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# Optimization Drying Zucchini Coated with Osmotic Solution and Ethyloleate Using a Central Composite Design

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***Abstract:*** Drying is one of the most common ways to increase the shelf life of food. In this study, the effect of food coating and osmotic dehydration as a pretreatment before drying the zucchini was studied. Zucchini after being chopped in different thicknesses (3, 5 and 7 mm), was coated with 2% ethyl oleate and then underwent osmotic dehydration process with salt solution containing different doses (1, 3 and 5%) (The ratio of the sample solution was 1 to 10). Then osmosized samples were dried by a drier at temperatures of 60, 70 and 80 ° C as supplementary drying. The effect of drying on parameters such as shrinkage, reduced volume, Re-hydrating, frying efficiency, density and color properties of dried samples were evaluated. The results showed that the extent of influence of independent variables on the quality properties of the dried product is as: thick strips> drying temperature> salt concentration in the osmotic solution. Optimized operating conditions that were achieved for drying include temperature C ° 80, thickness of 3 mm and salt concentration of 5%, and in this optimum condition shrinkage, volume reduction, Re-hydrateing, the efficiency of frying, density and color components (L*) were 83.34%, 40.2%, 90.78%, 52.4%, 0.78 grams per milliliter and 91.9, respectively. According to the results we can say that coating samples by 2% ethyl oleate samples and then using the osmotic process, due to producing a product with good appearance and good quality, can be considered a good pre-treatment for increasing the quality of dry zucchini.

***Key words:*** drying, osmotic solution, zucchini, ethyl oleate, optimization.

## 1. INTRODUCTİON

Zucchini is a plant product called Cucorbitaceae from Cucurbitpepo species (1). From botany science point of view this fruit is a summer fruit which is known as a rich source of vitamins k, c, thiamine, riboflavin and minerals like magnesium, potassium, phosphorus and fiber, and it has a lot of nutritional value. Also, studies have shown that it has very good antioxidant compounds, in a way that its antioxidants greatly improve memory and reduce the problems associated with age (2). High consumption of vegetables and fruits in the world has caused development of various methods for processing and storing them. One of the most common of these methods is drying that facilitates the transportation process (due to less volume of food), increase retention and reducing chemical and biological reactions (due to reduced water activity product). In recent years, an extensive effort has been done to find new methods to replace conventional drying methods that cause adverse effects in the final product (such as reducing the quality of color and texture, loss of color, flavor and reducing the density of the material nutrients). Also today, consumers' demand for processed vegetables and fruits that look like the fresh ones which have gone through low or moderate heat is increasing (3).

Among the most important new method of drying process is osmotic dehydration (4). Osmotic dehydration is a process to remove part of the water plant and animal food by soaking it in an osmotic solution and provides the driving force necessary to release water from the nutrient tissue to osmotic solution, and can be used as a stand-alone process or in combination with other processes, such as air drying, freezing,

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frying, microwave and canning (4 and 5). Also, due to the re-use of osmotic solution which is a natural source of pigments, flavors, and antioxidants, performing this process can be economically cost affective (6).

In a similar study Lombard *et al.* (2008) studied pineapple osmotic dehydration as a pre-process for drying. The results showed that osmotic dehydration for treatment of fresh products before the final drying improve sensory, functional and nutritional traits of the product stability and increases shelf life of finished products and stability of pigments (7).

Coating food by a thin layer of food stuff before osmotic dehydration process, without having a negative impact on water loss, prevents penetration of soluble solids to the texture of food (8 and 9). Edible coatings and strips can protect the food against transfer of gases, water vapor, dissolved solids and mechanical impact by immersion, spray and dragging over the surface of the food and nutrients. Also, these coatings act as a barrier to prevent the penetration of oxygen and its negative effects and improve product appearance and cause it to be brilliant (10). The use of ethyl oleate has been checked in sample preparation due to its positive effects on increasing the mass transfer of some fruits, especially grapes. Studies conducted by Argans *et al.* (1998) showed that the time required for drying seedless grapes treated with potassium carbonate solution and ethyl oleate air moving at speeds of 0.3 and 2 meters per second is respectively, 31 and 17 hours, and for untreated samples in the same conditions are respectively 70 and 42 hours, (11). Vazgoter *et al.* (1997) used potassium carbonate and ethyl oleate solution and sodium hydroxide as a pre-treatment solution in preparation of grape, the results showed that both of these pretreatments caused the porous of wax layer and reduce water diffusion resistance in grapes (12). According to tests conducted by Riva and Perry in 1986, using potassium carbonate and ethyl oleate reduce drying time and browning and other reactions that damage the quality by creating tiny cracks in the wax layer of grapes (13). According to research conducted by Basiri *et al.* (2008) the best treatment for drying apricots that has the least effect on its quality have been reported to be treating with 8% sodium sulfite and 2% in ethyl oleate at 50 and 60 ° C (14). Therefore the purpose of this study was to optimize the drying zucchini coated with 2% ethyl oleate using independent variables dryer temperature (° C), osmotic solution concentration (%) and thickness of the zucchini (mm).

