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EXPERIMENTAL RESEARCH ON DEHYDRATION OF SOME SPECIES AND VARIETIES OF FRUITS AND VEGETABLES

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ABSTRACT

A good tradition has been formed among Romanians regarding the preservation by drying of some important vegetables and fruits, such as plums, apples, bean pods, mushrooms, carrots, etc. In the peasant households the drying was done naturally, using solar heat, so that the conservation costs were quite low. The transition to the elimination of surplus water from vegetables and fruits by controlled dehydration, in high-capacity technical equipment, has proved beneficial for the possibility of storing and using products thus preserved for long periods, especially in winter and spring, when fresh products are rarer and more expensive even when the human body needs more of their contents. Technologies for preserving plant products by dehydration must be constantly improved in order to increase the quality of products, reduce nutrient losses, increase the safety and efficiency of technical equipment, etc. The experiments aimed at clearly defining the stages of dehydration technologies, with convective dryer, respectively in microwave controlled regime, of some species and varieties of fruits and vegetables, in order to eliminate the chemical processes of inactivation of oxidative enzymes and the application of strict green treatments.

INTRODUCTION

Dehydration of vegetables and fruits is done in different types of dryers, in which air is used as a drying agent, but also in the microwave field. When dehydrating vegetables and fruits, certain technical conditions must be observed, depending on the characteristics of the raw material and the finished product (Banu C., et al., 2002; Niculae, D. et al., 1997).

The dehydration process of fruits and vegetables is generally carried out in three successive phases (David C. T., 1984; Miron D. et al**.,** 1986):

a) the preheating period, during which the heat is consumed almost entirely for heating the product until the operating temperature is established;

b) the drying period with constant speed, which constitutes the dehydration period itself;

c) the drying period with decreasing speed (final period), in which the dehydration speed is gradually reduced.

Status parameters of the product, hat define and characterize the process of dehydration are the following: temperature (%); moisture (%); the speed of drying (% moisture/min).

Determination of mentioned state parameters was made taking into account the following factors:

- initial mass (m_i) of the load (g);
- the percentage of dry substance (DS) in the product (%);
- time intervals (Δt) between the measurements were made (min);
- quantities of water (Δw) extracted from samples during the time intervals Δt (g).

Expression of the percentage of the amount of water removed from the product is determined by the relation (Jones, P.L., 1995):

$$A=\frac{100(M_1-M_2)}{100-M_2}\ (\%) \qquad (1)$$

where: M_1 is the initial moisture and M_2 - final moisture content;

Drying speed (s_D) is given by the amount of water evaporated per unit time to 100 kg of dry matter:

$$s_D = F_{100}.s_{evap}\ (\%/min) \qquad (2)$$

where: $F_{100} = S\cdot 100\cdot\varepsilon$;

S - surface evaporation for 1 kg of the product (m^2);

ε=100/DS - the amount of material which contain 1 kg dry matter;

SU - the percentage of dry substance from the product (%).

Moisture evaporation rate is defined as the amount of water that is evaporated per unit area per unit time (Jones, P.L., 1995):

$$s_{evap}=\frac{\Delta_{w0}.100}{DS}\ (g/m^2\cdot min) \qquad (3)$$

where $\Delta_{w0}= \Delta_m/\Delta_t$ is the amount of water evaporated from the sample per unit time (g/min); Δ_m and Δ_t - the variation of the amount of mass of the sample, respectively the time interval in which it occurred.

The data recorded during the tests and the calculated physical quantities, which define the evolution of the state parameters during the dehydration process, allowed the establishment of the specific operating regimes of the installation for each experienced product. In all cases we started from the initial data of the test, namely: initial condition (natural/treated); initial mass of the sample (g); initial temperature (^{0}C); initial humidity (%) and the aim was to reach the final humidity (%), provided in the product standards.

MATERIAL AND METHOD

The main objective of the paper is to study the process of dehydration of fruits and vegetables, using two different types of dehydration equipments:

- convective dryer (provided with drying trays);
- microwave dehydration plant with continuous flow.

In figure 1 the convective dryer with drying trays (Sedona) used in the experiments is presented.

