DOI: 10.5281/zenodo.2557337
CZU 664.854:634.25

PEACHES CONVECTIVE DRYING

Vitali Vişanu

Technical University of Moldova, Faculty of Mechanical Engineering and Transport,
9/8, Studentilor Str., MD-2045, Chisinau, Republic of Moldova
Visanu Vitali: *visanuvitali@pmai.utm.md,* (+373) 069675995

Received: July, 31, 2018
Accepted: October, 05, 2018

Abstract. This article deals with convective drying kinetics process of peaches that were collected in Republic of Moldova climatic area, namely SPRINGCREST, CARDINAL and REDHAVEN varieties. The kinetics study was performed for different temperatures: 50°C, 60°C, 70°C, 80°C, 90°C, for different drying agent velocities: 0.5 $m\cdot s^{-1}$, 1.0 $m\cdot s^{-1}$, 1.5 $m\cdot s^{-1}$, 2.0 $m\cdot s^{-1}$, 2.5 $m\cdot s^{-1}$, and for different thicknesses $2\cdot10^{-3}$m, $4\cdot10^{-3}$m, $6\cdot10^{-3}$m, $8\cdot10^{-3}$m, $10\cdot10^{-3}$m. For the determination of the optimal quality and conditions of drying parameters there was also performed an appearance analysis for each dried sample.

Keywords: *drying process, convective drying kinetics, drying agent temperature, velocity, humidity, drying duration, peaches.*

Introduction

Currently, globally, the peach is the third after the apple and the plum in terms of surface and production volume. [1] Republic of Moldova exports about 5-7 k tons of fresh peaches per year. [18]. Peaches are highly appreciated thanks to their excellent taste, which is determined, by a fine pulp and pleasant aroma. The high food value of peaches is due to a complex and equilibrated composition consisting of 87.5% water, 12.49% of total dry substances and (10.54 %) soluble dry substances. Sugar content is 8.4 $g\cdot100^{-1}$ g of product as well as a treatable acidity of 0.5% (pH=4).

The chemical composition is generally represented by proteins (0.9 g $\cdot100^{-1}$g of product), lipids (0.30 $g\cdot100^{-1}$ g of product), carbohydrate (9.90$g\cdot100^{-1}$ g of product); The minerals are represented by an increased content of K (190 $mg\cdot100^{-1}$ g of product), P (20 $mg\cdot100^{-1}$g of product), Mg (9 $mg\cdot100^{-1}$ g of product) and Ca (6 $mg\cdot100^{-1}$g of product). Peaches contain as well a variety of vitamins such as A (326 IU), C (6.6 $mg\cdot100^{-1}$g of product), K (2.60 $mg\cdot100^{-1}$g of product), E (0.70 $mg\cdot100^{-1}$g of product), B3 (0.8 $mg\cdot100^{-1}$g of product), B5 (0.20 $mg\cdot100^{-1}$g of product), B8 (6.10 $mg\cdot100^{-1}$g of product), Betaine (0.3 $mg\cdot100^{-1}$g of product). [2-7].

Being a seasonal product, there are important quantities of peaches that remain unvalued as those have both short harvest and storing period. One of the most efficient method to preserve their value is drying. This processing method has many conveniences like reduced storing spaces, increased preservation terms and furthermore the obtaining of a new product bringing health benefits. Containing a lot of vitamins, fresh and dry peaches are low in calories and reach in sugars; they are a good source of carbohydrates, phytonutrients, antioxidants, carotenoids – that are of great importance for the healthy of eyes, flavonoids that protect against cancer and heart diseases.

