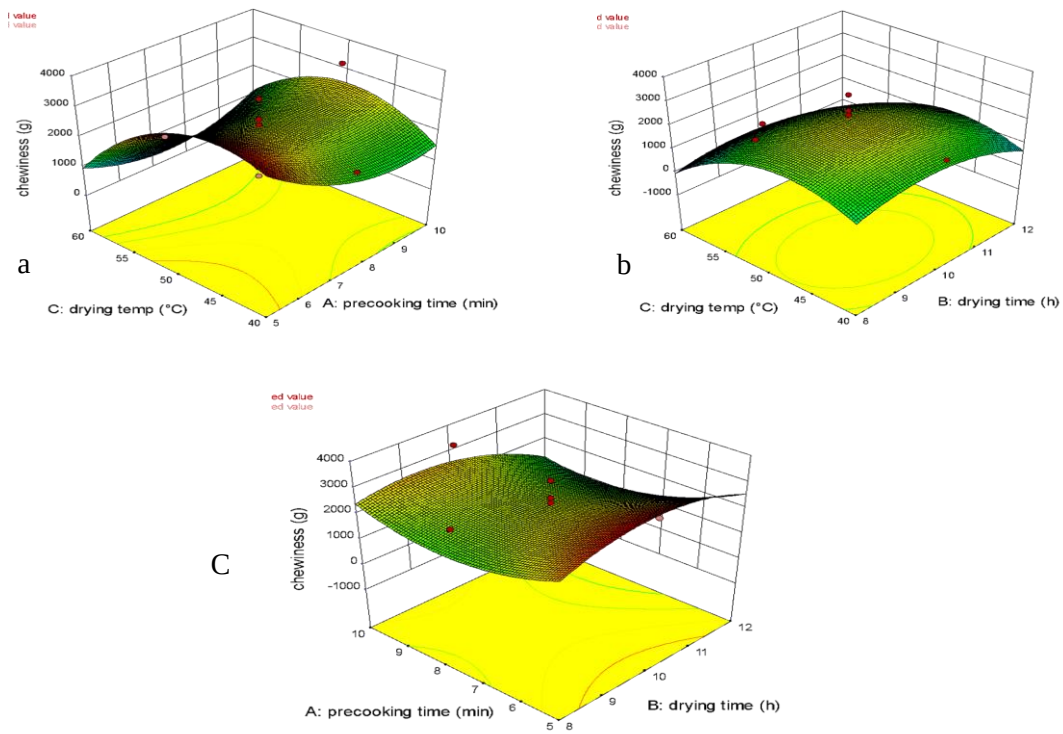

Figure 7- Effect of a) drying temperature and pre-cooking time, b) drying temperature and time, and c) pre-cooking time and drying time on cohesiveness

spent during the second pressure of the teeth is the same amount as in the first pressure.

The chewability index is one of the important factors in the marketability of dry products. According to the results, it can be stated that the processing conditions had no effect on the chewing ability ($p<0.05$). The chewability of the samples increased slightly by increasing the precooking time and decreasing the drying time, while the drying temperature did not change this characteristic (Figure 8). In this regard, Martynenko and Yanoshek [32] stated that the increase in the tissue chewability index indicates the need for more energy to chew dried fruit because it has a direct relationship with the hardness and chewability of the tissue. Chong et al. [33] also observed the chewability of dried product higher than that of fresh product. On the other hand, a decrease in chewability in dried apple slices has also been reported [34].