## 2. MATERIALS AND METHODS

### 2.1. Material

In this study, samples of fresh zucchini were prepared from the local market. Then they were rated in terms of color, diameter and weight. To reduce the severity of respiratory and physiological and chemical changes, all samples were kept in the fridge at 5 to 6 ° C. Samples of zucchini were cut with slicer (industrial salami cutter) in 3, 5 and 7 mm the thicknesses.

### 2.2. Methods

Before testing, the samples were taken outside the refrigerator and to reach room temperature, they were exposed to vitro environment. From the mass, few numbers were randomly chosen and their moisture was measured. Then the samples were put within the osmotic salt solution containing a concentration of 1, 3 and 5 percent (the ratio of product to the solution 1 to 10 for 3 hours), then they were placed on the filter paper to absorb the surface water and samples were put into a solution of ethyl oleate (2%) with a ratio of product to solution 1 to 2 (to make an equal case the solution was stirred) for 20 minutes at room temperature. After leaving the solution of ethyl oleate to get the surface water, samples were placed on filter paper. After weighing, aluminum foils was put on the samples and were weighed along with the samples again, then foils containing the samples were transferred to the drier with 60, 70 and 80 ° C temperatures. To determine the end time of tests (to achieve equilibrium moisture), foils containing the samples were weighed during the process. After achieving equilibrium moisture, samples were cooled in environmental conditions inside desiccator, in the last phase samples were fried for 2 minutes in the fryer with 130 °C oil temperature. Then, to prevent the reabsorption of water they were placed in plastic covers until biophysical experiments.

## 2.3. Tests

### *2.3.1. Moisture*

The extent of primary moisture of the zucchini samples with the oven temperature of 105 ° C was done to achieve a constant weight (15).

### *2.3.2. Dewatering*

Determining the reabsorption of water by the sample was done by pouring samples in distilled water at room temperature and dried samples were taken to measure weight gain (16). Methods was weighing the initial weight of each sample with accuracy of 0.01 g and putting in the beakers. Distilled water was added to the beakers so that the samples were completely in the water. At intervals of 15 minutes, samples were slowly taken out of water and put on dry tissues, so that only the surface water sample was taken and then they were returned to beakers with water. This continued as long as the difference between two consecutive weighing was less than 0.01 g, continued and the percent of samples water absorption (H) was calculated using equation 1 where w1 is initial sample weight and w2 is the weight after dewatering.

$$H = \frac{W_2 - W_1}{W_1} \times 100 \quad (1)$$

### *2.3.3. Shrinkage*

Determining the amount of shrinkage of samples was carried out using toluene and moving method. In this way, determining shrinkage amount was performed by pouring samples in a certain volume of toluene into a measuring cylinder and measuring the volume change (20). For this purpose, before drying, the initial volume of the sample was measured by putting them into a measuring cylinder containing toluene and after drying the dried sample volume was measured again. The extent of shrinkage (SH) was calculated by Equation 2. V1 is the initial volume and V2 is sample volume after the test.

$$SH = \frac{v_1 - v_2}{v_1} \times 100 \quad (2)$$

### *2.3.4. Color*

One of the methods used to measure food color is using LAB for which image j software was used and the samples were analyzed for color. Color differences between the samples dried and not-dried samples were calculated using colorimetric parameters in terms of brightness (L), red-green (a) and yellow - blue (b) and using equation 3. Not-dried samples were used as tested basis.

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \quad (3)$$

### *2.3.5. Frying Efficiency*

Frying efficiency is gained with respect to the weight of fried samples and the weight raw ones through equation 4 (17), where Cw is weight of fried coated samples and C is the weight of raw samples.

$$R = \frac{C_W}{C} \times 100 \quad (4)$$

### 2.4. Experimental design and statistical analysis

In this study, response surface methodology (RSM) with a straight central composite design was used to find the effect of independent variables: thickness of the zucchini slices (x1, 3-7 mm), the concentration of salt solution, (x2 ,1-5 g) and drying temperatures (x3, 60-80 ° C) on shrinkage (%) density (g / ml), volume reduction (%), Re-hydrating (%), color and frying efficiency (%) of the final product. The data obtained in this experiment were modeled using Design Expert software version 6.0.2 (Minneapolis US), and three-dimensional shapes (curve of response) to determine the relationship between the response and the independent variables were drawn. Response function (y) including shrinkage, density, volume, Re-hydrating, color and the efficiency of frying and based on them following quadratic polynomial model was fitted.

$$y = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_{11} x_1^{\ 2} + b_{22} x_2^{\ 2} + b_{33} x_3^{\ 2} + b_{12} x_1 x_2 + b_{13} x_1 x_3 + b_{23} x_2 x_3 + \varepsilon \qquad (5)$$

Polynomial regression coefficients is expressed as b0 (fixed expression), b1, b2, b3, (linear effect), b11, b22, b33 (second order effects) and b12, b13, b23 (interactions). Significance of regression coefficients of model were determined using analysis of variance for each answer. The adequacy of the model was conducted using R2, modified R2 Lack of fit test.

