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KINETICS OF PUMPKIN DEHYDRATION

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ABSTRACT *- The paper has studied the effect of drying temperature (50, 60, 70, 80, 90, 100ºC) and wind speed (1.3; 1.7; 3.3; 4.1 m/s) on the kinetics of dehydration in pumpkin. The experimental data were satisfactorily fitted to the generalized drying curve model, but closer correlations were achieved after dividing the period of the drying speed decrease in two parts. The drying period was highly affected by air temperature and wind speed during the drying process, while blanching before drying has exerted a negligible influence. The carotenoids content from dried pumpkin was measured and we found that drying at a higher than 70ºC temperature led to their destruction. The carotenoids content in the blanched sample was by 39% higher than in the control.*

Key Words: pumpkin, kinetics of dehydration, carotenoids

REZUMAT – Cinetica deshidratării dovleacului. *În lucrare s-a studiat efectul temperaturii de uscare (50, 60, 70, 80, 90, 100ºC) şi a vitezei vântului (1,3; 1,7; 3,3; 4,1 m/s) asupra cineticii de deshidratare la dovleac. Datele experimentale s-au potrivit cu modelul curbei generalizate de uscare şi au fost obținute corelații strânse, după împărțirea perioadei de scădere a vitezei de uscare în două zone. Perioada de uscare a fost puternic afectată de temperatura aerului şi de viteza vântului în întregul proces de uscare, iar blanşarea înaintea uscării a exercitat o influență neglijabilă. S-a măsurat conținutul de carotenoizi din dovleacul deshidratat şi s-a constatat că uscarea la o temperatură mai mare de 70ºC a dus la distrugerea acestora. Produsul blanşat a avut un conținut al carotenoizilor mai mare cu 39% față de martor.*

Cuvinte cheie: dovleac, cinetica deshidratării, carotenoizi

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INTRODUCTION

The pumpkin varieties, included in the Register of Plant Varieties from the Republic of Moldova for 2006, are of two types: *Cucurbita maxima Duch* and *Cucurbita moschata L.*

The eatable part of pumpkin is made of almost 90% water. Pumpkin is also rich in carotenoids, their presence determining the yellow colour of the pulp.

Nowadays, in the Republic of Moldova, a special interest of the dehydration-occupied enterprises was noticed in pumpkin. Pumpkin is a crop with good preservation capacity. Processing pumpkin by dehydration can be a means for a longer duration of preservation.

Krokida et al. (2003) have studied the influence of parameters of the drying agent and size of samples on the dehydration kinetics of different vegetables, inclusively the pumpkin. For the description of the process of humidity transfer during drying, the kinetic model of the first order reaction was used:

$$dW/dt = -K(W - W_e) \qquad (1),$$

where the *K* coefficient is a function of variable parameters of the process.

In equation (1), the proportionality coefficient (K), named the drying coefficient, depends on material and drying regime. In order to point out the part that depends on the dehydration regime in the drying coefficient, many researchers present the drying coefficient through $K = \chi N$ (2), where χ is the relative drying coefficient that depends on material and N (%/min) is the maximum drying speed that depends on the drying regime.

The integration of equation (1) with an initial level $W_0 = W_{cr1}$, considering equation (2), leads us to the following equation: $W - W_e = (W_{cr1} - W_e)e^{\chi Nt}$ (3), which describes the changes in the average humidity content of the material, in the second drying period. Formula (1) determines the duration of the second drying period [time (t, min) is considered since the beginning of the second period]: $t_{II} = (1/\chi N)\ln((W_{cr1} - W_e)/(W - W_e))$ (4).

By generalizing the experimental data, Krasnikov (1973) has established that for the same material, with the same initial humidity, the $N\tau$ value, calculated for different drying regimes, at the same humidity content, was constant and did not depend on the dehydration regime. Therefore, all the drying curves of the material, obtained at different regimes, are placed on a curve in coordinates $(W - W_e) - N\tau$. This curve is named the generalized curve. If the generalized curve is known, a curve for the studied regime may be obtained, requiring the *N* value. The importance of this method consists in the fact that it allows the identification of the duration of material drying from initial humidity in the period of speed decrease, taking into account the variable drying regime, typical for real conditions. Calculation is based on drying curves, obtained under laboratory, where the regime of the process for each experiment is constant.

The aim of this paper consists in the study of the influence of different parameters on the duration of pumpkin dehydration and the quality of dried product, and in the investigation concerning the application of the generalized method of drying curves for the description of the kinetics of pumpkin dehydration.

