This paper presents the research results on the color change of quince during combined drying. The applied combined drying includes osmotic drying in sucrose solution and convective tray drying with heated air. Quince cultivated Leskovacka was used in the experiment. The experiment was conducted with 15x15x15 mm samples. Osmotic drying was performed with the following combinations of the solution temperature and concentration: 60°C and 65°Bx, 40°C and 50°Bx, 60°C and 50°Bx and 40°C and 65°Bx. Color measuring in this experiment was performed with a three-filter colorimeter Konica Minolta CR-400. This instrument is capable of expressing quantitative color parameters in different systems. CIE L*a*b* color system was selected, based on the three-filter method. The change of the value L*, which describes sample brightness, has the similar trend to all the experimental units except for 60°C and 50°Bx. A small decrease of the value L* was determined, which denotes small changes of sample brightness. The negative value a* expresses mostly the green color, while the positive values expresses the red color. For all the experimental units, the negative value was within the range of -2 to -5. Significant increase of the value b* was observed in all the experiments. This fact points to the more intensive and “cleaner” yellow color. Convective drying influences the value reduction of the parameters L* and b* values. During the convective, as well as the osmotic drying, the value of a* parameter did not change.

**Key words:** quince, color, osmotic drying, convective drying.

**REZIME**

U radu su predstavljeni eksperimentalni rezultati promene boje dunje tokom kombinovanog sušenja. Primjenjeno kombinovano sušenje čine osmotsko sušenje u rastvoru saharoze i konvektivno sušenje na lesama pomoću zagrejanog vazduha. U eksperimentu je korističena dunja sorte leskovacka. Ova sorta odlikuje se intenzivnom prijatnom aromom i zbog toga pogodna je za preradu ovom tehnologijom. Eksperiment je obavljen sa uzorcima isekanih kockica tkiva dunje 15x15x15 mm. Osmotsko sušenje obavljeno je pri sličnim kombinacijama temperature i koncentracije rastvora: 60°C i 65°Bx, 40°C i 50°Bx, 60°C i 50°Bx i 40°C i 65°Bx. Konvektivno sušenje dunje obavljeno je pri temperaturi vazduha od 60°C u laboratorijskoj sastavski sa lesama. Mirenje boje u ovom eksperimentu obavljeno je trifilterskim kolorimetrom Konica Minolta CR-400. Odabrano je CIE L*a*b* sistema boja, baziran na trifilterskom metodu. Promena vrednosti L* koja opisuje sjajnost (brightness) uzoraka, ima sličan trend kod svih eksperimentalnih jedinica osim pri 60°C i 50°Bx. Primetan je mali pad vrednosti L* što ukazuje na male promene sjajnosti uzoraka. Negativna vrednost a* najviše izražava zeleno boju, a pozitivna crvenu. Kod svih eksperimentalnih jedinica izmerena je negativna vrednost u granicama od -2 do -5. Zapaža se značajni porast vrednosti b*, kod svih eksperimentata. To ukazuje na intenzivniju i „čistiju” z utoku. Konvektivno sušenje utiče na smanjenje vrednosti parametara L* i b* vrednosti. Vrednost parametara a* se tokom konvektivnog sušenja, kao i tokom osmotskog sušenja, nije značajnije menjala. Na osnovu ovoga može se tvrditi da osmotsko sušenje kao predtretman konvektivnom sušenju u kombinovanoj tehnologiji obezbeđuje kvalitet u pogledu očuvanja boje.

**Ključne reči:** dunja, boja, osmotsko sušenje, konvektivno sušenje.

**INTRODUCTION**

The first assessment of food by consumers is based on the product appearance. Color is one of the most significant properties related to a product appearance, and it can be crucial for the consumers’ decision whether or not to opt for that particular product. The subjective assessment of color results from the interaction of light spectrum reflected off the observed object and human eye. Light is electromagnetic wave of the defined range of wavelengths. The part of light visible to people is of relatively narrow wavelength intervals, between 0.40 and 0.76 μm (Mihailović et al., 2008).

Color is the consequence of perception and its interpretation is subjective. Different people perceive a color in a different way. Since color is the consequence of the reflected part of spectrum, color will differ when different lighting is provided. The background set behind the observed object also influences the appearance of the color. The angle under which the object is perceived, as well as the size of the observed surface, have influence on color definition, as well. The color of an object is determined by the pigments of a certain matter. Pigments are matter particles which determine the absorption and reflection of the illuminating light. The reflected part of the spectrum reaches the human eye. The human eye functions similarly to a camera, as the lens creates the picture of the object on the sensing surface in the retina of the eye. There are a number of cell types which receive light, which are sorted in three groups, each of which is responsible for a certain part of light spectrum, blue, green or red. The interactivity of these receptor groups is responsible for the incentive which is interpreted as a color in the brain. All the other colors, except blue, green and red, are perceived as their mixtures. This is a broadly accepted theory on colors, known as trichromatic theory. Due to the subjective character of color assessment by the human eye, people have been developing methods for quantitative, parameter-based expression of colors. The objective is to express colors in unambiguous and objective way as possible. Today, color can be measured by the instruments called colorimeter and spectrometers (Konica Minolta).