## 3. RESULTS AND DISCUSSION

### 3.1. Selection of an appropriate model

In order to obtain empirical models to predict any of responses quadratic polynomial equation (Equation 5) was used and fitted for the obtained data. Statistical significance of model was studied using F test and probability (P) where the absolute value of F is larger and the P value is smaller, the model significance will be more. It should also be noted that regarding statistics is a suitable model whose Lack of fit is not significant and has the highest value of R2 and adjusted R2 (Table 1). For a model with good fit, the value of R2 should be at least 0.08.

**Table 1**
**Results of statistical analysis of fitted model on response data**

| *Source of changes* | *SD* | *R2* | *Adjusted R2* | *P index forLack of fit* |
|---|---|---|---|---|
| Shrinkage | 1.41 | 0.92 | 0.89 | 0.15 ns |
| Density | 0.058 | 0.95 | 0.92 | 0.27ns |
| Volume reduction | 0.78 | 0.99 | 0.99 | 0.095 ns |
| Re-hydrating | 1.08 | 0.92 | 0.88 | 0.18 ns |
| Frying efficiency | 3.13 | 0.83 | 0.81 | 0.32 ns |
| L* | 3.25 | 0.82 | 0.80 | 0.078 ns |
| a* | 1.75 | 0.81 | 0.79 | 0.098 ns |
| b* | 2.38 | 0.86 | 0.82 | 0.11 ns |

ns means not significant at the 95% level of confidence

As can be seen in Table 1, in the test of weakness of fitting related to second degree polynomial model fitting of findings to response data at the 0.05 alpha level is not significant. Also, due to the high values of R2 and adjusted R2 related to second-degree polynomial models, it can be concluded that in data fitting it has a higher power.

### 3.2. Studying the effect of drying process variables on the quality properties of zucchini coated with ethyl oleate

#### *3.2.1. Shrinkage*

The effect of independent variables on the final product shrink in form of three dimensional response surface is shown in Figure 1. Analysis of variance and forms of response method show that the thickness of slices of zucchini has the greatest impact on wrinkles of samples ($p<0.05$) in a way by increase of thickness of zucchini samples from 3 to 7 mm, shrinks of samples during the drying process has increased (Figure 1). Although drying temperature had less effect on shrinks than the thickness of the samples, its effect was remarkable. In a way that the results showed that the samples were dried at temperatures above 80 ° C, had fewer shrinks than lower temperatures that may be due to the high speed of drying at higher temperatures. In a study Salehzadeh *et al.* (2011) studied the effects of temperature in the process of drying with movement method on the quality properties of the apricots. They reported that due to the use of ethyl oleate pre-treatment, which reduces the moisture differences on the surface and inside the samples, with increase in the rate of temperature no significant difference was observed in apricot sheets shrinks. (18)

Linear coefficient of osmotic salt concentration in osmotic solution had no significant impact on this character ($p>0.05$), but its quadratic effect was significant and therefore caused curvature (Fig. 1). As can be seen in Table 1, second degree polynomial fitted model for moisture was significant and lack of fit test is not significant ($p>0.05$) and R2 and adjusted R2 values improved in this model were 0.92 and 0.89 which was higher than 0.80 which confirms the strength of the model. Based on the results the order of impact of the independent variables was as follows: thickness of slices>drying temperature>osmotic salt concentration in the solution.

