EXPERIMENTAL RESEARCHES ON SOME SPECIES AND VARIETIES OF FRUITS AND VEGETABLES SUBJECTED TO DEHYDRATION TREATMENTS

Mihnea GLODEANU[1]

(1)University of Craiova, 19 Libertății street, Craiova, Romania

Author email: mihneaglodeanu@yahoo.com

Abstract

The main objective of the work is the study of the process of dehydration of fruits and vegetables, using two different types of equipment for dehydration: convective dryer, equipped with drying trays; microwave field dehydration instalation, with continuous flow. In the case of the 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: the initial and final humidity of the products; initial and final air temperature; the initial and final humidity of the air. 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 of 4.5 cm/min. The following parameters will be measured: the mass of the sample; the amount of water evaporated in the measuring interval; the final mass of the sample; the final humidity at the end of the dehydration cycle. The results obtained in the case of using the convective dryer with drying trays indicate that the measured values fall perfectly within the admissibility range imposed by the technology, regarding all the studied parameters. In the case of using the dehydration installation with microwaves, the dehydration process is very intense, producing rapid heating of the product to over 600 C^0, in approx. 5 min., in its entire volume, which leads to the inactivation of oxidative enzymes and reduces the risk of thermal browning and caramelization.

***Key words**: vegetables, fruits, convective dryer, microwave field*

INTRODUCTION

The traditional methods of dehydrating fruits and vegetables do not ensure the maintenance of color, aroma, texture, enzyme status, proteins, fats and vitamin content. For this reason, are needed treatments to inactivate oxidative enzymes, to fix the color and flavors with elements of chemical synthesis (Țenu I., 1999). That is why alternative methods, also called non-conventional methods, have been developed to reduce the effects caused by time and temperature on vegetable products, with the elimination of chemical treatments and the application of ecological procedures (Constantin Ș. and G. Grămada, 1986; David C.T., 1984). The purpose of the experiments was to clearly define the stages of dehydration technologies (with a convective dryer, respectively in a microwave-controlled regime) of some species and varieties of fruits and vegetables, in order to eliminate chemical processes for inactivating oxidative enzymes and applying strict green treatments (Banu C., et al., 2002).

Status parameters of the product that define and characterize the process of dehydration are the following (David C. T., 1984, Glodeanu M., et al., 2016, Miron D. et al., 1986): temperature (%); moisture (%); the speed of drying (% moisture/min).

Determination of mentioned state parameters was made taking into account the following factors (Glodeanu M., et al., 2016, Sărăcin I., 2015, Sărăcin I., 2016, Vasile C., 2021):

- initial mass (m_i) of the load introduced into the processing chamber with microwave (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 (A) removed from the product is determined by the relation (Jones, P.L., 1995, Lojewski G., 2005):

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

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 (Glodeanu M., et al., 2016):

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

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 (%);

The moisture evaporation rate is defined as the amount of water that is evaporated per unit area per unit time (Jones, P.L., 1995, Glodeanu M., et al., 2016):

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

where $\Delta_{w0} = \Delta_m/\Delta_t$ is the 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.

MATERIALS AND METHODS

The main objective of the work is the study of the process of dehydration of fruits and vegetables, using two different types of equipment for dehydration:

- convective dryer (equipped with drying trays);
- microwave field dehydration equipment, with continuous flow.

In figure 1 the convective dryer with drying trays (Sedona) used in the experiments is presented. In figure 2 is presented the scheme of the equipment used for dehydrating fruits and vegetables with microwaves.

The experiments were carried out in compliance with the technological operations. The experiments were carried out on the following species and varieties of fruits and vegetables: Plums (Agen); Carrots (Assol); Parsnip; Onion (Ceclama).

