

## **INFLUENCE OF OSMOTIC TREATMENT IN THE DRYING OF SULTANINA GRAPES (*Vitis vinifera* L.)**

N. PENOV<sup>1</sup>, V. ROYTCHEV<sup>2</sup> and CH. CHRISTOV<sup>1</sup>

<sup>1</sup> *University of Food Technologies, BG - 4000 Plovdiv, Bulgaria*

<sup>2</sup> *Agricultural University, BG - 4000 Plovdiv, Bulgaria*

### **Abstract**

PENOV, N., V. ROYTCHEV and Ch. CHRISTOV, 2009. Influence of osmotic treatment in the drying of Sultanina grapes (*Vitis vinifera* L.). *Bulg. J. Agric. Sci.*, 15: 386-392

The possibility for convection drying of grapes from the seedless cultivar Sultanina by applying a preliminary osmotic treatment, and the process kinetics has been investigated. By means of a complete factorial experiment of the type 2<sup>2</sup> regression models of the velocity coefficient of sugar solution concentration gradient in the osmotic treatment and a velocity coefficient model for the drying process in convection drying of the treated grapes have been derived. The influence of sugar solution concentration and its temperature on the kinetics of the studied processes has been determined. A taste evaluation of the different variants has been carried out. The dendrogram showing taste evaluation ranks for dried raisins is divided into two major clusters. Appropriate parameters for grapes treatment have been suggested.

*Key words:* osmotic treatment of grapes, seedless vine cultivar Sultanina, concentration and temperature of sugar solution, kinetics

### **Introduction**

Due to their excellent taste characteristics dried grapes are a popular and valuable product, which contains concentrated and easily-absorbed sugars, organic acids, vitamins, minerals and other substances essential for the human body. Drying is a basic procedure, often applied in the technological processing of various products of the food and biotechnological industries (Burich and Berky, 1978; Sharma, 1983; Christov et al., 2002, Ditchev et al., 2006). Being a heat and mass exchange process, it depends both on the parameters of the drying agent – temperature, velocity and relative air humidity, and on the cultivar

and properties of the material – physical and chemical properties; specific drier loading; product shape and size, type of the preliminary treatment and so on (Penov et al., 2002). The great significance of the seedless cultivar Sultanina for raisin production worldwide is undeniable (Logotetis, 1971; Deer and Whiting, 1989).

Determining the influence of individual parameters as well as their interactions is of great importance for the correct performance of the drying process in different vine cultivars. The current investigation aims at optimizing the drying process of Sultanina grapes by applying a preliminary osmotic treatment with a minimum energy consumption, which allows the develop-

ment of a finished product with certain qualitative and taste indices.

## Materials and Methods

Grapes from the seedless cultivar Sultanina, which is characterized by medium-sized berries (19.11-15.59 mm) and average berry weight 3.36g, were used. The seeds are rudimentary and not detectable during consumption. The structural composition of grape includes: stalks – 2.39%; berries – 97.61%; millerandage berries – 0.63%; mechanical berry analysis – berry skins – 7.39%, mesocarp (flesh) – 90.22%; physical and chemical composition – dry matter refraction percentage – 23.3%, dry matter weight percentage – 27.29%, total acid content - 3.80g/dm<sup>3</sup>. The grapes were freed from the stalks and bruised berries, immersed in 1 % solution of sodium bicarbonate with a temperature of 95°C for 1 minute, and then treated with a 0.01 % solution of sulphurous acid for 15 min. Having been prepared in this way the grapes were immersed in a sugar solution (solution : product ratio 3:1) with concentration and temperature values varying according to the design matrix of the experiment as shown in Tables 1 and 2. Follow-

ing this treatment the material was dried at a temperature of 65<sup>0</sup>C and drying agent velocity 1 m/s in a laboratory convection chamber drier. The physical and chemical analyses were performed according to methods included in the Bulgarian State Standard (BSS): dry matter – refraction and weight percentages BSS 17257-91; total acid content - BSS 6996-93.

In order to study the kinetics of osmotic treatment of grapes the functions

$$S = f(\tau) \text{ and } S - S_{\min} = f(\tau) \quad (1)$$

have been constructed,

Where: **S** – is the dry matter content of the sugar solution, %.