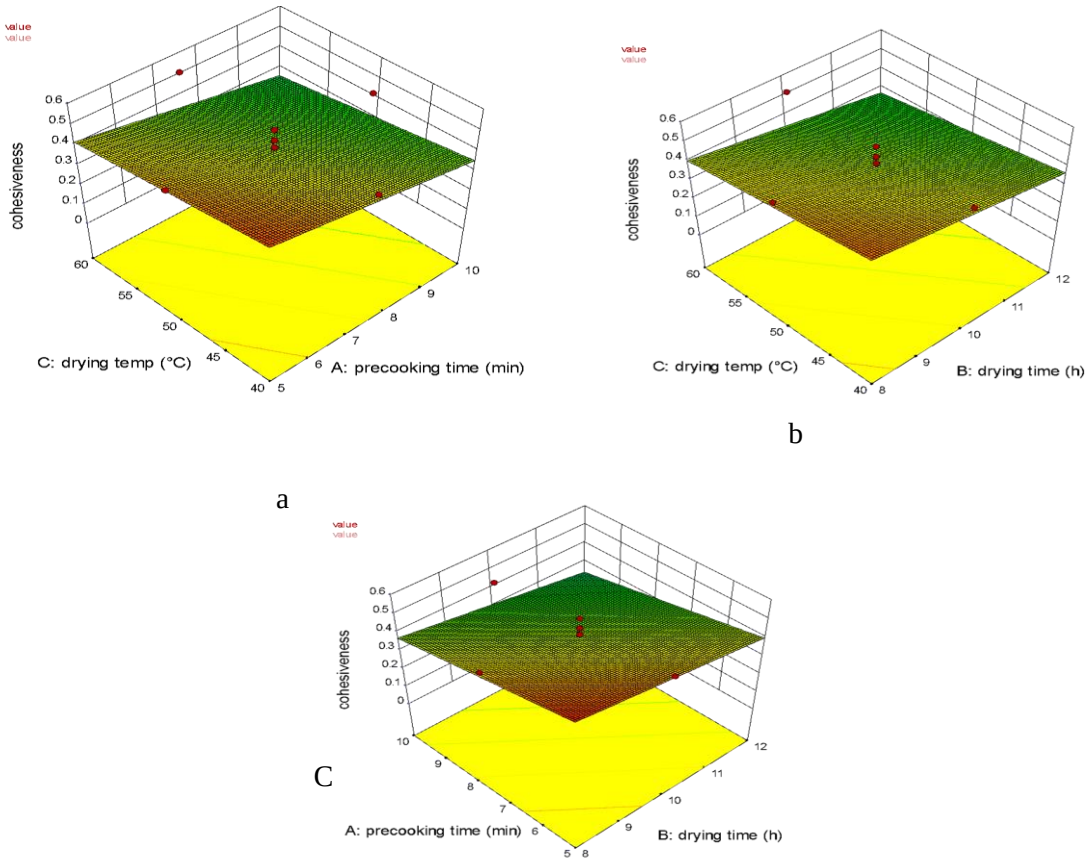

Figure 8- Effect of a) Drying temperature and pre-cooking time, b) Drying temperature and time, and c) Pre-cooking time and drying time on chewiness

3-5- Changes in color indicators

Color changes are one of the essential factors affecting the acceptability of dry fruits and vegetables. Producers also pay special attention to this quality feature in order to increase the marketability of dried products [35]. Among the independent variables, only the drying temperature had a significant effect on the L* index. The L* index of the samples increased and then decreased with increasing temperature up to 50 °C (Figure 9).

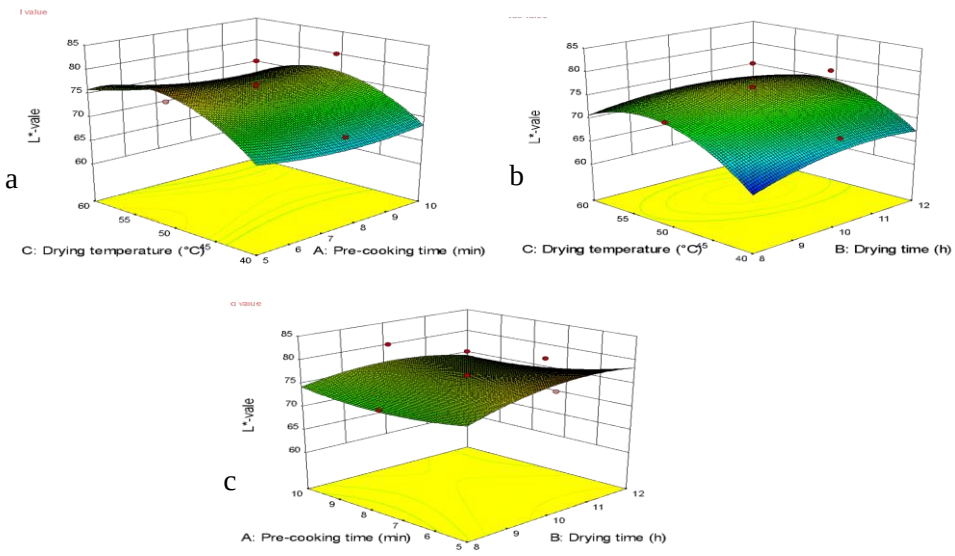

Figure 9- The effect of a) drying temperature and pre-cooking time, b) drying temperature and time, and c) pre-cooking time and drying time on L * index

According to Figure 10, none of the independent variables studied, as well as other operational parameters such as their interaction and second-order parameters of the process, had a significant effect on the a* index of the samples ($p<0.05$). The amount of this color characteristic did not change significantly with the change of pre-cooking time and drying time ($p<0.05$).