Fig. 1. The convective dryer with drying trays

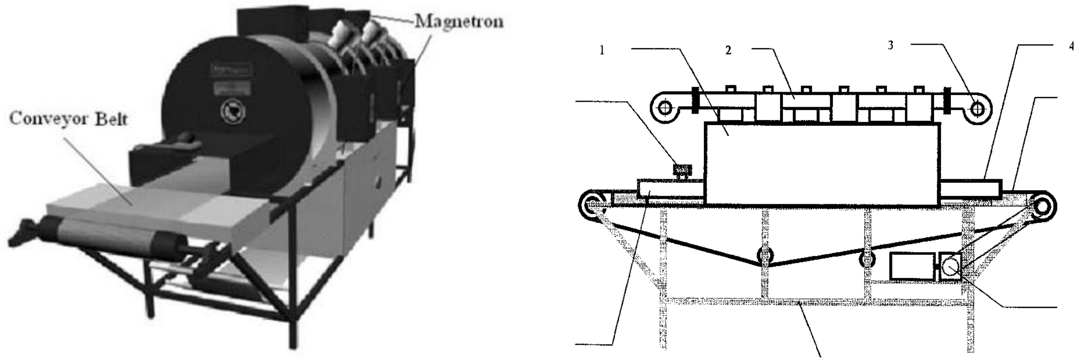

Fig. 2. Scheme of the equipment for microwave dehydration: 1 - microwave treatment enclosure; 2 - microwave distribution system; 3- magnetron cooling system; 4 - input mode; 5 - conveyor belt; 6 tape drive system; 7 - metal support; 8 - output mode; 9 - fan

In the case of the pilot convective dryer, the divided products will be placed evenly on the drying trays and the following specific parameters to the dehydration process will be determined: the initial humidity of the products to be dehydrated, a_1; initial air temperature; the initial humidity of the air; final air temperature; final air humidity; the final moisture of the dehydrated products.

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.)(Glodeanu M., et al., 2016, Sărăcin I., 2015, Sărăcin I., 2016, Vasile C., 2021). Test samples with the initial mass M_0=200.00 g will be used and the initial moisture a_1 of the products subjected to dehydration will be determined. The following parameters will be measured (at regular intervals of 5 min.): mass of the sample (g); the amount of water evaporated in the measuring interval Δm (g); specific humidity to the measurement range; the 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, the following will be calculated: drying speed (% moisture/min); water evaporation rate (g/m^2·min).

To determine the humidity of the products (Sărăcin I., 2015, Sărăcin I., 2016) in the initial, intermediate and final state, the high-performance humidity thermobalance Radwag – EU Model PMV50 was used, which has the following important technical characteristics (fig. 3): thermal source: microwave radiation; capacity: 50 g; division / accuracy: [d] 0.1 mg/0.05 %. The Avidsen 107240 thermohygrometer (fig. 4) was used to measure the initial, intermediate and final temperature values, as well as to measure the air humidity values (in the case of the convective dryer), which allows measuring the internal temperature (between -10 and +50 °C), but also humidity (the integrated hygrometer can read humidity values between 20% and 95%).

Fig. 3. Radwag High Performance Moisture Thermobalance – EU Model PMV50

Fig. 4. Avidsen thermohygrometer 107240

RESULTS AND DISCUSSIONS

The results of experiments for the dehydration regime of plums, using a convective dryer with drying trays are presented in table 1.

Table 1. The results of experiments for the dehydration regime of apples, using a convective dryer with drying trays

The initial moisture of the products a_1 (%)	Initial air temperature T_1 (C^0)	The initial humidity of the air 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 obtained results indicate that the measured values fall perfectly within the admissibility range imposed to the convective dryer dehydration technology, namely: initial air temperature=70°C-72°C; initial air humidity=20%-25%; final air temperature=45°C-50°C; final air humidity = 60%-65%; the final humidity of the dried plums must be in the range = 22-25%. The results of experiments for the dehydration regime of plums, using the microwave dehydration equipment, are presented in table 2. The typical curves of dehydration of plums in the microwave field are shown in figures 5 and 6.