The most practical and most successful techniques of non-destructive fruit quality assessment are based on fruit optical properties, its color and visual texture. The optical properties of fruit have been examined for a long time (Birth and Olsen, 1964; Worthington et al., 1976; Nattuvetty and Chen, 1980; Dull and Birth, 1989; Chen and Sun, 1991; Felfoldi et al., 1995).

Drying of alimentary products is one of the most widespread means of food protection and preservation of its stability,
by which water activity and microbiological activity are reduced, while enzyme reactions are inactivated (Mayor and Sereno, 2004). However, during the process of drying the material is exposed to increased temperatures, which can have unfavorable effects on fruit quality (Barreiro et al, 1997; Lozano and Ibarz, 1997; Avila and Silva, 1999; Ibarz et al, 1999). During convective drying considerable color changes occur frequently (Krokida et al, 1998). However, certain authors claim that osmotic drying reduces these changes, preventing enzyme activities which cause darkening. Therefore, the usage of sulphur dioxide is reduced, which increases the nutritive value of the product after the combined drying (Ponting et al, 1966).

Quince is fruit whose exceptional aroma gave rise to its usage due to its hardness and pungency, its usage is directed only to-wards processing. On the basis of the research at the Faculty of Agriculture in Novi Sad, it was concluded that osmotic dehydration of quince, as a part of combined drying, provides the final product of favorable mechanical properties (Babić et al, 2008). This led to further examination of quince quality during osmotic and convective drying. During the process of drying, certain changes were observed on the surface of quince sample. The aim of this paper is to determine these changes by quantitative and qualitative means, depending on the assumed influential factors of osmotic solution temperature and concentration.

Nomenclature

\[ L^* \] - CIE colour parameter representing brightness
\[ a^* \] - CIE colour parameter representing red (+a) and green (-a) color
\[ b^* \] - CIE colour parameter representing yellow (+b) and blue (-b) color
\[ L_o^* \] - initial values of brightness fresh fruit
\[ a_o^* \] - initial values of red (+a) and green (-a) color on fresh fruit
\[ b_o^* \] - initial values of yellow (+b) and blue (-b) color on fresh fruit
\[ XYZ \] - tristimulus values (red, green, blue)
\[ X, Y, Z \] - tristimulus values for any illuminant
\[ ΔE_{ab} \] - total colour change
\[ C^* \] - chroma
\[ t(°) \] - temperature
\[ τ (min) \] - time
\[ c (Bx) \] - concentration

**MATERIAL AND METHOD**

**Material**

Quince cultivar Leskovačka was used in the experiment. The preceding research proved that its sort, which stands out for its aroma, is convenient for drying regarding its shape and dimensions. The fruits are of medium size and round, which secures aroma, is convenient for drying regarding its shape and dimensions. Magdić and Dobrićević (2007) state that the value of the measured sample color cannot be regarded as objective, as it is not possible to measure the same surface with colorimeter every time. This problem was avoided in this research by measuring the color on the same 15x15x15 mm samples. For this approach to the experiment, it was decided that the color of a single sample is observed with multiple measurements. It was the same sample surface that was always measured. The samples of quince quarters were previously peeled, the seed were removed, and then the samples were sulfurized with SO2. The average moisture content of fresh quince was around 80%.

Osmotic drying was performed in the originally designed osmotic drier (Babić et al, 2005). The osmotic solution temperature was controlled at the two levels: at 40°C and 60°C. The initial solution concentrations were 500Bx i 650Bx. The ratio of fruit mass and the solution was 1:12. After osmotic drying, convective drying in tray driers was performed (Babić, Ljiljana and Babić, M., 2000). After 180 minutes of osmotic drying, the color was measured every 20 minutes.

**Color measuring**

Colorimeter is an instrument for scanning color. The results of scanning are similar to human perception of color. The instrument contains sensors for color and a microprocessor (Fig. 1). It most frequently has the standard source of light, marked with C, and the visible field angle 2°. The standard source of light C corresponds to the day light, but without ultraviolet light spectrum. Color measuring in this experiment was performed using three-filter colorimeter Konica Minolta CR-400. Three-filter colorimeters are instruments, the working principle of which is based on trichromatic theory.

**Nomenclature**

\[ L^* \] - CIE colour parameter representing brightness
\[ a^* \] - CIE colour parameter representing red (+a) and green (-a) color
\[ b^* \] - CIE colour parameter representing yellow (+b) and blue (-b) color

**Material and method**

In the experiment, the following equations (Konica Minolta):  
\[ L^* = \frac{116 Y}{Y_0} - 16 \]  \hspace{1cm} (1)  
\[ a^* = 500 \left( \frac{X}{X_0} \right)^{1/3} - \left( \frac{Y}{Y_0} \right)^{1/3} \]  \hspace{1cm} (2)  
\[ b^* = 200 \left( \frac{Y}{Y_0} \right)^{1/3} - \left( \frac{Z}{Z_0} \right)^{1/3} \]  \hspace{1cm} (3)