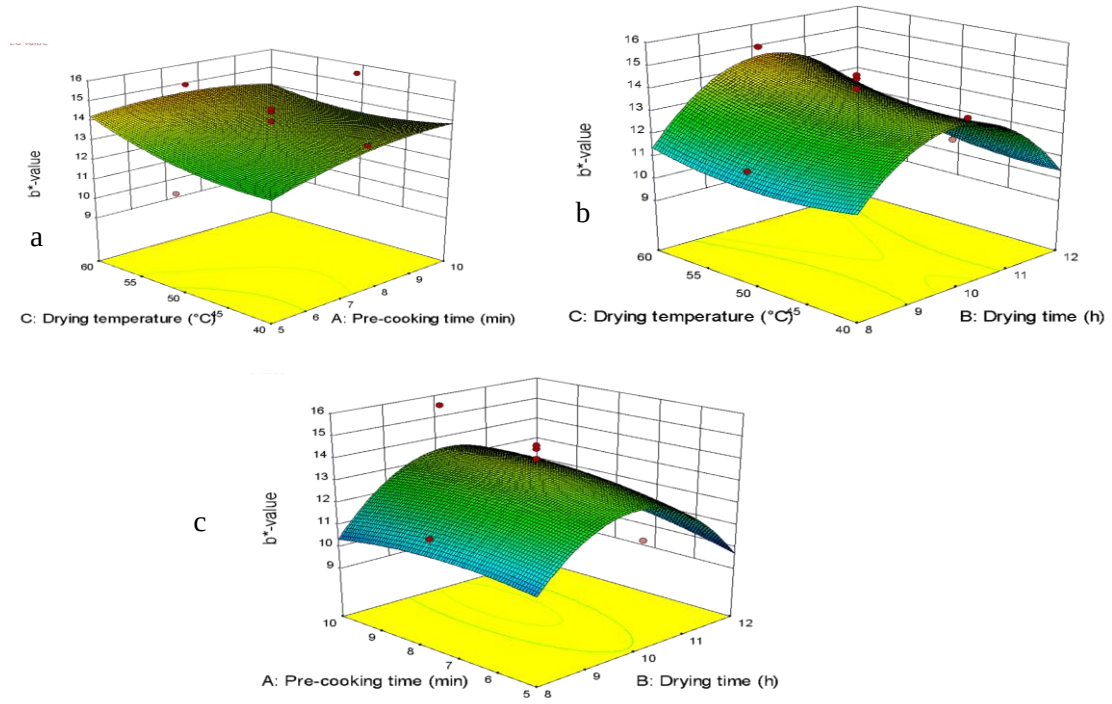

Figure 10 - The effect of a) drying temperature and pre-cooking time, b) drying temperature and time, and c) pre-cooking time and drying time on the index a

*

According to the analysis, it can be stated that the second power of the drying time, unlike other independent variables, had a significant effect on the amount of b* index ($p<0.05$). The amount of this index first increased (up to 10 hours) and then decreased with increasing drying time (Figure 11). Changing pre-cooking time and drying time had no effect on the amount of b* of the samples ($p<0.05$).