From equation (1) by means of graphical differentiation the curves, depicting the velocity of the sugar syrup concentration change have been derived:

$$S - S_{\min} = f\left(\frac{d(S - S_{\min})}{d\tau}\right) \quad (2)$$

By linear approximation of the curve, depicting the velocity of the sugar syrup concentration change, it is possible to write the equation:

**Table 1**

**Variation levels and names of the independent variables in osmotic drying**

Independent variables, $z_j$ ,	Upper level, $z_j^u(x_i^u)$	Lower level, $z_j^l(x_i^l)$	Plan centre, $z_j^o(x_j^o)$	Variation interval, $Dz_j$
Sugar solution concentration, $z_1$ , %, ( $x_1$ )	82	62	72	10
Sugar solution temperature, $z_2$ , °C, ( $x_2$ )	75	55	65	10

**Table 2**

**Plan of the experiment in a natural form NFE 2<sup>2</sup>**

Variant	$Z_1$ , (S, %)	$Z_2$ , (t, °C)
1	62	55
2	82	55
3	62	75
4	82	75
5	72	65

S - sugar solution concentration, %

$$\frac{d(S - S_{\min})}{d\tau} = K_s (S - S_{\min}) \quad (3)$$

where:  $K_s$  is the velocity coefficient of the sugar syrup concentration gradient,  $\text{min}^{-1}$ .

By integrating equation (3) within the limits of concentration and time change, the following expression is derived:

$$\ln\left(\frac{S - S_{\min}}{S_{\max} - S_{\min}}\right) = -K_s \tau \quad (4)$$

This expression could be written as:

$$S = S_{\min} + (S_{\max} - S_{\min}) e^{(-K_s \tau)} \quad (5)$$

In order to study the kinetics of convection drying the curve of the drying process -  $U^c = f(\tau)$  has been plotted, from which the curve of drying velocity-

$$\frac{dU^c}{d\tau} = f(U^c),$$

$$\text{and } \ln(U^c - U_p^c) = f(\tau)$$

has been derived,

Where:  $U^c$  - water content, %;

$\tau$  - drying time, min (Kolarov, 1990).

The velocity coefficient of drying has been determined using the equation of the drying process curve:

$$-\frac{dU^c}{d\tau} = K_c (U^c - U_p^c) \quad (6)$$

Where:

$U_p^c$  - equilibrium water content, %;

$U^c$  - current water content, %;

$K_c$  - velocity coefficient of drying,  $\text{min}^{-1}$ .

A complete factorial experiment of the type  $2^2$  was applied with three replications in each point of the experiment. The influence of independent variables was determined by means of the response surface method (Bojanov and Vuchkov, 1973; Lambrev, 1994).

The taste evaluation was carried out using the rank-

ing method. A total of seven tasters participated. Each of these experts ranked the dried grape samples in descending order. In order to evaluate the obtained rankings the function of Euclidian distance between two objects (Everitt 1979, Murphy et al., 1986, Romesburg 1990) was applied:

$$R(X, Y) = (\sum(X_i - Y_i)^2)^{0.5} = 1, n \quad (7)$$

The statistical program SYSTAT 6.0, SPSS Inc. Y1996 SPSS Inc. was used for plotting the response surface and the cluster analysis dendrogram.

## Results and Discussion

The analysis of the kinetics of osmotic treatment of grapes is connected with the function  $S = f(\tau)$ , which allows the maintenance of constant osmotic solution concentration throughout the process.

The curves of sugar solution concentration gradient -

$$\tau = f\left[\ln\left(\frac{S - S_{\min}}{S_{\max} - S_{\min}}\right)\right]$$

are presented in Figure 1, while in Table 3 their velocity coefficients ( $K_s$ ) for the different variants of the experimental plan are shown. The values of the determination coefficients ( $R^2$ ) vary from 0.9173 to 0.9771 and they are adequate for the corresponding degrees of freedom. The analysis of the curves of sugar solution concentration gradient reveals that the process of osmotic dehydration of Sultanina grapes is most intensive at high values of sugar solution concentration (Figure 2). The following regression model for the velocity coefficient of sugar solution concentration gradient has been obtained:

$$K_s \cdot 10^3 = 115.276 - 1.32 \cdot S + 0.028 \cdot S \cdot t, \text{ min}^{-1} \quad (8)$$