Table 2. Experimental results for plums dehydration regimen

Nr.	Drying time between measurement sΔt (min)	Temperature (°C)	Sample weigt m (g)	The amount of water evaporated from within the measurement range Δm (g)	Moistu re (%)	Speed drying (%moist/min)	Rate of evaporation of water (g/m²min)	Obs.
1	0	18	200	0	81.0	0	0	
2	5	41.5	200	0	81.0	3.9	11.4	Initial heating
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	30	22.5	1.2	2.9	Cooling

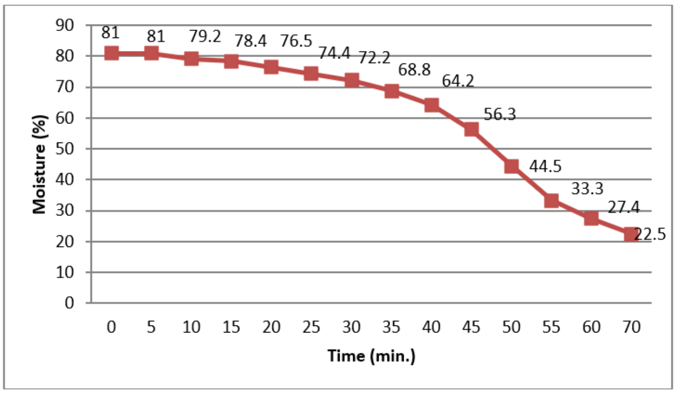

Fig. 5. Variation of humidity during the dehydration process of plums of the Agen variety

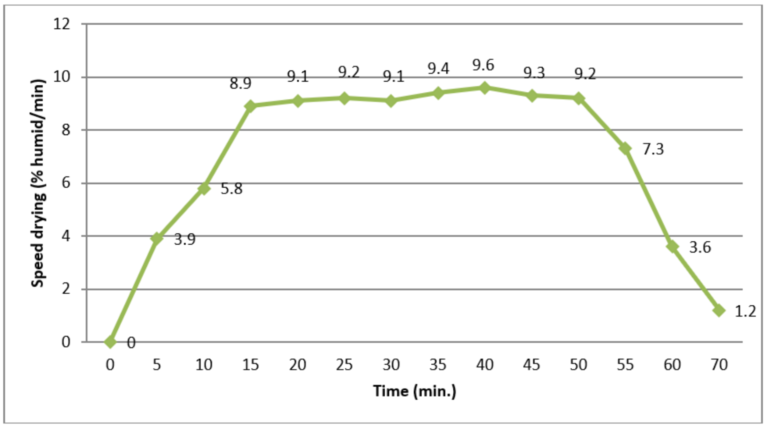

Fig. 6. The evolution of the drying speed during the dehydration process of plums of the Agen variety

Analyzing the data from table 2 and following the evolution of the state parameters (temperature, humidity, drying speed) from figure 5.4, the following are highlighted:

- the process of dehydrating plums from 81% to 22.5% humidity was carried out with the rate of water evaporation in the drying regime with a constant speed of 36.4 g/m^2·min.;
- the operating temperature at constant drying mode was approx. 63 ^{0}C;
- the dehydration speed during the constant speed drying period was approx. 9.3% humidity/min.

The results of laboratory analyses highlight the quality of plums dehydrated in a microwave-controlled regime. Figure 7 shows the appearance of dehydrated Agen plums obtained by applying the technology that uses the microwave field as an energy source.

Fig. 7. Dehydrated Agen plums in controlled microwave mode.

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

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

The initial moisture of the products a_1 (%)	**Initial air temperature T_1 (C^0)**	**The initial humidity of the air 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 obtained results indicate that the measured values fall perfectly within the admissibility range 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 experiments for the dehydration regime of carrot and parsnip roots, using the microwave dehydration equipment, are presented in table 4. The typical curves of dehydration of plums in the microwave field are shown in figures 8 and 9.