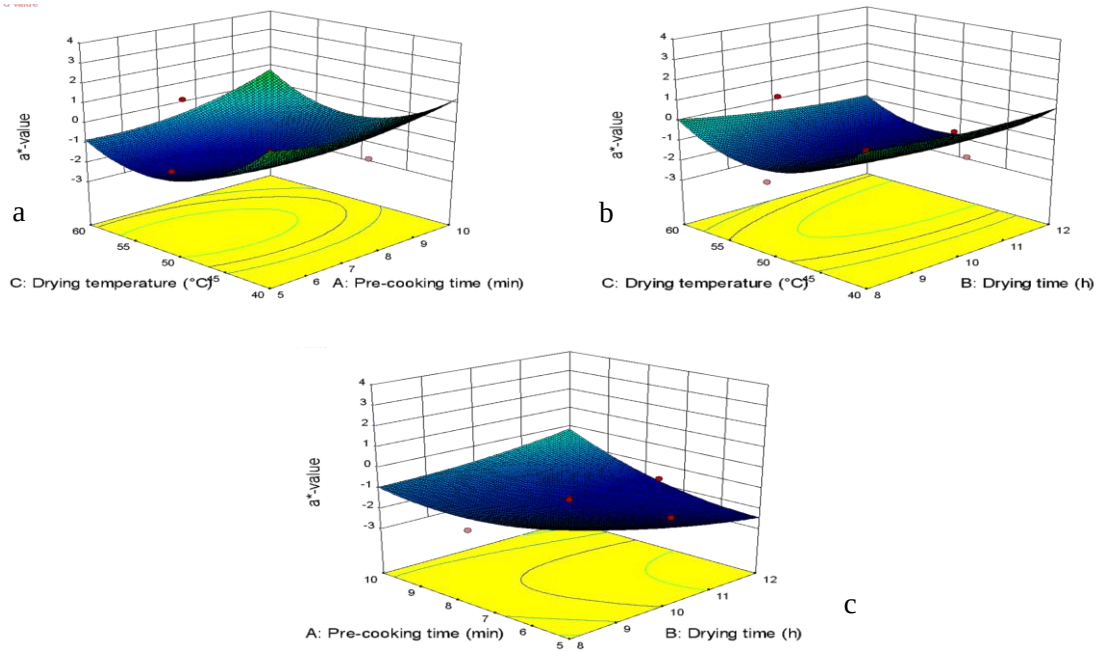

Figure 11- The effect of a) drying temperature and pre-cooking time, b) drying temperature and time, and c) pre-cooking time and drying time on index b *

In most cases, the color is related to the quality of the product and is an indicator of the destruction of the natural quality of the fresh product. Osmosis treatment can increase the preservation of pigments and minimize the browning of the product due to natural oxidations and make the color of the product more attractive [36]. This phenomenon can be interpreted in the way that during the osmosis drying stage, the samples are out of reach of oxygen, which slows down the progress of browning reactions and is more attractive to the consumer due to less color change. The changes in a* and b* indices also seem to be due to the active role of sugars in the chemical reaction of dyes during drying [37]. Also, in samples containing sucrose osmotic solution, the penetration of sugar compounds into the tissue of the sample is a complex process that depends on several factors. In the first stage of osmotic dehydration, sucrose is dissolved on the surface of the sample layer, which makes it difficult to absorb water inside the porous capillaries, and as a result, water is retained by absorbent forces. Apparently, these forces cause osmotic pressure and in the continuation of osmotic dehydration, a certain amount of sucrose leaks into the structure of the sample and thus forms the structure of the sample. The results of Ren et al [37] confirm the results of the present research. The results of Patil et al.'s study [15] showed that the lightness of onion color dried by hot air osmosis combination method was more and the yellowness of these samples was less than the samples dried by hot air method.

3-6- General acceptance

Figure 12 shows the results of sensory evaluation. Sensory perception is a complex process that is influenced by the appearance, texture, and flavor characteristics of the product and is determined by the accumulation or interpretation of signals produced by chemicals, by smelling, tasting, and evaluating the appearance of food. Therefore, the balance of flavor compounds in food products determines the overall acceptability of the food product [38]. tailO drying and interaction effect of drying temperature Preparatory cooking time significantly changed the overall acceptance results ($p<0.05$). The overall acceptance of the product's appearance, textural attributes, and flavor affects its sensory perception. The osmosis process keeps the texture, color and shape better. The sugar substance in the osmotic solution protects the tissue to a significant extent and causes minimal damage, disintegration and destruction of the cell wall, and the final product has a texture and color similar to fresh food. Also, due to conducting the test in an osmotic environment and away from oxygen, oxidation reactions occur less and vitamin C is better preserved, which increases the taste, aroma and color of the product and overall acceptance by the consumer. The pre-osmosis process reduces the final drying time by removing water from the sample tissue. By applying

osmotic pre-treatment and increasing pre-baking time, as a result of shorter drying time, better quality is maintained and can compete with other samples. Also, due to the reduction of energy consumption time (dryer), it also adds to the superiority of these samples from an economic point of view. The obtained results are consistent with the results of Sami et al. [38] in drying strawberry slices. Fathi Achacheloi and Hessari [39] showed that apricots dried by osmosis pretreatment method had good appearance, color and flavor characteristics.