This model describes the relation between the dependent variable (velocity coefficient of sugar solution concentration gradient) and the independent vari-

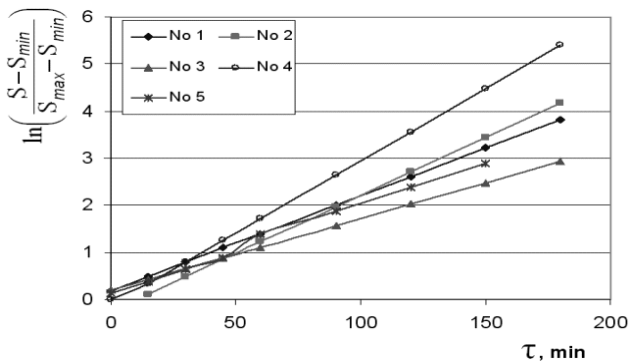


Fig. 1. Curves of sugar solution concentration gradient

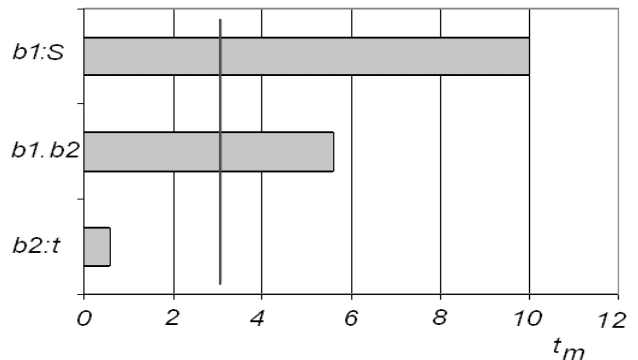


Fig. 2. Student's distribution values of the regression model coefficients for the velocity coefficient of sugar solution concentration gradient ( $K_s, \text{min}^{-1}$ )

Table 3  
Velocity coefficient of the sugar syrup concentration gradient

Coefficients	Variants				
	No1	No2	No3	No4	No5
$K_s, \text{min}^{-1}$	0.0202	0.0246	0.0152	0.0308	0.0167
$R^2$	0.9173	0.9274	0.9624	0.9771	0.9567

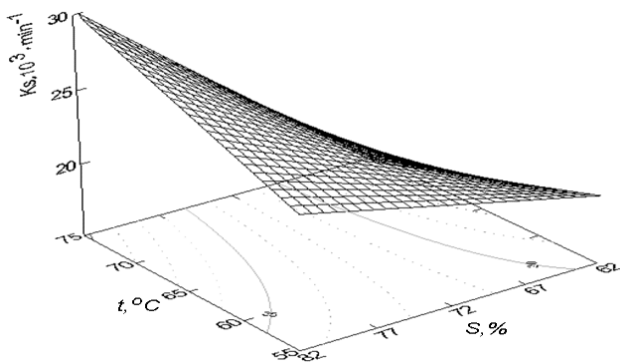


Fig. 3. Response surface of the regression model of the velocity coefficient of sugar solution concentration gradient ( $K_s, \text{min}^{-1}$ )

ables (sugar solution concentration and temperature).

The determination coefficient of the regression equation  $R^2 = 0.978$  is high, Standard Error of Est. is 0.000994, and MAE is 0.00059, which means that the model describes the process adequately at the corresponding degrees of freedom. Sugar syrup concentration exerts the greatest influence on osmotic treatment of grapes, followed by inter-factorial inter-

action between independent variables. The temperature of the syrup in the studied interval does not have a significant influence.

In Figure 3 the response surface of the obtained regression model is presented. The response surface is slightly saddle-shaped.