Besides those listed, there are other health benefits like stimulating immune system, normalizing the intestinal transit, stimulating gastric juice secretion, as well as helping in different diseases treatment like gastritis, anemia, high blood pressure, asthma and bronchitis, renal lithiasis, etc. [8-13]. In the research process, three varieties of peaches cultivated in the Republic of Moldova were used, with different characteristics, as follows:

SPRING CREST *tree*, originally from Fort-Valley, Georgia, USA, is vigorous, high cropping and abundant blossom. The *fruit* is medium sized (70÷100 g), regulate and round with glossy, strong red blush over a yellow background *peel*, as well as low pubescence. The *flesh* is semi-freestone, yellow, melting with a medium texture, good aroma and no red infiltrations around the stone. Its *maturity* comes 22-24 days earlier than Red haven (first decade of August). As *technological particularities*, one can mention its early, high productivity and good transportation resistance, but alas, it requires heavy thinning to attain a commercial size and because of its early blossom it could be affected by the late spring frosts. Since 2015, it was approved for the Republic of Moldova Central, South and Southeast fruit-growing zones.

CARDINAL *tree*, originally from Fort-Valley, Georgia, USA, is medium vigorous, having mixed branches and, abundant, relative early blossom.

The *fruit* is medium sized (80÷140 g), asymmetric with claret red blush over a yellow background *peel*, as well as low pubescence. The *flesh* is clingstone, orange-yellow, medium melting with a fine consistent texture, good aroma and great sweet and sour flavor. Its *maturity* comes in the third decade of July. As *technological particularities*, one can mention its high productivity, good resistance, and medium frosts and drought resistance; prefers fertile and irrigated soils. Since 1980, it was approved for the Republic of Moldova Central and Southeast fruit-growing zones.

REDHAVEN *tree*, originally from Agricultural Experiment Station, Michigan, USA, is medium to vigorous, very reliable cropping, mid-season bloom and becomes fertile in the 3rd year after planting.

The *fruit* is medium to very large (130÷170 g), round or rounded-ovate with red streaks and red blush over 90% of the surface over an orange-yellow background *peel*, along with a low pubescence.

The *flesh* is semi-freestone, orange-yellow, medium melting, good aroma and good sweet and sour flavor, with small red infiltrations around the stone. Its *maturity* comes in the first decade of August. As *technological particularities*, one can mention its high regular productivity, being considered as etalon and one of the best peaches varieties; prefers fertile and irrigated soils, medium drought resistance, and somewhat susceptible to bacterial spot. Since 1980, it was approved for the Republic of Moldova Central and Southeast fruit-growing zones. [1]

Materials and methods

To study the drying process, the following peach varieties served as raw material: Springcrest, Cardinal and Redhaven. Fresh peach fruit was characterized by firmness, dry substance content and initial humidity. Table 1.

Table 1

Fresh peach fruit characteristic

Peach varieties	Firmness (Kg· f/cm2)	Dry substances (%)	Humidity (%)
Springcrest	1,22	10,65	89,35
Cardinal	1,07	10,52	89,48
Redhaven	0,88	11,33	88,67

Drying installation (DRYER)

All experiments were performed applying the laboratory drying installation (figure 1) that permits convective drying process study. As drying agent, one can use air or other gases, like CO_2. Using the heater (4), the drying agent can reach a temperature spectrum of 20÷100°C, applying the temperature convertor (6) one maintains the needed temperature. In our case, we used five temperatures for the drying agent, specifically 50±0.5°C, 60±0.8°C, 70±1.0°C, 80±1.2°C and 90±1.5°C. To register drying agent's data, we used a group of temperature (DALLAS 8820 – error ± 0.1°C) and humidity sensors (DALLAS 8820 – error ± 0.5 %) (8), installed right before and after the connection between the agent recycling pipe and the drying chamber (1).