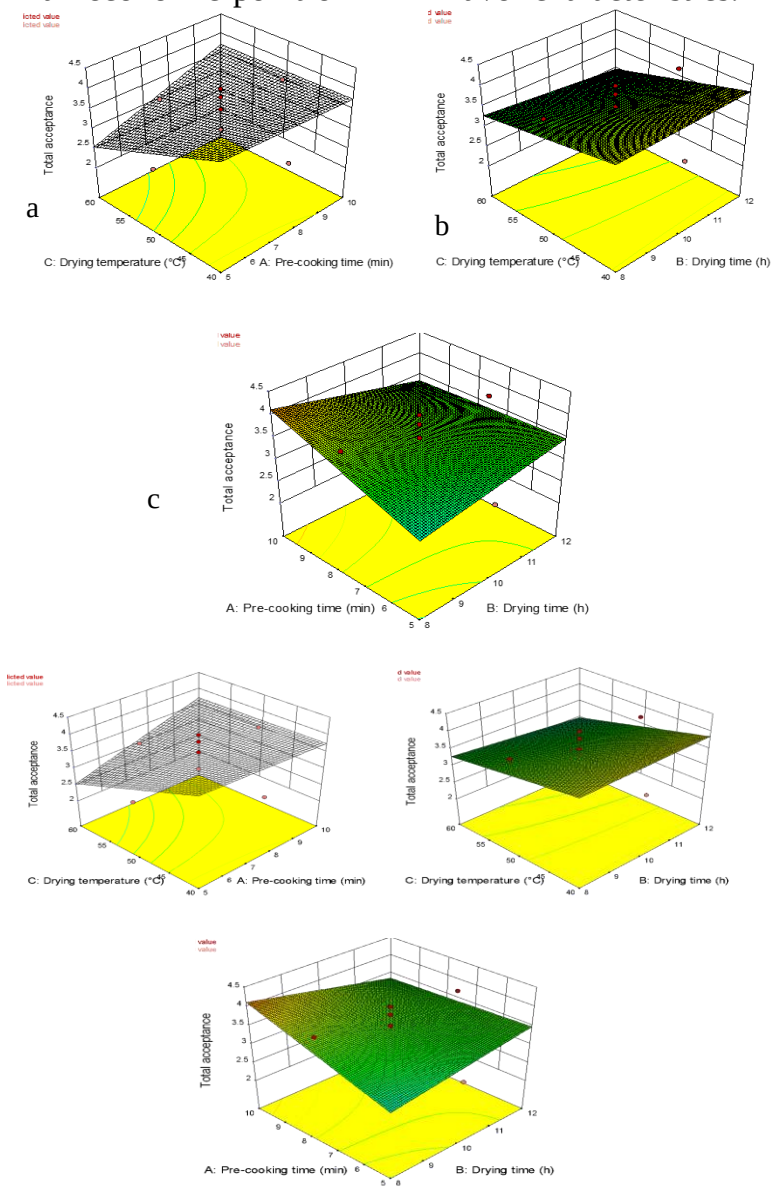

Figure 12- Effect of(a) drying temperature and pre-cooking time,(b) drying temperature and time, and(c) pre-cooking time and drying time on overall acceptance.

Optimization of process conditions

The main purpose of the drying process is to increase the shelf life of the product. The drying process should be done in such a way that, in addition to preserving food from spoilage, the quality indicators of the product, such as color, taste, aroma, and texture, are harmed as little as possible. The use of the pre-process of osmotic dehydration can be effective in the process of drying the product with hot air due to the small changes in aroma, taste and increasing the quality of the final product. Also, by examining the kinetics and mathematical modeling, it is possible to choose the most appropriate drying method and the best operating conditions for product production. The proposed models for predicting changes in dependent variables are shown in Table 2.

In this research, in order to optimize the processing conditions, it was used to review the sources and evaluate the samples, based on the limits set for the independent variables, the optimal area and the results are shown in the figure. The aim of this optimization was to produce a sample with higher brightness and overall acceptance, as well as lower water activity, higher moisture reabsorption percentage and lower shrinkage. Other parameters were within the study range. According to the obtained results (Figure 13), it can be stated that the use of pre-cooking for 10 minutes, heating at a temperature of 53.93 degrees Celsius for 8 hours produces a product with the best characteristics (desirability rate = 665/ 0).

Table 2- prediction models for independent variables

Dependent Variable	Prediction model	R^2
Water reabsorption	$y= + 1.44 + 0.098 A + 0.1 B + 0.53 C + 0.13 AB - 0.13 AC -0.15 BC + 0.037 A^2 + 0.04 B^2 + 0.57 C^2$	**0.95**
Water activity	$y=+0.73 - 4.9\times10^{-3} A – 3.1\times10^{-3} B – 1.4\times10^{-3} C + 5\times10^{-4} AB + 2.5\times10^{-4} AC – 1.5\times10^{-3} BC – 5.091\times10^{-3} A^2 - 9.091\times10^{-3} B^2 + 0.014 C^2$	**0.5**
Shrinkage	$y= + 92 + 0.9 A + 0.17 B - 0.72 C -0.02 AB + 0.085 AC + 0.084 BC - 0.062 A^2 + 0.19 B^2 - 2.994 C^2$	**0.95**
Firmness	$y= + 13413.97 + 771.23 A - 603.72 B - 3787.79 C - 1661.03 AB - 604.96 AC - 963.48 BC + 3702.81 A^2 - 3815.96 B^2 -7873.73 C^2$	**0.75**
Adhesiveness	$Y= -5.02 + 0.86 A – 0.42 B – 0.91 C + 2.98 AB – 0.43 AC + 1.79 BC$	**0.45**
Chewiness	$y=+ 1645.14 + 465.95 A – 586.53 B + 19.02 C$	**0.68**
L*	$y=+ 76.13 – 1.13 A + 0.9 B + 2.61 C – 0.93 AB – 0.60 AC –0.96 BC + 1.42 A^2 - 2.04 B^2 – 5.92 C^2$	**0.72**
a*	$y=+ 76.13 – 1.13 A + 0.9 B + 2.61 C – 0.93 AB – 0.60 AC –0.96 BC + 1.42 A^2 - 2.04 B^2 – 5.92 C^2$	**0.67**