For defining the sample color changes the total colour change \( ΔE_{ab} \) and chromaticity \( C^* \) were used. Chromaticity is
quantitative expression of color harmony. The total color change is (Konica Minolta):
\[ \Delta E^{*ab} = \sqrt{(L_o^{*} - L^{*})^2 + (a_o^{*} - a^{*})^2 + (b_o^{*} - b^{*})^2} \]  
(4)

where \( L_o^{*}, a_o^{*} \) and \( b_o^{*} \) represent the initial values of fresh fruit samples, while \( L, a \) and \( b \) represent the values after osmotic drying. Color chromaticity is expressed in the following way (Konica Minolta):
\[ C^* = \sqrt{a^{*2} + b^{*2}} \]  
(5)

RESULT AND DISCUSSION

Parameters \( L^{*}, a^{*}, b^{*} \)

The results acquired by measuring the color by colorimeter during osmotic drying of quince are presented in the diagrams (Fig. 3, 4, 5 and 6). The presented values \( L^{*}, a^{*} \) and \( b^{*} \) are acquired by measurements under different conditions of osmotic drying. Osmotic drying was performed under the following combinations of the solution temperature and concentration: 60°C and 65 oBx (Fig. 1), 40 oC and 50 oBx (Fig. 2), 60 oC and 50 oBx (Fig. 3) and 40 oC and 65 oBx (Fig. 4). The value of the parameter \( L^{*} \), which defines the brightness of the sample, has no highly significant changes during drying for all the experimental units. In this case, there is a slight decrease of the value \( L^{*} \), which points to very small changes of the sample brightness. Such results denote the positive effect of osmotic drying on color preservation. Osmotic drying secures that the color of the final product is very similar to fresh fruit, which was also concluded by Rodrigues et al., (2003). The negative value of the parameter \( a^{*} \), which indicates the green color, is within the range of -2 to -5 for all the experimental units. In all the experiments, there is the significant change of the value \( b^{*} \). This result points to the change towards the area of the more intensive and “cleaner” yellow color. The increase of the value \( C^{*} \) (Table 2) is in accordance with this conclusion. There is the increase of the value \( b^{*} \), evident generally during all 180 minutes of the experiment. The greatest value change \( b^{*} \) was determined when the solution temperature was 60°C and the concentration 65 oBx (Figure 3), while certain deviations from this general trend can be, so far, ascribed to measurement mistakes. Of course, in the continuation of the research, a certain number of repetitions need to be performed, with the purpose of acquiring the results of greater reliability.

The values \( L^{*}, a^{*} \) and \( b^{*} \) measured during the convective drying are presented in Table 1. These results indicate the decrease of the values of \( L^{*} \) and \( b^{*} \) parameters. This means that the products become less bright while the yellow color becomes darker. The value of the parameter \( a^{*} \) did not change substantially during the convective drying.

Table 1. Comparison of the changes of the parameters \( L^{*}a^{*}b^{*} \) during osmotic and convective drying

The total colour change \( \Delta E^{*ab} \) and chromaticity (color harmony) \( C^{*} \)
The color change $\Delta E^{*}_{ab}$ is calculated by using the equation 4. This value defines the total color change, but not the values of the changes of individual colors. The values $\Delta E^{*}_{ab}$ are often presented as the brown index and it is used for comparison of fruit colors during drying (Maskan, 2000; Chua, 2002). During osmotic drying, in all the four experiments, the values of $\Delta E^{*}_{ab}$ increased. On the basis of the results in Table 2 it can be assumed that the solution temperature and concentration do not significantly affect the overall color change in any of the combinations. This was confirmed also by the analysis of variance for the threshold of significance of 95%.

The value $C^*$ represents the color chromaticity (harmony, uniformity). It was calculated by using the equation 5. During osmotic drying, this value increased, and higher values mean cleaner and more intensive colors (Pomeranz and Meloan, 1971). Similar results were reached also by Rodrigues et al., (2003).

<table>
<thead>
<tr>
<th>Table 2. Parameters $\Delta E^{*}_{ab}$ and C for all the four experiments</th>
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<td>Time (min)</td>
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**CONCLUSION**

The color change of quince was measured during the osmotic and after convective drying. Osmotic drying was performed with the following parameters: 60°C and 65°Bx, 40°C and 50°Bx, 60°C and 50°Bx, and 40°C and 65°Bx. In all the four experiments, there is a considerable increase of the value of the parameter $b^*$, while the values of the parameters $L^*$ and $a^*$ do not change during 180 minutes of osmotic drying. During the convective drying, the values of the parameters $b^*$ and $L^*$ decreased to the approximately similar values as before osmotic drying. The values of the parameter $a^*$ did not change even after convective drying. Accordingly, it can be concluded that osmotic drying, as a pre-treatment of convective drying in the combined technology, secures the quality in terms of color preservation.

**ACKNOWLEDGEMENT**: The results of the research were enabled by the financial support of the Ministry of Science of the Republic of Serbia, the register number of the project 20065, called “QUALITY OF DRIED FRUIT PRODUCTION”, within the Project of Technological Development in the field of Biotechnology, for the period 2008-2010.

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Received: 25.03.2010. Accepted: 01.04.2010.