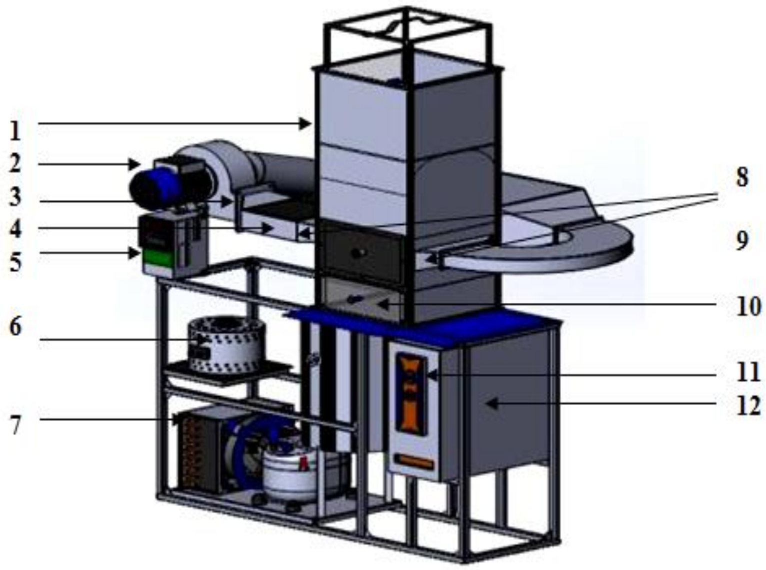


Figure 1. Experimental drying installation. *1 – drying chamber, 2 – electric motor, 3 – fan, 4 – electric resistors (heater), 5 – frequency converter, 6 – temperature controller, 7 – auxiliary device, 8 – temperature and humidity sensors, 9 – switches, 10 – electronic scale, 11 – control block SHF, 12 – electronic device for monitoring and recording of input and output data.*

The drying agent is being recycled with the help of a 0.16 kW ventilator (VORTICE SPA C15/2T) (3), which assures an up 3.0 m/s airflow velocity. In our case, we used five drying agent velocities, namely 0.5±0.05 $m \cdot s^{-1}$, 1.0±0.05 $m \cdot s^{-1}$, 1.5±0.06 $m \cdot s^{-1}$, 2.0±0.07 $m \cdot s^{-1}$and 2.5±0.08 $m \cdot s^{-1}$. Using frequency convertor (5), we can change ventilator (3) speed thus modifying and maintaining drying agent velocity. Agent drying velocity was measured applying an anemometer (AM50 – error ± 3.0%). Inside the working chamber, the peaches are arranged on a support installed on top of an electronic scale (G&G JJ2000 – error ±0.01 g) (10) this way permitting an online registering of drying process product mass dropping. For product surface temperature measurement during the drying process, one used an infrared thermometer (IR laser – error ±2.0°C or 2.0%). All listed sensors are connected to a

PC software IgiCOM & UTM Drier – V 2.0 thus granting us the possibility to create an online registration database of product drying mass dropping, drying agent temperature and humidity (figure 2). This way allowing us to monitor and control agent drying velocity and product surface temperature through the entire drying process.

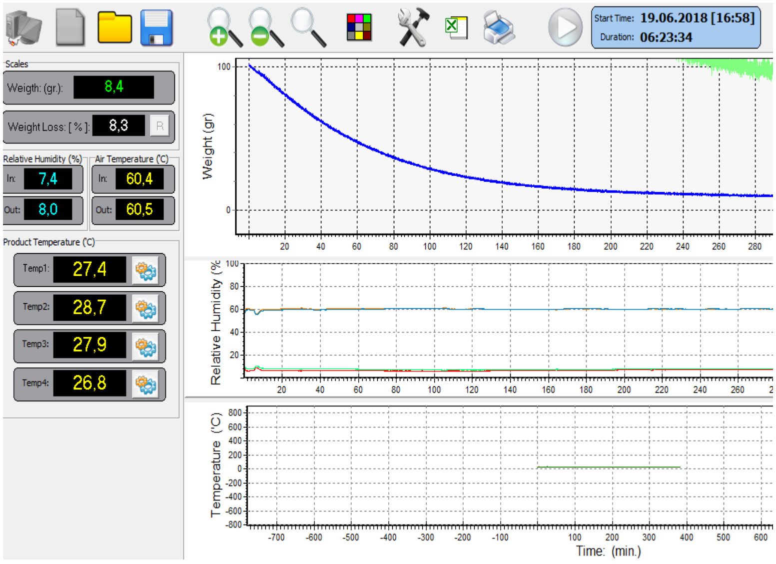


Figure 2. Data electronic processing. *1 – dial (indicates product's mass dropping curve), 2 – dial (indicates drying chamber input and output drying agent temperature) 3 – dial (indicates drying chamber input and output drying agent humidity).*