b*	y=+ 13.59 + 0.31 A – 0.025 B + 0.48 C + 0.4 AB – 0.38 AC + 0.36 BC – 0.37 A^2- 2.80 B^2 + 0.48 C^2	**0.74**
Total acceptance	y=+ 3.49 + 0.25 A – 0.06 B – 0.35 C – 0.31 AB + 0.34 AC – 0.087 BC	**0.62**

A: precooking time, B: drying time, C: drying temperature

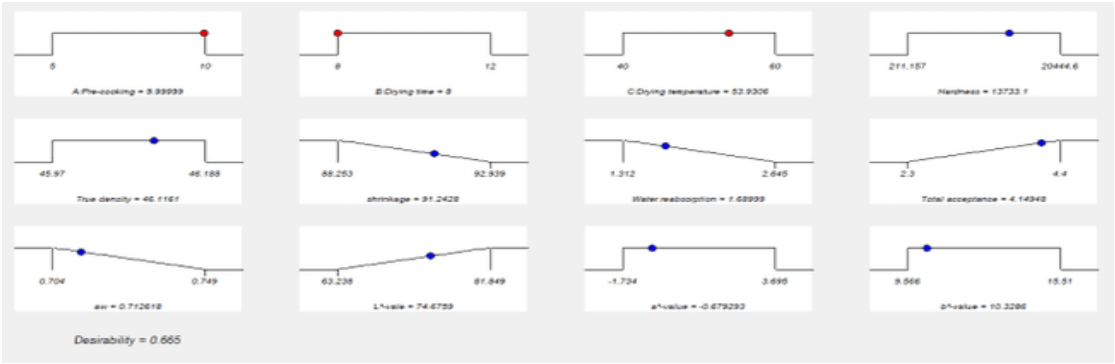

Figure 13- Ramp diagram of optimal drying conditions of aloe vera by osmotic-hot air combination method

total resulting

The use of osmosis-hot air pre-process is economically viable due to maintaining quality and reducing the final drying time. In this study, in order to produce dry aloe vera, aloe vera gel was poured into boiling water for 5-9 minutes. To perform osmotic dehydration pretreatment, osmotic solution prepared from sugar at 30°C with Brix 31 and sample to solution ratio of 7.5 to 1 was used. The samples were placed in a hot air dryer for (8 to 12 hours) and at a temperature of (50 to 70 degrees Celsius) to achieve the desired texture and moisture. For 10 minutes, heating at a temperature of 53.93 degrees Celsius for 8 hours produces a product with the best characteristics (desirability rate = 0.665).

4- Reference

[1] Karimi, Z., Ranjpour, R., Motefaker-Azad, M. A., Asadzadeh, A., Bagherzadeh Azar, F. 2018. Novel approach for estimate food security in Iran by GFSI index and study of prices index and population effect. Agriculture economy and development, 101: 181-218. (In Persian)

[2] Imam Jameh, Z., Yousefi, Gh., Karami, Z., Pourmehdi, K. 2014. Modelling and optimization of osmotic ultrasound pretreatment and complemental drying of black cherry. Iranian Biosystem Engineering, 45(2): 151-141. (In Persian)

[3] Chiralt, A., Talens, P. 2005. Physical and chemical changes induced by osmotic dehydration in plant tissues. Journal of Food Engineering, 67: 1-67.

[4] Torres, L. M., Calderas, F. Minjares, R. 2016. Structure preservation od aloe vera mucilage in spray drying process. LWT-Food Science and Technology, 66: 93-100

[5] Alma, M., Amarjit, S., Sawheny, B. K. 2010. Response surface optimization of osmotic dehydration process of aonla slices. Food Science and Technology, 47(1): 47-54.