Table 4. Experimental results for carrot and parsnip roots dehydration regimen

Nr.	Drying time between measurement sΔt (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

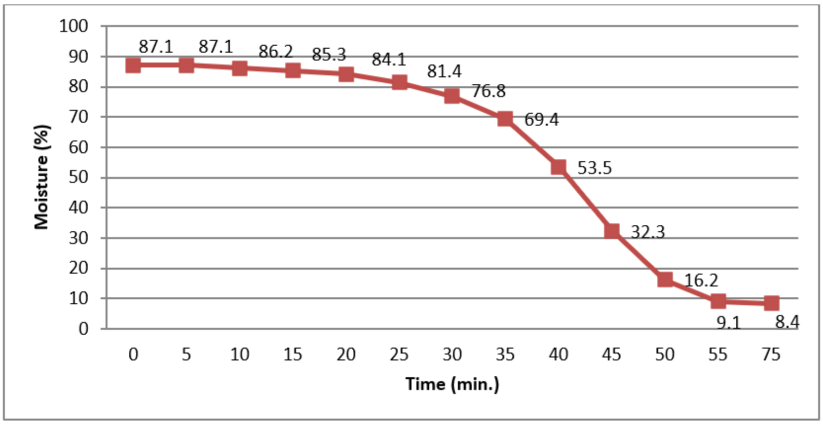

Fig. 8. Variation of humidity during the dehydration process of carrot and parsnip roots

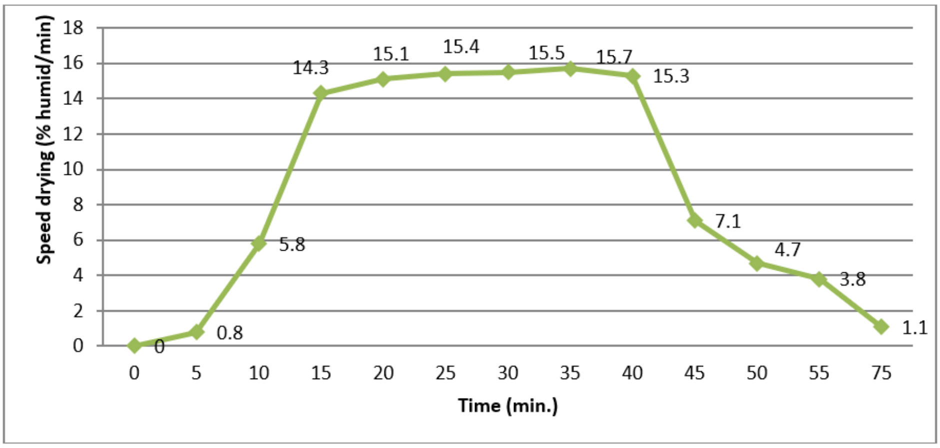

Fig. 9. The evolution of the drying speed during the dehydration process of carrot and parsnip roots

Analyzing the values of the parameters presented in table 4 and following the evolution of the state parameters (temperature, humidity, drying speed), the following can be found:

- the process of dehydrating carrot and parsnip roots from 87.1% to 8.4% humidity was achieved with the rate of water evaporation in the constant speed drying regime, of 35.4 g/m^2· min.;
- the operating temperature at constant drying mode was between 63 ^{0}C-67 ^{0}C;
- the dehydration speed during the constant speed drying period was approx. 15% humidity/min.

Figures 10 and 11 show the appearance of the carrot, respectively the appearance of the dehydrated parsnip by applying the technology that uses the microwave field as an energy source.

Fig. 10. Dehydrated carrot with microwave

Fig. 11. Dehydrated parsnip with microwaves

The results of experiments for the dehydration regime of onion, using a convective dryer with drying trays, are presented in table 5.