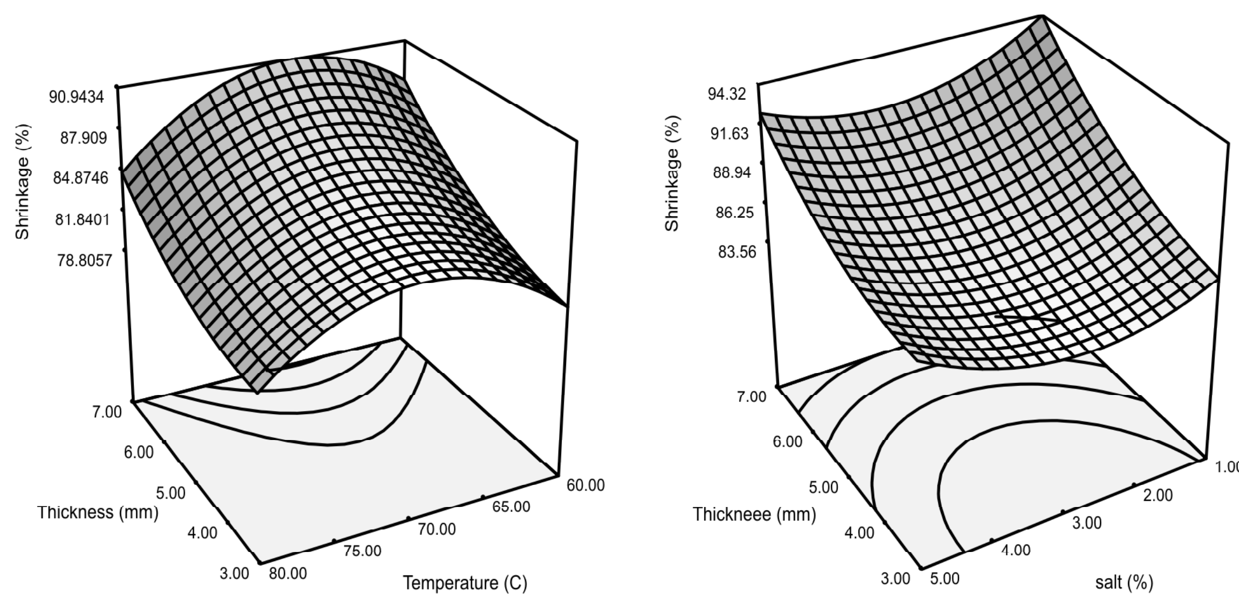


**Figure 1: Diagram of response procedures (a) the effect of salt concentration and thickness of the slice (T=70°C) and (b) the impact of temperature and thickness of the slice (C=3%) on shrink of final product.**

### *3.2.2. Re-hydrating*

From the figure of procedures it appears that the relationship between the hydration with the independent variables particularly with thickness of samples is shared which is confirmed with significance of the second degree effect ($p<0.05$). Based on the results of analysis of variance and the shape of response process, it was observed that all three variables' linear effects including drying temperature, salt concentration and thickness of slices had a significant effect on hydration of dried zucchini samples ($p<0.05$), while their interaction was not significant ($p>0.05$).

As can be seen, adding salt to 3% concentration in osmotic solution increases the re-absorption of water in dried samples of zucchini, while increasing the amount of salt in excess of this amount has a negative impact on hydration, although reduction of this parameter to 5% salt concentration was not significant (Figure 2). Thickness of samples to 5 mm also has a positive impact on re-hydration of samples after drying, but by thickening of samples up to 7 mm, this parameter showed a decreasing tendency, in a way that slices with 5 and 7 mm thickness had re-hydration of 86 and 91 percent, respectively. Because by rising temperature to a certain level (70 °C), drying rate increases, therefore, material structure has changed less and as a result after drying, the product can attract water better. While increasing temperatures more (80 °C), due to irreversible changes such as denaturing proteins and degrading carbohydrates, reduce further re-hydration. Salehizadeh, *et al.* (2011) in their research which was on apricot sheets concluded that re-absorption of water to 60 °C temperature increases and then by increase of temperature, re-hydration due to changes in tissue reduces (18).

As can be seen in Table 1, second degree polynomial fitted model for hydration is significant and its lack of fit test is not significant (p>0.05) which indicates that the quadratic model is appropriate. R2 and adjusted R2 values in this model were respectively 0.92 and 0.88 which was higher than 0.80 and have fitness that confirms high power of the model.

Based on the results of analysis of variance the order of impact of variables is like this: stripes thickness > drying temperature> osmotic salt concentration in the solution. Zomordi et al (2009) also examined the impact of different methods of preparation and solar drying on quality of tomatoes sheet and said that the stabilized sheets ability to absorb more water increases with salt water, but the stabilized sheets with boiling water and control are in the same statistical group. According to the results of the researchers, using blanching process for drying tomatoes, significantly increased the ability to absorb water in dried products (19).