[6] Hatami Bavil, A., Mortazavi, S. A., Rafe, A, Sharifi, A. 2016. Investigation of

slices research. Journal of Recent Sciences, 1(1): 51-59.

[16] Ayoubi, A. and Bloordi, M. 2021. The effect of osmotic dewatering before drying on physicochemical and sensory properties of dried onion slices. Journal of Food Science Research, 31(2):51-65. (In Persian)

[17] Chen, Q., Bi, Y., Bi, J., Zhou, L., Wu, X. and Zhou, M. 2017. Glass Transition and State Diagram for Jujube Powders with and Without Maltodextrin Addition. Food and Bioprocess Technology, 10(9): 1606- 1614.

[18] Mozafari, M., Asefi, N., Soleimani, J., and Jafarian P. 2011. The effect of osmosis process on the quality properties of hot air dried onions. Journal of Food Hygiene, 1(2): 49-60.

[19] Jangam, S. V., Law, C. L. and Mujumdar, A. S. 2010. Drying of Foods, Vegetables and Fruits. 1st ed. Singapore

[20] Pourmehdi, A., Mohebbi, M., Gohari Ardabili, A., Varidi, M., Salahi, M.. 2018. Optimization of potato puree production by floor drying method. Iranian Journal of Food Science and Technology Research, 14(14): 585-600 (In Persian).

[21] Daraee Garmekhani, A. and Moradi, M. 2018. Optimization of Combined Drying (Osmosis-Hot Air) of Apple Tree Leaves Using Response Surface Method. Iranian Journal of Nutrition Sciences and Food Industry, 13(3), 114-103. (In Persian)

[22] Maskan, M. 2001. Drying, shrinkage and rehydration characteristics of kiwifruits during hot air and microwave drying. Journal of Food Engineering, 48 (2): 177-182.

[23] Heidari Foroushani, M. M. and Nasiri, S. 2016. Study on textural characteristics of pear fruit during the drying process in a cabinet dryer. Iranian Food Science and Technology Research Journal, 12(238): 214-225. (In Persian)

the effect of time and ultrasound on the drying process of aloe vera gel by osmotic pretreatment. Journal of Innovation in Food Science and Technology, 8(1): 35-42. (In Persian)

[7] Dehbur, M. and Esmaeili, M. 2009. Effect of final drying by microwave and hot air on the drying parameters of dried grape. Iranian Researches of Food Science and Technology, 5(2): 108-122

[8] Ebadati, H. R., Sharifi, A. and Niakosari, M. 2016. Optimization of Doogh powder production by foam mat drying using response surface methodology. Journal of Innovation in Food Science and Technology, 8(4): 15-26. (In Persian)

[9] Galvez,A. T., Uribe, E., Perez, M. 2011. Effect of high hydrostatic pressure on drying kinetic, antioxidant activity, firmness and microstructure of aloe vera. LWT-Food Science and Technology, 44(2): 384-391.

[10] Sahin, S. and Sumnu, S. 2005. Physical properties of foods. Springer.251 pages.

[11] Sun, D. W., Zheng, C. and Zhang, L. 2006. Recent development and applications of image features for food quality evaluation and inspection –a review .Trend in Food Science and Technology, 17: 642-655.

[12] Salehi, f., Kashaninejad, M., Akbari, E., Sobhani, S., Asadi, F. 2016. Potential of sponge Cake Making using Infrared-Hot Air dried carrot. Journal of Texture Studies, 47(1): 34-39.

[13] Zomorodi, Sh. 2012.Technology of processing dried fruits and quality control. Urumia University Jihad Publication. 320 pages.(In Persian)

[14] Feng, H. and Tang, J. 1998. Microwave finish drying of diced apples in a spouted bed. Journal of Food Science, 63: 679-683.

[15] Patil, M. M., Kalse, S. B. and Jain, S. K. 2012. Osmo-convective drying of onion

apple slices. Drying Technology, 32(5): 567-577.

[33] Chong, C. H., Law, C. L., Cloke, M., Abdullah, L. C. and Daud, W. R. W. 2008. Drying kinetics, texture, color, and determination of effective diffusivities during sun drying of Chempedak. Drying Technology, 26 (10),1286-1293.

[34] Sabbaghi, H., ZiaeeFar, A. and Kashaninejad, M. 2020. Tissue profile analysis (TPA) of dried apple slices by infrared irradiation by intermittent heating method. Iranian Journal of Food Science and Technology Research, 16(1): 72-57.

[35] Rashid Nejad, S. and Fard, M. Kh. 2014. Optimization of control process of browning and osmotic dehydration in semi-wet apple rings by response surface method. Journal of Food Industry Research, 24(1): 49-53.