For the experimental drying process, there were selected 89.5±0.75% initial humidity ripe peaches. After being water washed and dried at room temperature, all the samples were tested for the technical requirements correspondence, including visual and tactile examination, and after confirming the fruits were sliced in well defined (3÷4 mm) rings. A 100±0.5 g portion of slices was arranged on the drying tray.

To study the kinetics of the drying process of peaches, the *"convection drying"* method was used, as it is a known and applicable method in research. [14, 15, 16]

There are multiple, technological process (*velocity, humidity, drying agent temperature*, etc.) and drying product, the peach, properties (*thermal conductivity, porosity, density, geometrical parameters,* etc.) parameters that affect the process of drying kinetics. [17, 22]

To study the kinetic curves of the drying process: the following thermal agent temperatures were used: 50°C, 60°C, 70°C, 80°C, and 90°C for all three varieties of peaches; different thicknesses of the product layer ($2\cdot10^{-3}$m, $4\cdot10^{-3}$m, $6\cdot10^{-3}$m, $8\cdot10^{-3}$m, $10\cdot10^{-3}$m) and different working agent speeds (0.5 $m\cdot s^{-1}$, 1.0 $m\cdot s^{-1}$, 1.5 $m\cdot s^{-1}$, 2.0 $m\cdot s^{-1}$, 2.5 $m\cdot s^{-1}$). To achieve high-precision experimental results, each experience was performed three times, maintaining the same technical conditions (temperature, humidity and speed of the working agent, temperature, pressure, and environmental humidity).

The processing of experimental data and the development of the electronic curves of kinetics of the drying curves was based on the IgiCOM & UTM Drier - V 2.0 PC software.

Results and discussions

Processed by convective method and different thermal agent temperatures, peaches drying curves shows a standard form, displaying stable moisture per time diminution (figure 3). [15, 21] From initial 89.5% to final 18.0% humidity drop duration depends on the drying agent temperature. Thus for the same 2.0 m· s^{-1} drying agent velocity and initial 89.46% humidity, but different temperatures, the drying period will be: for 50°C a 270 min length, 60°C a 225 min length, 70°C a 185 min length, 80°C a 160 min length and for 90°C a 110 min length.