MATERIALS AND METHODS

For the experiment, we have used two varieties of pumpkin, purchased in January. The common pumpkin (influence of air parameters) has a yellow coloured pulp and a content of dry matter of 5-8%. The "Mramornaia" variety (influence of pre-treatment) has an intense orange coloured pulp and a DM content of 11.3%. For carrying out these series of experiments, we have used the pulp of the same pumpkin, cut into regular pieces of 10 cm each. The prepared pieces have been dried in laboratory, which includes a section for preparing and adjusting the air parameters and a special chamber for dehydration. The initial product was placed on a control pan with the size of 230x230 mm, made of stainless network. During dehydration, the control pan with the product was periodically drawn out of the drying chamber, weighed, and put again to its place. The temperature was measured with an accuracy of 1ºC, the air speed being of – 0.15 m/s. The value of air relative humidity was of 2...7%.

Three series of experiments were carried out concerning the influence of technological parameters on dehydration kinetics in air temperature (T,ºC): 50; 60; 70; 80; 90; 100 (air speed 3.3 m/s); air speed (V,m/s): 1.3; 1.7; 3.3; 4.1 (air temperature 75ºC); the initial specific weight of the product: 10 and 15 kg/m^2 (75ºC; 3.3 m/s).

The fourth series concerns the influence of pre-treatment on the kinetics of dehydration and the content of carotenoids from the dried product. The pre-treatment was done by steam blanching during 5 minutes. The studied dehydration regimes are: a) 60ºC; 1.7 m/s and b) 90ºC; 3.3 m/s. The samples of dried pumpkin, processed and unprocessed before dehydration, were closed in polymer parcels, which are introduced in more layer paper parcels, for protecting their content against light. The sum of carotenoids was determined by the standard method.

Knowing the changes of the product weight during dehydration, we have calculated the changes in the humidity content of the product, and then the graphic correlations were drawn in coordinates $W,\% - t,\text{min}$ (drying curves), and the generalized drying curves were calculated for each series of experiments.

RESULTS AND DISCUSSION

The analysis of drying curves has shown that the variation of temperatures has significantly affected the duration of dehydration. When temperature has decreased from 100 to 50ºC, the duration of dehydration has increased at the ratio 1:1.2:1.5:1.8; 2.9:3.3 (W=20%). The influence of temperature has slightly increased at the same time with the humidity decrease. The variation of the air speed has significantly affected the duration of dehydration, too. When the air speed diminished from 4.1 to 1.3 m/s, the duration of dehydration became longer at the ratio 1:1.25:1.4:1.9 (W=20%). The ratio between the duration of drying pumpkin pieces did not change according to the humidity content of the product. The increase in the specific load from 10 to 15 kg/m^2 has diminished significantly (by 1.5 times) the intensity of water evaporation at the beginning of the process, but at the same time with the product dehydration, the duration of drying has also decreased. At the humidity content of 20%, the duration of dehydration did not depend on the initial load of the product.

The pre-treatment did not influence the pumpkin drying duration, indifferently of the drying regime. The pumpkin blanching has diminished the duration of drying by 5-10%, only in the middle zone of drying curves. The obtained values of N and W_{cr} were expressed according to the investigated parameter (air temperature or speed) by linear-type equations $y = ax + b$ (*Table 1*).

Table 1

Variation of maximum drying speed and critical humidity, according to the studied air parameter: statistical characteristics and empiric coefficients

Function	Empiric coefficients		Statistical characteristics	
	a	b	Coefficient of R^2 correlation	Standard error
$N = f(T)$	0.48	-2.52	0.935	2.38
$W_{cr1} = f(T)$	-12.71	2308	0.845	101.6
$N = f(V)$	4.88	2.82	0.933	1.72
$W_{cr1} = f(V)$	49.6	631	0.921	19.1

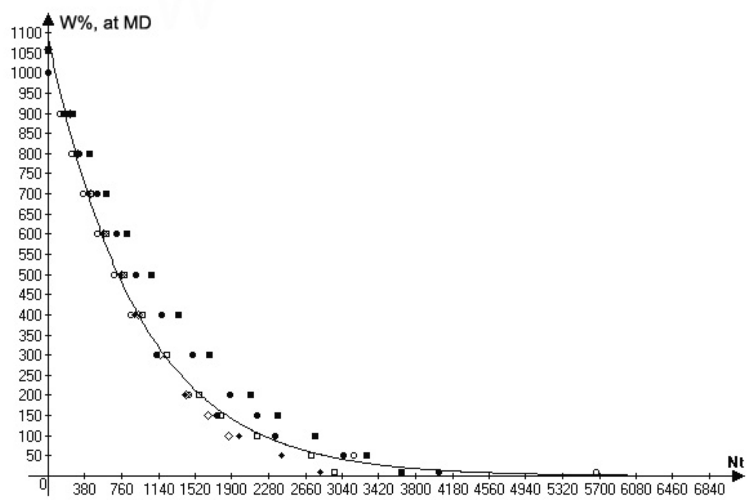

Fig. 1 – Generalized drying curve of pumpkin at different temperatures

The generalized drying curve within $W_{cr} - W_f$ (1060-10 %), concerning all the six values of studied temperatures was presented in *Figure 1* and by the empiric model (*Table 2*).