Table 5. Results of experiments for dehydration regime of onion using a convective dryer with drying trays

The initial moisture of the products a_1 (%)	**Initial air temperature T_1 (C^0)**	**The initial humidity of the air u_1 (%)**	**Final air temperature T_2 (C^0)**	**Final air humidity u_2 (%)**	**Final moisture of the products a_2 (%)**
85.9	**59**	**23**	**42**	**64**	**5.8**

The obtained results indicate that the measured values fall perfectly within the admissibility range imposed by the dehydration technology, namely:

- initial air temperature = 58°C - 60°C;
- initial air humidity = 20% - 25%;
- final air temperature = 42°C – 44°C;
- final air humidity = 60% - 65%;
- the final humidity of the dehydrated onion must be max. 6%.

The results of experiments for the dehydration regime of onion, using the microwave dehydration equipment, are presented in table 6. The typical curves of dehydration of plums in the microwave field are shown in figures 12 and 13.

Table 6. Experimental results for onion dehydration regimen

Nr.	Drying time between measurement sΔt (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	16.5	200	0	85.9	0	0	Initial heating
2	5	43.2	200	0	85.9	0	0	
3	5	61.4	191.0	9.0	84.7	6.1	13.2	
4	5	62.3	175.8	15.2	83.4	13.5	36.3	Drying with approx. constant speed
5	5	63.5	157.5	18.3	81.2	13.2		
6	5	64.9	136.5	21.0	75.8	13.6		
7	5	66.8	114.1	22.4	72.3	13.7		
8	5	66.4	92.7	21.4	66.4	13.4		
9	5	66.2	69.2	23.5	51.8	13.3		
10	5	65.9	50.2	19.0	35.7	9.2	16.8	Final drying
11	5	66.6	36.8	13.4	21.3	5.4	9.4	
12	5	45.2	31.6	5.2	13.6	3.1	6.2	
13	10	35.0	29.4	2.2	6.7	0.8	2.3	Cooling

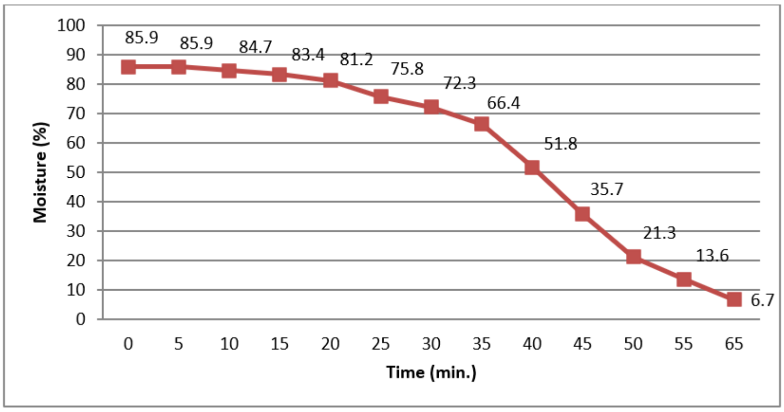

Fig. 12. Variation of humidity during the dehydration onion.

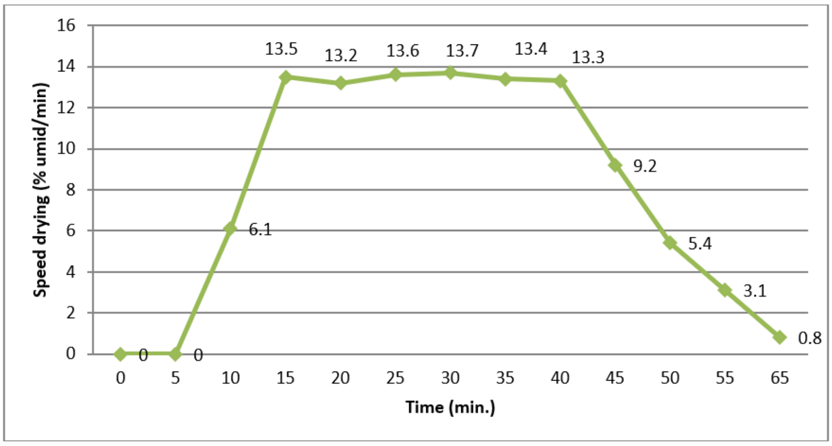

Fig. 13. The evolution of the drying speed during the dehydration process of onion.