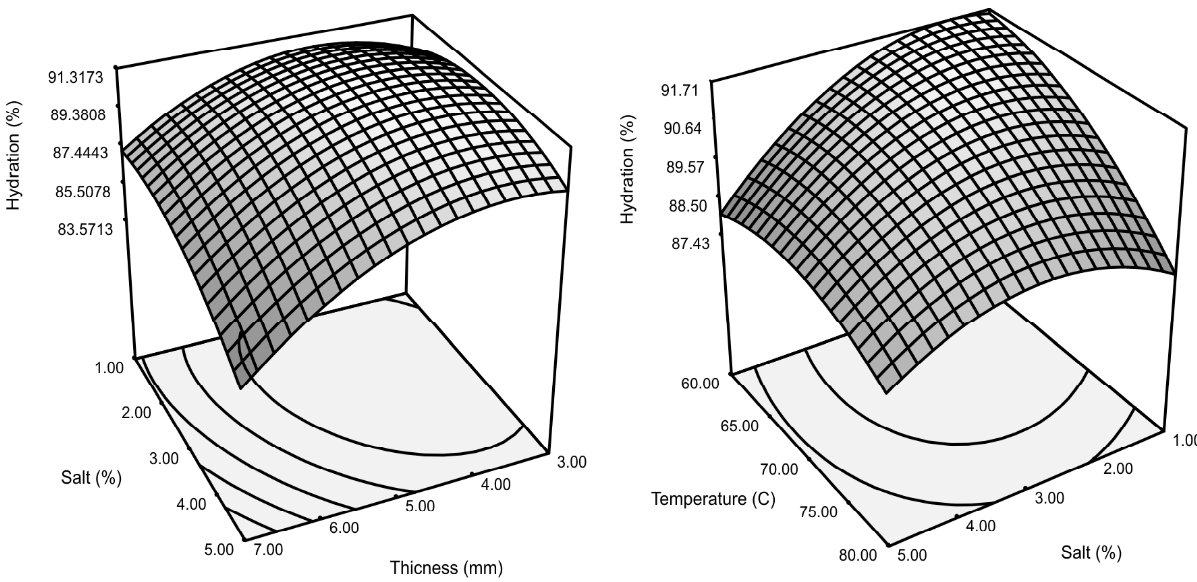


**Figure 2: Response procedures graph (a) The effect of salt concentration and temperature (Th=5 mm) and (b) the effect of the thickness of the slices and salt concentration (T=70°C) on re-hydration on final product**

### *3.2.3. Density*

The impact of independent variables on density of dried samples in form of three-dimensional response processes is shown in Figure 3. As can be seen slice thickness has a major impact on density of the samples (p<0.001). The results of analysis of variance and the shapes of response procedures shows by increasing the thickness from 3 to 7 mm, density of samples showed decrease from 1.45 to 0.95 grams per milliliter. Also, due to significance of the impact of square of the thickness and its interaction with salt concentration, there is a curve in the response process (Figure 3). The other independent variables that had a significant effect on the density was salt concentration in the solution (p<0.05) that had a similar effect like that of thickness, which means with an increase of salt from 1 percent to 5 percent in osmotic solution, the density of samples after the drying process is reduced, in a way that the lowest density was related to of the samples containing 5% dehydrated salt in osmotic solution. The results showed that the linear effect of drying temperature on the density is not significant in the model (p>0.05), while the quadratic effects, as well as interaction with salt concentration was greatly significant, therefore, there is a curve in shape of response procedures (Figure 3). As can be seen, temperature increase as a share reduces the density of dried zucchini samples. It is clear that the low density of the samples after drying is desirable because it increases the size and porosity of the zucchini and thus re-hydration of samples increased. R2 and adjusted R2 values in the model are 0.95 and 0.92, respectively and its fitness weakness test is not significant (>0.05), which confirms the strength of the model (Table 1). Based on the results of analysis of variance variables the impact order of the variables is as: slice thickness > salt concentration in the solution> drying temperature.

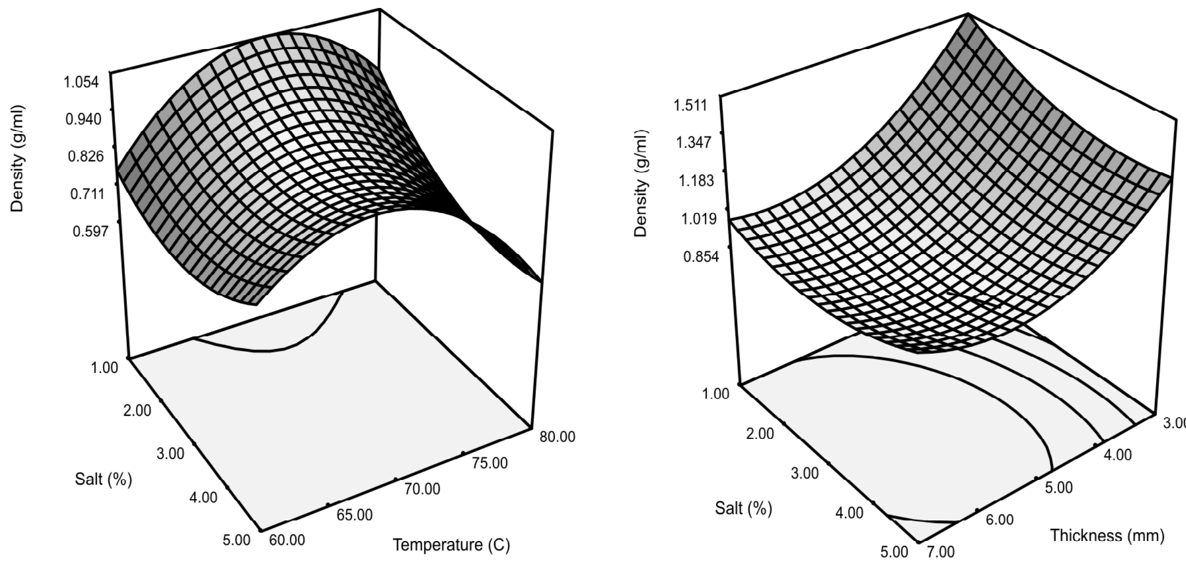


**Figure 3: Diagram of response procedures (a) The effect of salt concentration and temperature (Th= 5mm) and (b) the effect of the thickness of the slice and salt concentration (T = 70°C) on the density of the final product**