Table 2

Generalized drying curves: statistical characteristics and empiric coefficients

Model: $W - W_e = (W_{cr} - W_e)e^{\chi N t}$					
Field W, %	Parameter	Empiric coefficients		Statistical characteristics	
		$(W_{cr} - W_e)$	χ	Coefficient of R^2 correlation	Standard error
1060-10	50...100ºC	1087	-0.00107	0.904	53.71
1060-200	50...60ºC	1010	$-9.146*10^{-4}$	0.944	47.11
	70ºC	1113.5	$-7.903*10^{-4}$	0.995	23.02
	80...100ºC	1121	-0.00113	0.990	26.80
690-10	1.3...4.1 m/s	804.1	-0.00222	0.930	53.71
690-200		707.9	-0.00168	0.966	25.07
200-10		186.5	-0.00253	0.870	14.78

When analysing the generalized curve, we established that in case of splitting, during the speed diminution of phase $W_{cr1} \le W \le W_{cr2}$, by dividing the temperature range in 50...60; 70 and 80...100ºC, we have obtained models with a closer correlation for the indicated area (*Table 2*). The value of W_{cr2} was represented at a rate of 200%.

According to the authors, W_{cr2} determined the passage from removing the osmotic associated humidity to removing the absorbed humidity, but in case of the passage from temperatures of 80...100ºC to relatively low temperatures (lower than 70ºC), the type of water transfer from studied material was changed.

The generalized drying curves were determined in the same way at different air speeds. Splitting the diminution period of drying speed in two zones $W_{cr1} \le W \le W_{cr2}$ (II-1) and $W_{cr2} \le W \le W_f$ (II-2) in point $W_{cr2} = 200\%$, models of generalized drying curves were obtained for three fields of the humidity content (Table 2). Therefore, the duration of total drying was determined as $t = t_I = t_{II-1} + t_{II-2.}$ The comparison between experimental and obtained data by empiric equations (*Table 1*) and models (*Table 2*), as concerns the periods 690-200% and 200-10 %) was shown in *Figure 2*. The calculated drying curves reflected the experimental data.

The analytical data on pumpkin dehydrated samples, after 4 months of preservation, have shown a diminution in the quantity of carotenoids, while the drying temperature increased. This effect was seen especially at temperatures over 70ºC (*Table 3*). The blanched product before drying had the content of carotenoids higher by 39%, compared to the control.

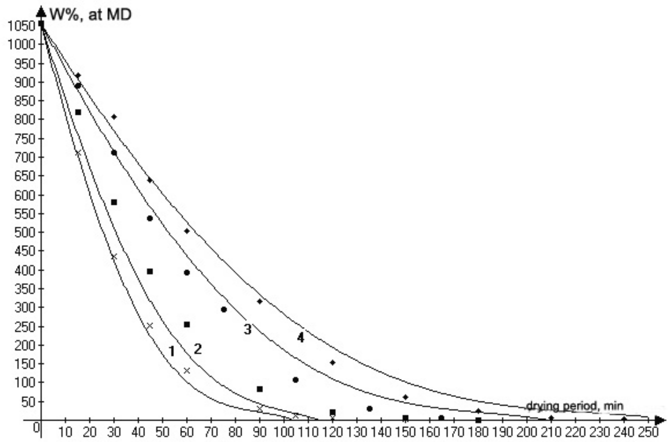

Fig. 2 - Experimental data (points) and drying curves calculated according to air speed

Table 3

Variation of carotenoids in the dehydrated pumpkin, according to the drying temperature

Index	Drying temperature, ºC					
	50	60	70	80	90	100
Mg/100 g DM	11.22	9.63	11.62	6.74	5.60	4.41

CONCLUSIONS

The temperature and air speed have a great influence on drying time during the process.

They demonstrated the possibility of applying generalized drying curves for describing the kinetics of dehydration. Equations and empiric models were drawn.

The quantitative characterization of the drying process is useful for establishing drying regimes.

The blanching before dehydration and dehydration at maximum temperatures of 70ºC have a positive action on preserving carotenoids in the dried pumpkin.

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