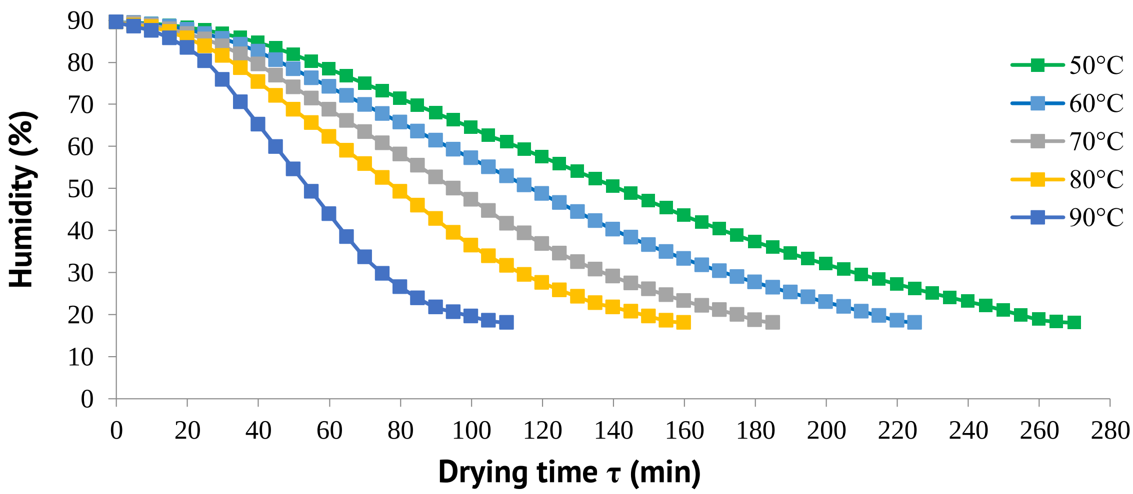


Figure 3. SPRINGCREST peaches different thermal agent temperatures drying curves *(Thermal agent velocity 2.0 m· s^{-1}, thermal agent relative humidity 60.0%, slices thickness 3·10^{-3}m).*

Figure 4 shows peaches different thermal agent temperatures drying velocity curves. Their form also corresponds to the classical one, described in references. [19, 20, 21]

There are presented as well the three drying periods, namely 1 – of product heating, 2 – of constant drying velocity and 3 – of decreasing drying velocity.

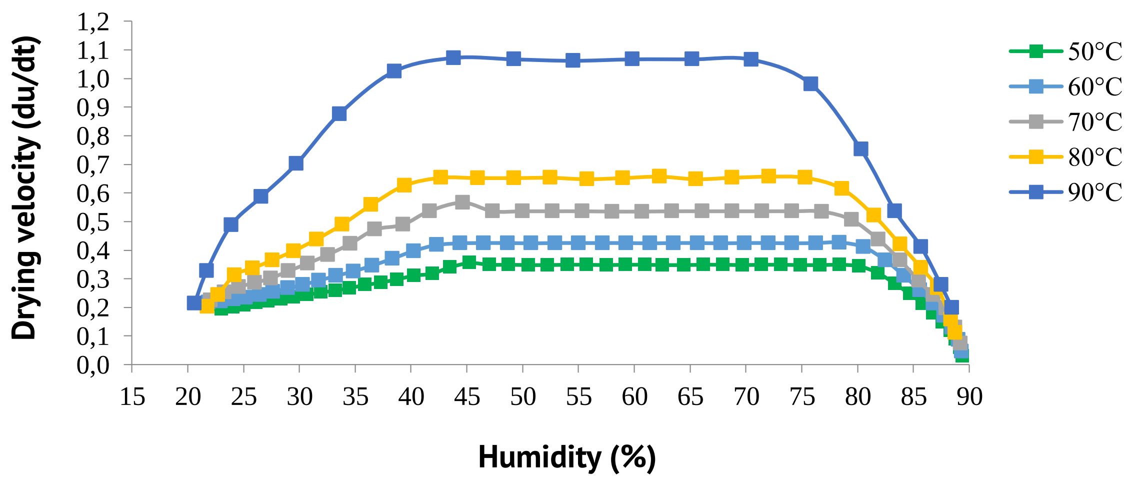


Figure 4. SPRINGCREST peaches different thermal agent temperatures drying velocity curves *(Thermal agent velocity 2.0 m· s^{-1}, thermal agent relative humidity 60.0%, slices thickness 3·10^{-3}m)*

Graphics show that as thermal agent temperature increases from 50°C to 90°C the drying speed increases as well. Moreover, for the drying agent speed of 2.0 m/s and its relative air humidity of 60%, the drying rate increases from 0.35 m· s^{-1} to 1.05 m· s^{-1} according to a polynomial law Eq. (1):

$$\frac{du}{d\tau} = 0{,}0005 \cdot t^2 - 0{,}048 \cdot t + 0{,}976, \quad R^2 = 0{,}976 \tag{1}$$

At the same time, there has been observed some correlation between the duration of the constant drying rate and the temperature of the thermal agent. Thus, with the temperature increase of the agent, in the range of 50÷90°C, the duration of the second period – of the constant drying rate decreased from 155 min. to 70 min., which in turn reduces the duration of the drying process.