### *3.2.4. Volume reduction*

In Figure 4 we can see the influence of the independent variables on the dry product volume changes by osmotic solution. Analysis results showed that the linear effects of each independent variable and their quadratic effects on volume reduction of dried samples was significant (p>0.05), while the interplay of these variables on this trait was not significant (p>0.05). As can be seen by increasing the thickness of the slices, reducing the volume of samples after drying compared to the initial sample before drying process is significantly higher. This means that the greater the thickness of the sample, the smaller the sample size after drying. Samples which were dried at higher temperatures showed a lower volume reduction (had greater volume), that is probably due to the positive impact of high temperatures n speeding up the drying, reducing shrinks and reducing the density, which the collection of these factors leads to a less reduction of zucchini samples size dried at high temperature conditions. R2 and adjusted R2 values in the model were respectively 0.99 and 0.99 and their fitness weakness test is not significant (P>0.05), which confirms the strength of the model (Table 1). Based on results of analysis of variance the impact order of the variables is as: slice thickness > drying temperature> salt concentration in the osmotic solution, respectively.

### *3.2.5. Frying efficiency*

The impact of independent variables on the efficiency of the fried dried samples in form of three-dimensional response procedure is shown in Figure 5. As can be seen thickness of slices does not have a major impact on the efficiency of the frying of samples (p<0.001), in a way that by increasing the thickness of slices the

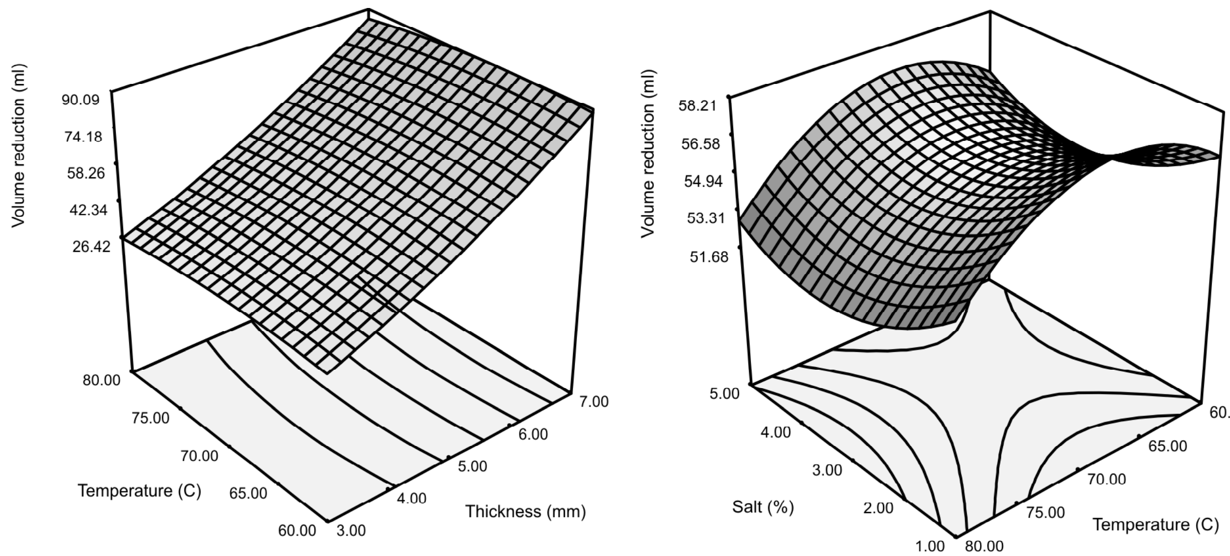


**Figure 4: Diagram of the response procedure (a) The effect of temperature and slice thickness (C=3%) and (b) the impact of temperature and salt concentration (Th=5mm) on reduction the size reduction of the final product**

efficiency of frying of samples after osmotic drying significantly reduced. Based on the results of analysis of variance only the linear effect of slice thickness was significant while the effects of other variables, as well as interactions of these features on this variable was not significant ($p>0.05$). But although the linear effect of temperature was not significant, it was close to be significant, so its effect is significant (Figure 5). As you can see, the efficiency of the frying of the dried samples at a temperature of 80 °C was less compared to samples at to 60 °C. based on the results of the analysis of variance the order of impact of variables is: slice thickness > drying temperature> salt concentration in the osmotic solution, respectively. Frying results in the loss and evaporation of water in zucchini slices. Coating slices with materials such as ethyl oleate reduces moisture loss during frying.

In a study Garmeh Khani *et al.* (2009) examined the effect of hydrocolloids on oil absorption and quality properties of semi-fried potato slices and reported that all hydrocolloids coatings used statistically significantly reduced water waste while frying, which is due to their ability barrier properties.

The highest moisture loss was observed during frying treatments of control (uncoated). As frying efficiency represents the amount of weight of the finished product, so based the results it can be said that by coating slices of potato, weight of the product is higher, which is due to the ability to retain moisture by resins (20) and these results are consistent with the results of Akdeniz (2004). According to the results of this researcher on hydrocolloids due to their prevention property, stop the moisture loss out of the fried stuff tissue, and so the final weight of the product will be higher compared with uncoated samples (17).