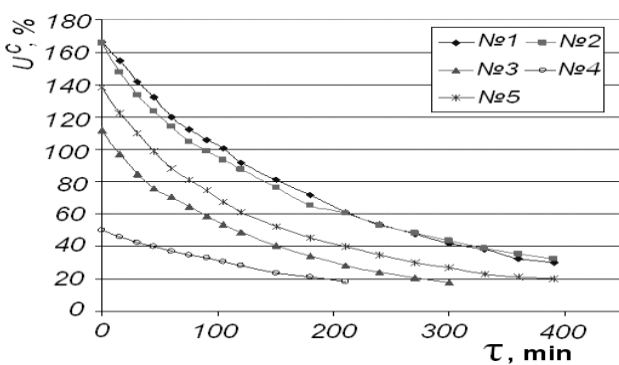
The highest value of sugar solution concentration gradient  $K_s = 0.0308 \text{ min}^{-1}$  is observed in osmotic treatment with sugar solution concentration 82% at a temperature of 75°C (Variant No4), while the lowest  $K_s = 0.0152$  is reported at sugar solution concentration 62% and a temperature of 75°C (Variant No3). The combination of high concentration and temperature of the sugar solution provides more favorable conditions for the development of osmotic-diffusion processes. No significant variation of the sugar solution concentration gradient  $K_s = 0.020 \text{ min}^{-1}$  is observed in the intervals  $t = 55\text{--}60^\circ\text{C}$  and  $S = 62\text{--}68\%$ .

Of great importance in dried grapes production is not only the osmotic treatment of the material but also the influence of this treatment on the following drying process in a convection chamber drier, or the drying

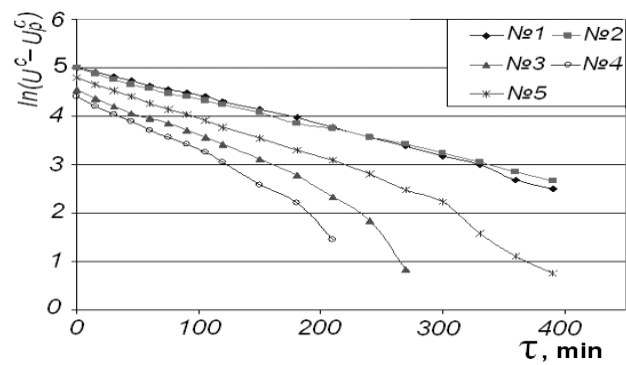
kinetics of osmotically treated raisins. The data on the influence of sugar syrup concentration and temperature in osmotic treatment on the velocity coefficient of convection drying helps to select a drying regime with minimal duration. The curves of convection drying of the osmotically treated grapes –  $U^c=f(\tau)$  and the curves of correlation

$$\ln(U^c - U_p^c) = f(\tau)$$

are presented in Figure 4a and 4b.



A



B

Fig. 4. A - Curves of drying of osmotically treated grapes  $U^c=f(\tau)$ ; B - Curves of correlation of osmotically treated grapes

Table 4

Velocity coefficients ( $K_c$ ) in convection drying of osmotically treated Sultanina raisins

Coefficients	Variants				
	No1	No2	No3	No4	No5
$K_c, \text{min}^{-1}$	0.0063	0.0058	0.0121	0.0131	0.0098
$R^2$	0.9964	0.9985	0.9554	0.9804	0.9805

The velocity coefficients ( $K_c$ ) in convection drying of osmotically treated Sultanina raisins for the different variants of the experimental plan are shown in Table 4. The values of their determination coefficients ( $R^2$ ) vary from 0.9554 to 0.9985 and are adequate for the corresponding degrees of freedom. A period of constant drying velocity is absent in all variants. The process takes place at a constant decreasing of drying velocity since the initial humidity cannot reach the critical value. At the beginning of the process a relatively short period is observed in which the temperature of the product reaches the temperature of

the drying agent. This period lasts for about 20 min, during which 10 - 15% of the expendable water content is eliminated. The duration of convection drying varies from 3.5 to 8.5 hours depending on the osmotic treatment of the material. As a result the following regression model for the velocity coefficient of convection drying of osmotically treated raisins has been obtained:

$$K_c \cdot 10^{-3} = 4.748 + 0.0575 \cdot t + 0.00375 \cdot S \cdot t, \text{min}^{-1} \tag{9}$$

Sugar solution temperature in osmotic treatment of grapes and inter-factorial interaction between independent variables exert the strongest influence on convection drying of osmotically treated grapes from the studied cultivar, whereas the influence of sugar solution concentration proves to be insignificant (Figure 5).