The mass transfer in the product is largely influenced by the humidity and temperature gradients, as well as by the thickness of the product layer that the humidity needs to pass. [22] This way, the kinetics of the peach drying process was as well studied at different thickness of the slices, namely 2·10^{-3}m, 4·10^{-3}m, 6·10^{-3}m, 8·10^{-3}m, and 10·10^{-3}m. (according to figures 5 to 7).

At convective drying of SPRINGCREST peaches at thermal agent's 2.0 m·s^{-1} speed, 60°C and relative humidity of 65%, the drying curves for different thickness of the slices bear the same character (Figure 5), different being only their inclination angle.

Moreover, the correlation between slices thickness variation and drying curves inclination angle is inversely proportional, which determines that the reduction of slices thickness accelerates the drying process, as confirmed by the drying velocity curves (Figure 6) showing an increase in drying rate while reducing the slices thickness. Thus, at 10·10^{-3}m slices thickness, a drying rate of 0.21 ± 0,024 %/min was recorded, while at 2·10^{-3}m thickness of – 0.47 ± 0.063 %·min^{-1}.

The decrease of the drying velocity with the increase of the peach slices thickness within 2÷10·10^{-3}m takes place according to Eq. (2):

$$\frac{du}{d\tau} = 214{,}3 \cdot 10^3 \cdot t^2 - 72{,}86 \cdot t + 0{,}496, \quad R^2 = 0{,}998 \tag{2}$$

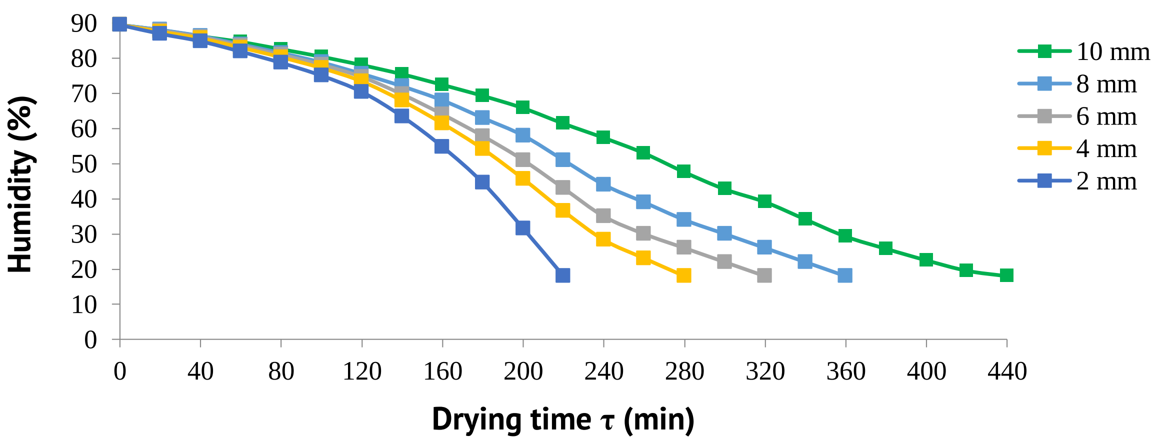


Figure 5. SPRINGCREST peaches different slices thickness drying curves *(Thermal agent velocity 2.0 m· s^{-1}, thermal agent relative humidity 65.0%, thermal agent temperature 60°C)*.