### *3.2.6. Color properties*

Measuring the color of samples was done by the colorimeter. Colorimeter parameters are expresses in terms of brightness (L), red- green (a) and yellow-blue (b). Color values L, a, b and color difference ($\Delta E$) of samples were calculated. The impact of independent variables on the efficiency of the frying of dried samples in form of three-dimensional shapes of response process is shown in Figure 6. The results showed that among independent variables only the effect of linear and quadratic effects of salt concentration in osmotic solution on color components L and a were significant, but on component b the linear effect of salt concentration and its interaction with temperature was significant ($p<0.05$ ). Thus, by increasing the salt concentration in osmotic solution, the amount of apparent brightness of dried zucchini samples reduced, in a way that the most favorable apparent brightness in the examples was in the one that had pretreatment

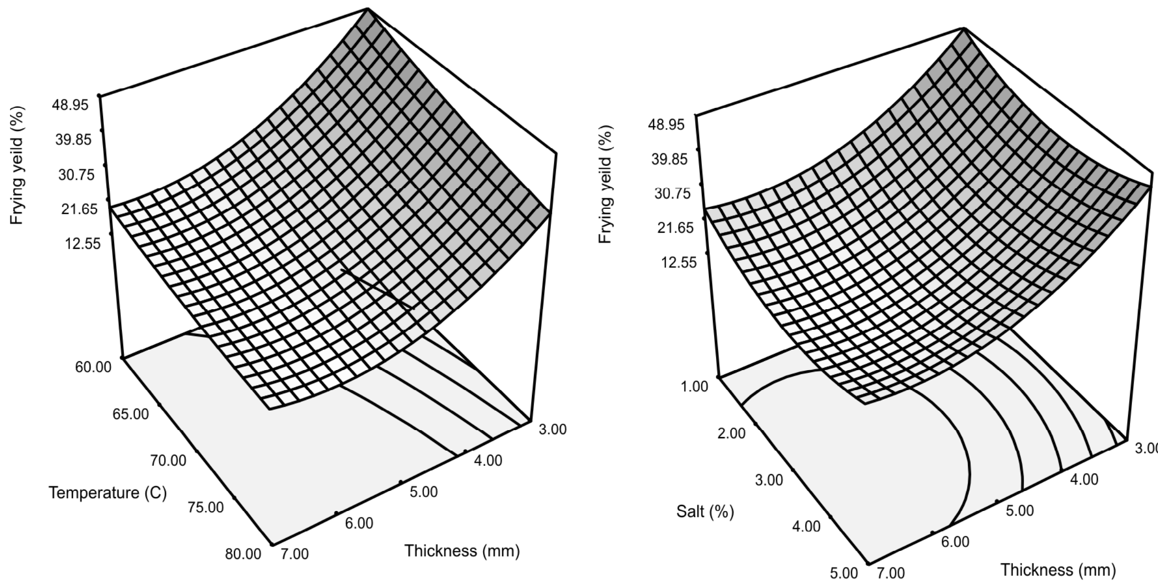


**Figure 5: Diagram response procedures (a) The effect of the thickness of the slice and salt concentration (= T 70° C) and (b) the impact of temperature and thickness of the slice (C = 3%) on the efficiency of frying the final product**

solution containing low percentages of salt, and as the salt concentration increased, the brightness of samples reduced. Thus, according to changes in the components of a and b and increases in the salt concentration in the osmotic solution the favorability of dried zucchini models fell regarding the apparent color. In general, the color changes of samples with osmosis that were coated with a solution of 2% oleate compared to control samples that were dried without coating or pre-treatment was much less. So, according to the results, the concentration of salt is the most effective parameter affecting the apparent color of the dried samples. In a similar study Seraji and colleagues (2012) examined the effect of edible coatings based on carboxy methyl cellulose-ascorbic acid and osmotic hydration in drying zucchini. They reported that index L of samples with osmosis compared to control samples has increased, but a index dropped. They also said color difference ($\Delta E$) of coated samples is less than uncoated samples. During the process of drying with hot air, for example by osmosis less change was observed compared to non-osmosis samples. The reason of color preservation in osmosis samples is seemingly because of the sample pieces' being under osmotic solution, and apparently away from oxygen. This lack of oxygen slows the enzymatic browning reactions (21). Jayaraman *et al.* (1990) showed that sugar and salt in the process of osmosis greatly protect the tissue and prevent browning reaction. Also, the osmosis process, due to keeping the color of samples, reduces the need to sulfur-containing compounds to prevent color changes (22, 23).