[36] Basiri, Sh. And Gheibi, F. 2019. The effect of osmotic dehydration and different methods of drying squash on the quality and color of the final product. Journal of Food Science Research, 29(1): 153-141. (In Persian)

[37] Ren, X. E., He, R., Huang, Y. C., Zhang, J. M. and Yang, F. 2010. Osmotic dehydration of pineapple enhanced by ultrasonic treatment. Journal of Food Science, 22: 061.

[38] Sami, A., Ghavami Jolandan, Sh., Zaki Dizaji, H. and Hojjati, M. 2019. The effect of osmotic and ultrasonic pretreatments on the quality of strawberry leaf drying process by hot air drying method. Iranian Biosystem Engineering, 50(3): 706-715. (In Persian)

[39] Fathi Achachloui, B. and Hesari, J. 2016. Drying of apricot leaves using osmotic dewatering process (sucrose solutions, salt). Journal of Food Industry Research, 26(3): 493-505.

[24] Zanjirabad, M. and Zomordi, S. 2017. The effect of different pretreatments on color and physicochemical properties of hot-dried eggplant slices. Journal of Innovation in Food Science and Technology, 9(3), 13-23.

[25] Nieto, A. B., Salvatori, D. M., Castro, M. A. and Alzamora, S. M. 2004. Structural changes in apple tissue during glucose and sucrose osmotic dehydration: shrinkage, porosity, density and microscopic features. Journal of Food Engineering, 61 (2): 269-278.

[26] Rahman, M. S. 2007. Handbook of food preservation 2nd ed. CRC press.

[27] Jayaraman, K. S., Das Gupta, D. K. and Babu Rao, N. 1990. Effect of pretreatment with salt and sucrose on the quality and stability of dehydrated cauliflower. International Journal of Food Science and Technology, 25: 47-60.

[28] Mujumdar, A. S. 2001. Drying Technology in Agricultural and Food Science. Drying Technology, 19(6): 1217-1218

[29] Zou, K., Teng, J., Huang, L., Dai, X. and Wei, B. 2013. Effect of osmotic pretreatment on quality of mango chips by explosion puffing drying. LWT- Food Science and Technology, 51: 253-259.

[30] Motavi, A. and Hashemi, S. J. 2018. The effect of different pretreatments on the characteristics of color and texture change in drying apple layers. Journal of Food Science and Technology, 15(75): 123-136.

[31] Adhikari, B., Howes, T., Bhandari, T. and Truong, V. 2001. Stickiness in foods: a review of mechanisms and test methods. International Journal of Food Properties, 4 (1):1–33.

[32] Martynenko, A. and Janaszek, M. A. 2014. Texture changes during drying of

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بهینه‌سازی خشک کردن ترکیبی (اسمزی –هوای‌داغ) ورقه‌های آلوئه‌ورا با روش سطح پاسخ

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چکیده

هدف از این مطالعه تولید ورقه آلوئه‌ورا خشک به روش خشک کردن اسمزی-هوای داغ و بررسی اثرات این روش بر بافت، رنگ، چروکیدگی، بازجذب آب و فعالیت آبی بود. متغیرهای مورد مطالعه شامل زمان پیش پخت (۵، ۷ و ۱۰دقیقه)، زمان خشک کردن (۸، ۱۰ و ۱۲ ساعت) و دمای خشک کردن (۴۰، ۵۰ و ۶۰ درجه سانتی گراد)، با روش سطح پاسخ در قالب طرح مرکب مرکزی با شش تکرار در نقطه مرکزی مورد بررسی قرار گرفت. نتایج به دست آمده نشان داد که افزایش دما تا ۵۰ درجه سانتی‌گراد موجب افزایش سختی بافت گردید اما افزایش بیش‌تر دما، سختی نمونه‌ها را کاهش داد. میزان باز جذب رطوبت متاثر از دمای فرآیند خشک کردن بود به طوری که با افزایش دما، میزان بازجذب رطوبت در نمونه‌ها افزایش یافت و این در حالی است که زمان فرآیند پیش‌پخت و خشک کردن تاثیری بر میزان این پارامتر نداشت. هیچ یک از متغیرهای مستقل مورد مطالعه، تاثیر معناداری بر میزان فعالیت آبی محصول نداشتند. نتایج بهینه سازی فرآیند نشان داد که پیش پخت ورقه آلوئه‌ورا به مدت ۱۰ دقیقه، حرارت دهی در دمای ۵۳/۹۳ درجه سانتی گراد به مدت ۸ ساعت موجب تولید محصولی با بهترین کیفیت می‌گردد.