The analysis of the data from table 6 and the evolution of the state parameters in the onion dehydration process, highlights the following aspects:

- the process of dehydrating the onion from 85.9% to 6.7% humidity was carried out at a water evaporation rate in the constant speed drying regime of 33.3 g/m^2·min.;
- the operating temperature at constant drying mode was approx. 66^{0}C;
- the dehydration speed during the constant speed drying period was approx. 13.2% humidity/min.

Fig. 14 shows the dehydrated onion rings in the microwave treatment enclosure.

Fig. 14. Dehydrated onion rings

CONCLUSIONS

The results obtained in the case of using the convective dryer with drying trays indicate that the measured values fall perfectly within the admissibility range imposed by the technology, regarding all the studied parameters (initial air temperature; initial air humidity; final air temperature; humidity final air; final moisture of dehydrated products.

The results obtained in the case of using the dehydration installation with microwave, highlight the following:

- the dehydration process is very intense, producing rapid heating of the product to over 600C, in approx. 5 min., in its entire volume, which leads to the inactivation of oxidative enzymes and reduces the risk of thermal browning and caramelization;
- when heating with microwaves, the product heats up, while the surrounding air remains cold.

The quality of dehydrated fruits and vegetables obtained by applying the presented technologies meets the requirements of domestic and international standards: the products have elastic flesh, clean surface, no traces of sugaring, no mold colonies, no mineral and vegetable impurities and preserve the organoleptic properties of fruits/vegetables: pleasant taste and smell, sweet aromatic, light color, etc.; the analysis of the results obtained during the experiments, compared to the requirements of the product standards, highlights the fulfillment of the quality requirements in the case of fruits and vegetables.

REFERENCES

Banu, C., & al. (2002). Engineer's handbook of food industry. *Technical Publishing House*, Bucharest.

Constantin, Ş., & Grămadă, G. (1986). Controlul tehnic de calitate în industria alimentară. *Technical Publishing House*, Bucharest.

David, C. T. (1984). Microwawe heating for the food industry in overview. *Trumpler*, R. F. G.

Glodeanu, M., & al. (2016). Dehydration of fruits and vegetables in the microwave field, 7 pp. , *Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series*, Vol. XLVI.

Jones, P.L. (1995). The Industrial Applications of RF and Microwave Heating - Microwave and high frequency heating - Short Course. *International Conference St. John's College*, Cambridge University, U.K.

Lojewski, G. (2005). Microwave Devices and Circuits. *Technical Publishing House*, Bucharest.

Miron, D., & al. (1986). Technological installations with microwave with applications in industry. *Symposium "Academy Days Iasi"*, Iaşi, Romania.

Niculae, D., & al. (1997). Microwave Heating Application, Microwave and High Frequency. *Heating International Conference*, Fermo, Italy.

Pandia, O., Saracin, I., & Bozga, I. (2016). Research regarding the usage of the capsaicin-corn flour-ethylic alcohol in the naturist treatments. *Scientific Papers-Series Management Economic Engineering In Agriculture And Rural Development* , 16, 243-247.

Pandia, O., Saracin, I., & Tanasie, S.E. (2015). Methods of reducing the profound hybernation of ceratonia siliqua seeds. *Scientific Papers-Series Management Economic Engineering In Agriculture And Rural Development* , 15, 209-212.

Ţenu I. (1999). Tehnologii, maşini şi instalaţii pentru industrializarea produselor vegetale. *Junimea Publishing House*, Iaşi, Romania.

Vasile, C. (2021). Monitoring thermotechnical parameters of the processing installations from a compound feed factory. *Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series*, 51(2), 584-593.