Fig.1. Convective dryer with drying trays.

In figure 2. is presented the scheme of the equipment used for dehydration of fruits and vegetables in the microwave field.

Fig. 2. Scheme of the microwave dehydration equipment.

In the case of the pilot convective dryer, the divided products will be placed evenly on the drying trays and the following specific parameters of the dehydration process will be determined: initial moisture of the products to be dehydrated, a_1 (%); initial air temperature, T_1 (^{0}C); initial air humidity, u_1 (%); final air temperature, T_2 (C^0); final air humidity, u_2 (%); final moisture of dehydrated products, a_2 (%) (http://uscatoare.ro; Marin, A.L., Brătucu, Gh, 2010).

In the case of microwave dehydration equipment, the divided products will be placed in a uniform layer on the conveyor belt (which moves at a constant speed v_b=4.5 cm/min.). Sample samples with an initial mass M_0 = 200.00 g shall be used and the initial humidity of the products subjected to dehydration shall be determined;

The following parameters will be measured (at 5 min regular intervals): mass of the sample (g); the amount of water evaporated in the measuring range Δm (g); humidity specific to the measuring range; final mass of the sample M_f (at the end of the dehydration cycle); final humidity a_2 (at the end of the dehydration cycle).

Based on the measured parameters will then be calculated (Miron D. et al., 1986):

- drying speed (% humidity/min);
- water evaporation rate (g/m^2· min).

To determine the humidity of the products, in the initial intermediate and final state, the high-performance humidity thermobalance Radwag-EU Model PMV50 was used, which has an accuracy of 0.05% (fig. 3.a). The Avidsen 107240 thermohygrometer (fig. 3.b) was used to measure the values of the initial, intermediate and final temperatures, as well as to measure the values of air humidity (in the case of the convective dryer),

a) b)

Fig. 3: a). High performance humidity thermobalance Radwag-EU Model PMV50; b) Avidsen thermohygrometer 107240.

The experiments were carried out in accordance with the technological operations described above, and were carried out on the following species and varieties of fruit and vegetables: plums (Agent); carrots (Assol); parsnip; onion (Ceaclama).

RESULTS AND DISCUSSIONS

Based on measurements made during the course of the experiments and applying mathematical relationships calculation above, it was determined state parameters of the product during the drying process. The results of the experiments for the dehydration regime of plums, using a convective dryer with drying trays are presented in table 1.

Table 1

Results of the experiments for the dehydration regime of plums, using a convective dryer with drying trays

Initial moisture of the products a_1 (%)	Initial air temperature T_1 (C^0)	Initial air humidity u_1 (%)	Final air temperature T_2 (C^0)	Final air humidity u_2 (%)	Final moisture of the products a_2 (%)
81	70	22	49	63	23

The results obtained indicate that the measured values fit perfectly into the range of admissibility required for convective dryer dehydration technology: initial air temperature 70°C-72°C; initial air humidity 20%-25%; final air temperature 45°C-50°C; final air humidity 60%-65%; final humidity of the dehydrated plums in range 22-25%.

Table 2

Experimental results for the dehydration regime of plums

Nr.	Drying time between measurement Δt (min)	Temperature (^0C)	Sample weight m (g)	The amount of water evaporated from within the measurement range Δm (g)	Moisture (%)	Speed Drying (%moist/min)	Rate of evaporation of water (g/m^2min)	Obs.
1	0	18	200	0	81,0	0	0	Initial heating
2	5	41,5	200	0	81,0	3,9	11,4	
3	5	62,2	193	7,0	79,2	5,8	16,7	
4	5	63,0	180,4	12,6	78,4	8,9	36,4	Drying with approx. constant speed
5	5	63,6	165,2	15,2	76,5	9,1		
6	5	63,9	147,8	17,4	74,4	9,2		
7	5	63,2	133,5	14,3	72,2	9,1		
8	5	63,0	118,2	15,3	68,8	9,4		
9	5	63,8	103,2	15,0	64,2	9,6		
10	5	63,4	87,8	15,4	56,3	9,3		
11	5	63,2	73,2	14,6	44,5	9,2		
12	5	61,9	60,4	12,8	33,3	7,3	21,6	Final drying
13	5	60,5	53,6	6,8	27,4	3,6	10,7	
14	10	37,6	50,6	3,0	22,5	1,2	2,9	Cooling
Total time: **75 min.**								

In table 2 are presented the results of the experiments for the dehydration regime of plums, using a microwave dehydration equipment.