The presented response surface of the regression model is of a linear type (Figure 6). The shortest dry-

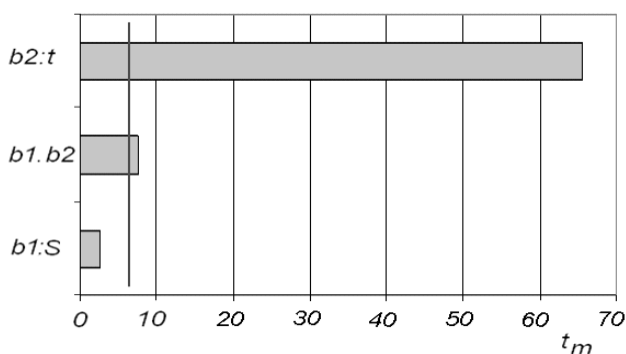


Fig. 5. Student's distribution values of the regression model coefficient for the velocity coefficient of convection drying of osmotically treated raisins

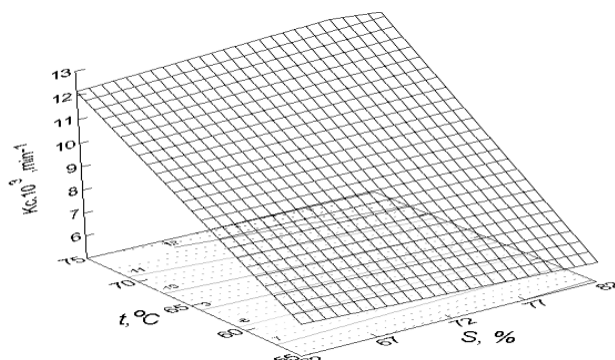


Fig. 6. Response surface of the regression model for the velocity coefficient of convection drying ( $K_c, \text{min}^{-1}$ ) of osmotically treated raisins

Table 5

Taste evaluation of osmotically treated and convection dried Sultanina raisins

	Variants				
	№ 1	№ 2	№ 3	№ 4	№ 5
$\Sigma a_{ij}$	27	35	21	14	8
Q	4	5	3	2	1
R	1	0	2	2	1
Dj	-6	-14	0	7	13
$D_j^2$	36	196	0	49	169
$\Sigma D_j^2 = 450; a_i j = 21$					
aj	3.857.143	5	3	2	1.142.857
Std.Err. Mean	0.1429	0	0.2182	0.2182	0.1429

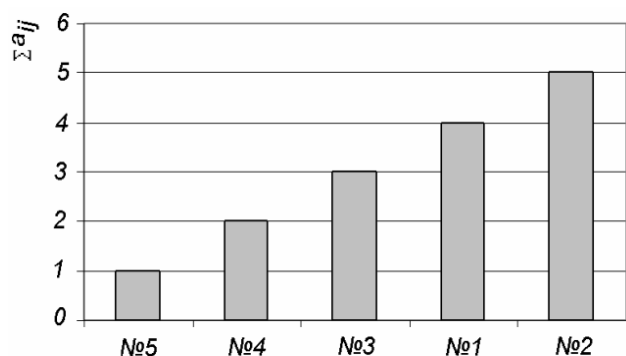


Fig. 7. Diagram of taste evaluation ranks of osmotically treated and convection-dried Sultanina raisins

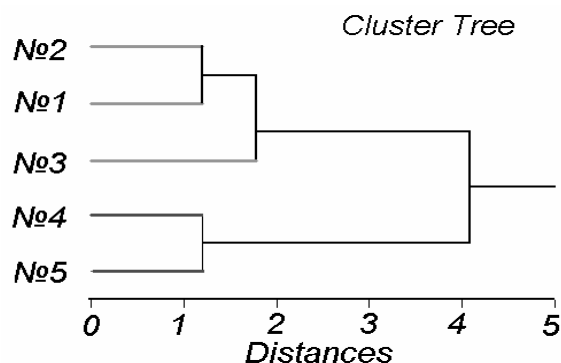


Fig. 8. Dendrogram of the results from cluster analysis of the taste evaluations of osmotically treated and convection-dried Sultanina raisins

ing duration is reported at sugar solution concentration 82% and a temperature of 75°C ( $K_c = 0.0131 \text{ min}^{-1}$ ), while the longest drying duration is observed at sugar solution concentration 82% and a temperature of 55°C ( $K_c = 0.0058 \text{ min}^{-1}$ ). The influence of sugar solution concentration in osmotic treatment of grapes on the following drying of the material in a convection chamber drier is not significant.