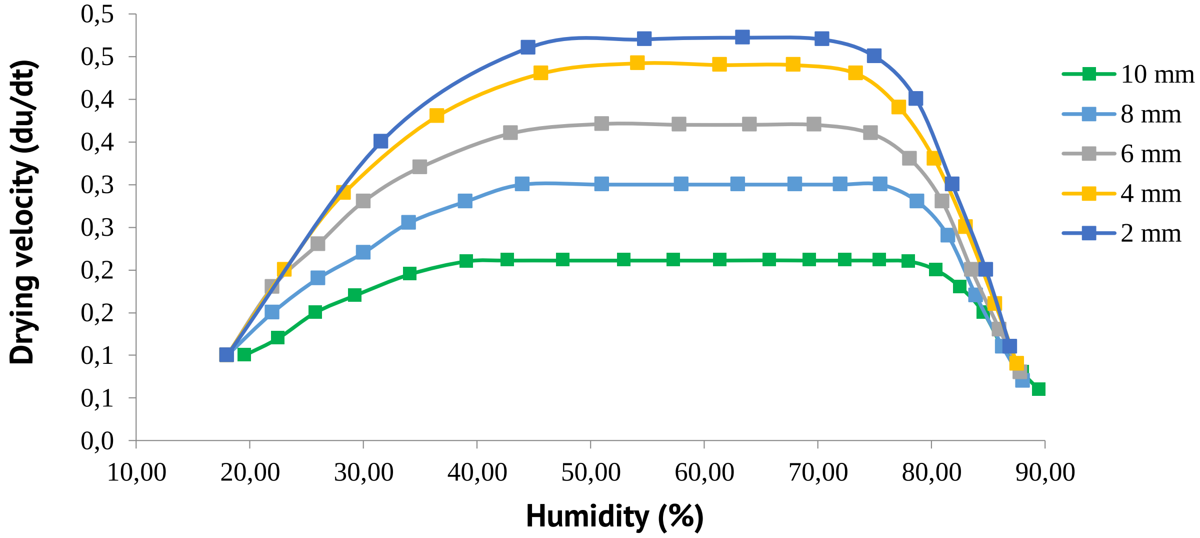


Figure 6. SPRINGCREST peaches different slices thickness drying velocity curves *(Thermal agent velocity 2.0 m· s^{-1}, thermal agent relative humidity 65.0%, thermal agent temperature 60°C).*

As mentioned earlier, the decrease in the peach slices thickness reduces the drying time, as shown in Figure 7. Using convective drying in a flow of 2.0 m/s, 60°C and 60% initial humidity air, one can observe, that 2·10^{-3}m thick peaches slices, have a minimum drying time of 220 min., 4·10^{-3}m thick has a drying time of 280 min., for a thickness of 6·10^{-3}m the duration is 320 min., for 8·10^{-3}m a 360 min. and for a thickness of 10·10^{-3}m the drying time is 440 min. The correlation between the drying time and the thickness of the product layer, of slices, within 2÷10·10^{-3}m bears a linear character Eq. (3):