Typical microwave dehydration curves are shown in figures 4, 5 and 6.

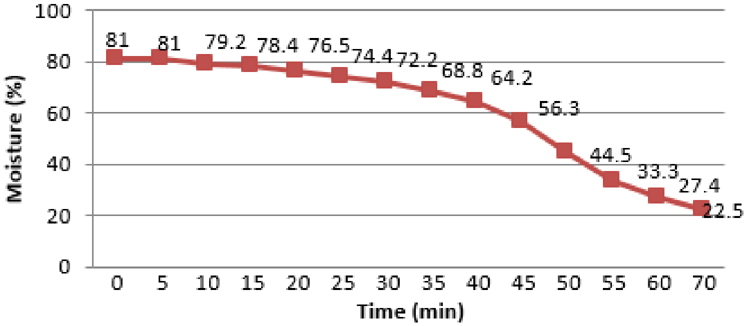

Fig. 4. Variation in humidity during the process of dehydration of plums.

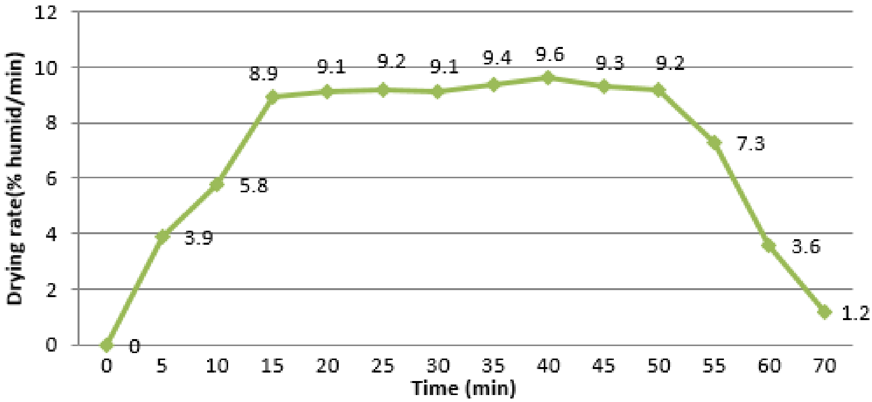

Fig. 5. The evolution of the drying speed during the dehydration process of plums.

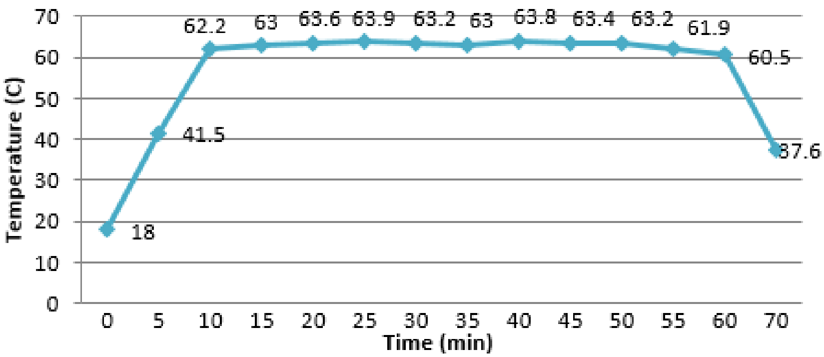

Fig. 6. Temperature evolution during the dehydration process of plums.

Following the evolution of the state parameters (temperature, humidity, drying speed), the following are highlighted: the process of dehydration of plums from 81% to 22.5% humidity was carried out with the evaporation rate of water in the drying regime with constant speed of 36.4 g/m^2 min.; the operating temperature at constant drying regime was approx. 63^{0}C; the dehydration speed during the drying period with constant speed was approx. 9.3% humidity/min.