The taste evaluations of osmotically treated and convection-dried Sultanina raisins according to the ranking method are presented in Table 5, when the number of the degrees of freedom is  $k_1=4$  and the rate of significance  $\alpha=0.01$ ;  $W=0.918$ ;  $\chi^2=25.71$  and  $\chi_r^2=7.78$ .

After comparing  $\chi^2 > \chi_r^2$  it could be stated that the tasters have reached a consensus of opinion. The diagram of taste evaluation ranks of Sultanina dried grapes belongs to the growing linear function type and it could be divided into two major groups: 1<sup>st</sup> group - variants № 5 and 4; 2<sup>nd</sup> group – variants № 1, 3 and 2 (Figure 7). This conclusion is also supported by the cluster analysis dendrogram, which implies that the variants in the 1<sup>st</sup> group of the preliminary osmotic treatment of Sultanina grapes are the most suitable for drying (Figure 8).

## Conclusions

- In the drying process of grapes from the seedless cultivar Sultanina by applying a preliminary treatment in osmotic solutions, sugar solution concentration exerts a stronger influence on the osmotic-diffusion process than its temperature does. The highest value of the velocity coefficient of sugar solution concentration gradient -  $K_s=0.0308 \text{ min}^{-1}$  is observed at concentration 82% and a temperature of 75°C, while the lowest value of  $K_s=0.0152$  is reported at sugar solution concentration 62% and a temperature of 75°C.

- Depending on the osmotic treatment of grapes, the duration of convection drying varies from 3.5 to 8.5 hours, sugar solution temperature having the strongest influence on it. It is best to perform the preliminary treatment of Sultanina grapes for raisin production at sugar solution concentration 72% and a temperature of 65°C for a period of 3 hours.

Received June, 24, 2009; accepted for printing September, 2, 2009.

## References

- Bojanov, B. and I. Vuchkov**, 1973. Statistical methods for modelling and optimizing multi-factorial objects. *State Publishing Company "Technology"*, Sofia, 530 pp. (Bg).
- Burich, O. and F. Berky**, 1978. Drying of Fruits and Vegetables. Moscow, 279 pp. (Ru).
- Christov, Ch., N. Penov and S. Ditchev**, 2002. Kinetics investigation on a low temperature heat pump drying method. Science Congress 2002, University of Technologies- Sofia, Reports Collection, **Vol. II**: 30-36.
- Deer, T. W. W. and J. R. Whiting**, 1989. Evaluation of Sultanina grapevine selections for table grape production. *Australian Journal of Experimental Agriculture*, **29**: 901-904.
- Ditchev, S., Ch. Christov, N. Penov and V. Roichev**, 2006. Kinetics investigation on a combined (osmotic and low temperature heat pump) method of grape drying. 3<sup>rd</sup> Central European Congress on Food, 22-24 May 2006, Sofia, Bulgaria, Reports Collection (P46), pp. 1-2.
- Everitt, B. S.**, 1979. Unresolved problems in cluster analysis. *Biometrics*, **35**: 169-181.
- Kolarov, K.**, 1985. Processes and devices in the food industry. Plovdiv, "Ch. G. Danov" Publishing Company, 322 pp. (Bg).
- Lambrev, A.**, 1994. Bases of the Engineering Experiment in the Investigation of Machines and Devices for the Food Industry. Plovdiv, "Ch. G. Danov", 211 pp. (Bg).
- Logotetis, V.**, 1971. Raisin production from Sultanina grapes (White seedless), *Viticulture Issues*, Sofia, pp. 301-308.
- Murphy, J. P., T. S. Cox and D. M. Rodgers**, 1986. Cluster analysis of red winter wheat cultivars based upon coefficients of parentage. *Crop. Sci.*, **26**: 672-676.
- Penov, N., D. Ludneva, D. Braikov and V. Roytchev**, 2002. Investigation on the influence of osmotic treatment in the drying of seedless vine cultivars-I. International Science Congress "Stara Zagora 2002", 6-7 June 2002. **Vol 2. Agricultural Sciences**. Horticulture and Stock-Breeding, pp. 158-162.
- Romesburg, Ch.**, 1990. Cluster analysis for researchers. *Robert E. Krieger Publishing Company*, 334 pp.
- Sharma, R. Ch.**, 1983. Investigation on osmotic drying of fruits and vegetables. Dissertation, University of Food Technologies, Plovdiv, 279 pp. (Bg).