### 3.3. Optimization drying procedures

The optimum operating conditions for drying zucchini using the drying temperature, slice thickness and concentration of salt in osmotic solution on the parameters of shrinkage, reduction of volume, re-hydration, frying efficiency, density and color properties of the dried samples of zucchini were studied by software numerical optimization techniques. The values of the independent variables at the optimum drying conditions (where the parameters of shrinks, reduction of volume and density, at least while further re-hydration efficiency frying and color properties, were considered maximum) for the drying temperature, slice thickness and concentration of osmotic solution were obtained respectively as 80 ° C, 3 mm and 5%. In these optimum conditions amount of shrinks, reduction of volume, re-hydration and density, frying efficiency, density and color components (L *) were obtained as 83.34%, 40.2%, 90.78%, 52.4%, 0.78 g ml and 91.9, respectively.

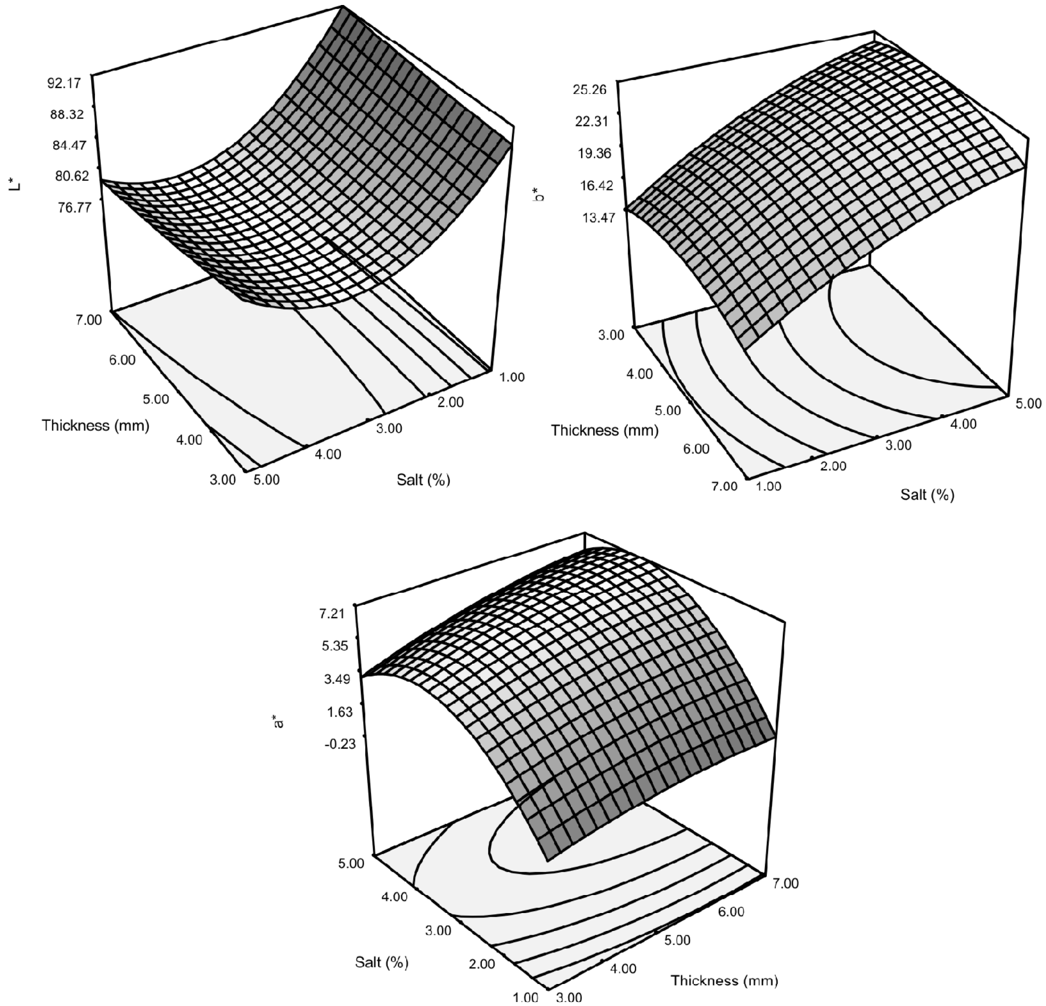


**Figure 6: Figure of process of the impact response on the color components L, a and b in the final product**

## 4. CONCLUSION

In recent years an extensive effort is done in new methods to replace conventional drying methods that cause adverse effects in the final product. Also today, consumers' demand for processed vegetables and fruits that look like the fresh ones and have gone through low or moderate heat during the process is growing. Among the most important new method of drying is osmotic hydration process. In this study, the effect of drying temperature, slice thickness and concentration of salt in osmotic solution on qualitative indicators of dried zucchini samples were analyzed. The results of the trials showed that an increase in the drying temperature up to 80 °C has a favorable impact while increasing the thickness of the slice of zucchini has a negative impact on the properties of the dried product's quality. Among the treatments under study, the most suitable condition for drying zucchini samples was with a thickness of 3 mm, osmotic solution containing 5% salt and dried with hot air at a temperature of 80 °C. Finally, one can conclude that coating samples by 2% ethyl oleate at first and then using osmosis process, due to shortening the drying time and creating a product with a suitable look and quality, can be considered as a suitable pre-treatment for increasing the quality of dried zucchini be.

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