The results of the experiments for the dehydration regime of the carrot and parsnip roots, using a convective dryer with drying trays are presented in table 3.

Table 3

Results of the experiments for the dehydration regime of carrot and parsnip roots, using a convective dryer with drying trays

Initial moisture of the products a_1 (%)	Initial air temperature T_1 (C^0)	Initial air humidity u_1 (%)	Final air temperature T_2 (C^0)	Final air humidity u_2 (%)	Final moisture of the products a_2 (%)
86,5	68	21	46	63	8,2

The results obtained indicate that the measured values fit perfectly into the range of admissibility imposed by the dehydration technology, namely: initial air temperature 65°C-70°C; initial air humidity 20%-25%; final air temperature 44°C-47°C; final air humidity 60%-65%; the final humidity of the carrot and parsnip roots should be in the range 8-9%. The results of the experiments for the dehydration regime of plums, using a microwave dehydration equipment are presented in table 4.

Table 4

Experimental results for the dehydration regime of carrot and parsnip roots

Nr.	Drying time between measurement Δt (min)	Temperature (^{0}C)	Sample weigt m (g)	The amount of water evaporated from within the measurement range Δm (g)	Moisture (%)	Speed drying (%moist/min)	Rate of evaporation of water (g/m^{2}min)	Obs.
1	0	18	200	0	87,1	0	0	Initial heating
2	5	41	199	1,0	87,1	0,8	1,0	
3	5	56	184	5,0	86,2	5,8	15,2	
4	5	62	165,6	18,4	85,3	14,3	35,4	Drying with approx. constant speed
5	5	63,7	145,8	19,8	84,1	15,1		
6	5	63,9	126,4	19,4	81,4	15,4		
7	5	64,3	106,7	19,7	76,8	15,5		
8	5	64,8	85,8	20,9	69,4	15,7		
9	5	65,4	64,7	21,1	53,5	15,3		
10	5	66,8	47,3	17,4	32,3	7,1	16,2	Final drying
11	5	67,4	37,8	9,5	16,2	4,7	8,3	
12	5	66,6	30,0	7,8	9,1	3,8	4,1	
13	10	32,5	27,6	2,4	8,4	1,1	1,8	Cooling

Total time: **70 min.**

Typical microwave dehydration curves are shown in figures 7, 8 and 9.

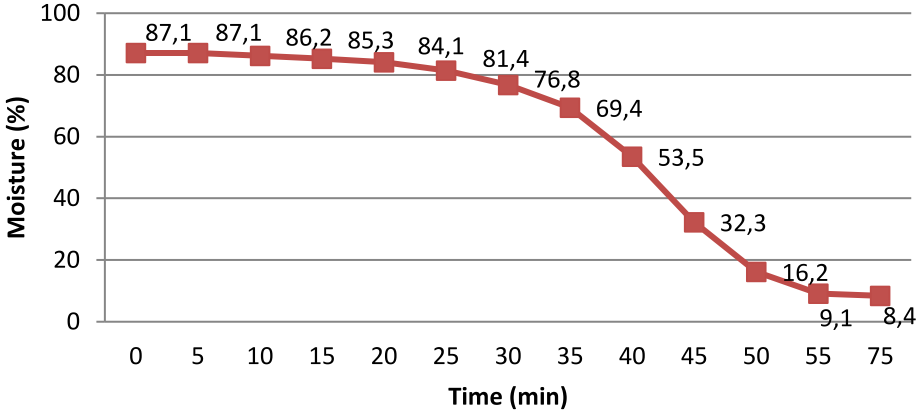

Fig. 7. Variation in humidity during the process of dehydration of carrot and parsnip roots.

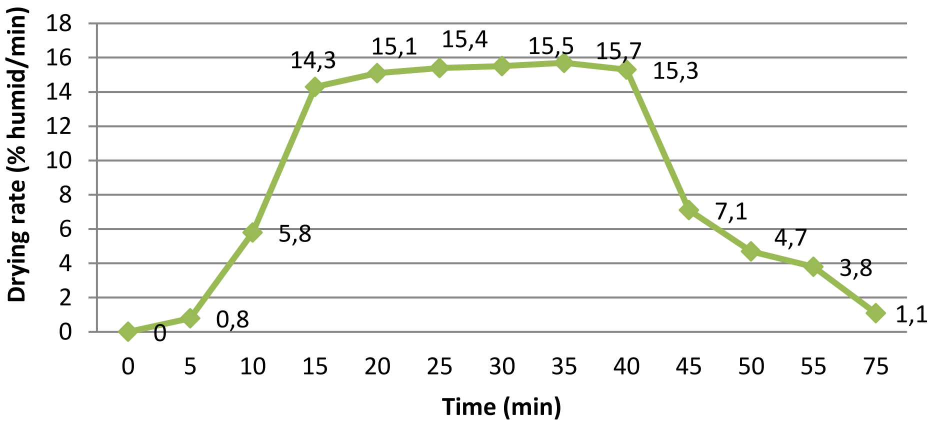

Fig. 8. The evolution of the drying speed during the dehydration process of carrot and parsnip roots.

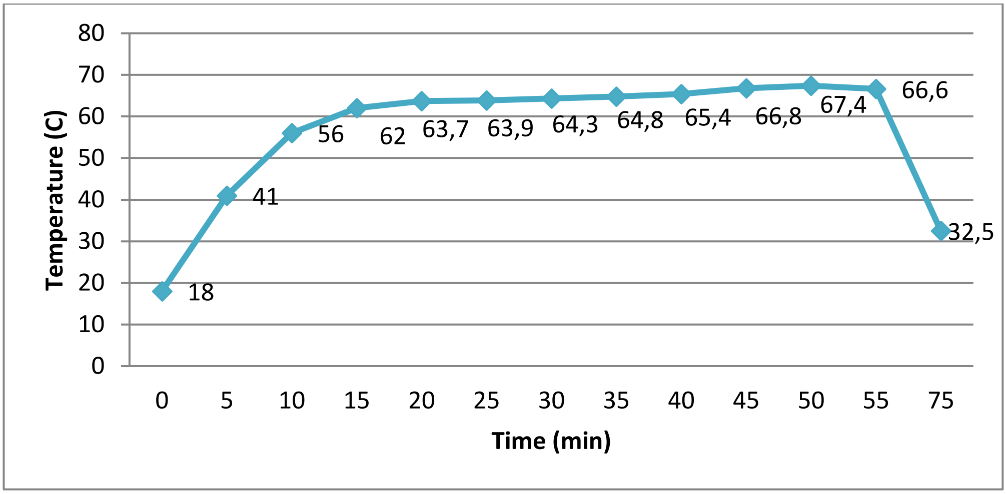

Fig. 9. Temperature evolution during the dehydration process of carrot and parsnip roots.

Following the evolution of the state parameters (temperature, humidity, drying speed), the following are found: the dehydration process of the carrot and parsnip roots from 87.1% to 8.4% humidity was performed with the evaporation rate of water in the drying regime with constant speed, of 35.4 g/m^2 min.; the operating temperature at constant drying regime was between 63^{0}C-67^{0}C; the dehydration speed during the drying period with constant speed was approx.15% humidity/min.

CONCLUSIONS

1. In order not to use treatments for the inactivation of oxidative enzymes, for fixing the color and flavors with elements of chemical synthesis, dehydration technologies of vegetables and fruits were applied, using a convective dryer with drying trays, respectively a microwave equipment; these technologies allow the elimination of oxidative enzyme inactivation treatments with acid solutions;
2. The results obtained when using the convective dryer with drying trays indicate that the measured values fit perfectly in the range of admissibility imposed by technology, in terms of all parameters studied (initial air temperature; initial air humidity; final air temperature; humidity final air, final humidity of dehydrated products);
3. The results obtained when using the dehydration installation in a microwave controlled regime highlight that the dehydration process is very intense, producing the rapid heating of the product at over 60^{0}C, in approx. 5 min., in its entire volume, which leads to the inactivation

of oxidative enzymes and reduces the danger of thermal browning and caramelization;

4. The quality of dehydrated fruits and vegetables obtained by applying the technologies presented corresponds to the requirements of domestic and international standards.

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