$$\tau(\delta) = 0{,}0378 \cdot \delta - 6{,}224, \quad R^2 = 0{,}983 \tag{3}$$

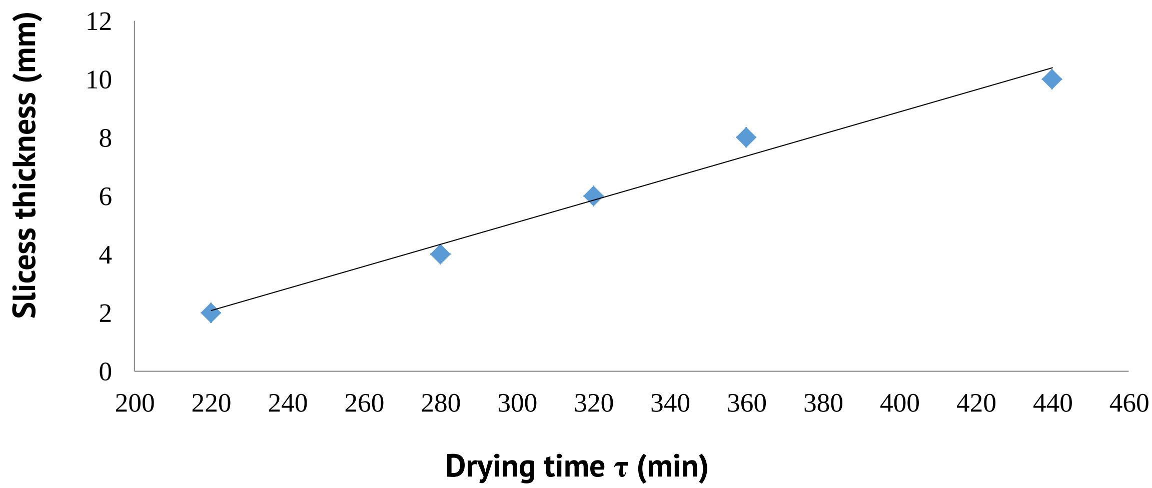


Figure 7. Correlation between SPRINGCREST peaches slices thickness and drying time *(Thermal agent velocity 2.0 m· s^{-1} thermal agent relative humidity 60.0%, thermal agent temperature 60°C).*

Wet products drying process, particularly peaches, among others are greatly influenced by the speed of the thermal agent. Figure 8 shows the drying curves and in Figure 9 curves of the drying speed of peaches cut in $3 \cdot 10^{-3}$m thickness rounds using thermal agent temperature of 60°C for different speeds. Both the drying curves and the drying speeds curves indicate an intensification of the process as the thermal agent speed increases [15, 17].

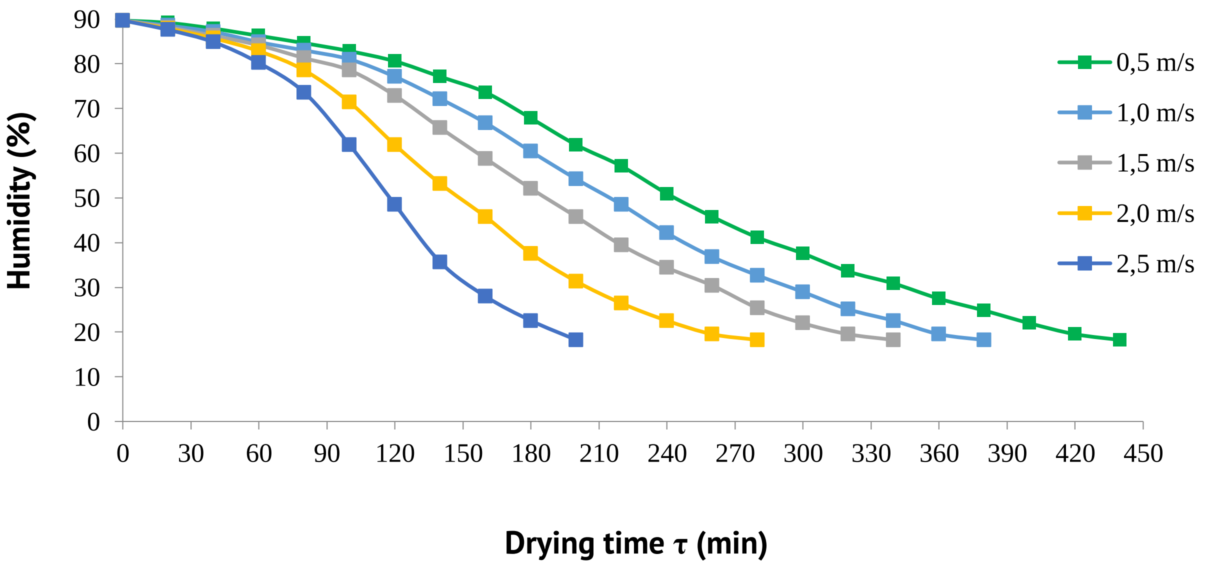


Figure 8. Peaches different thermal agent velocities drying curves *(Thermal agent relative humidity 65.0%, thermal agent temperature 60°C, slices thickness $3 \cdot 10^{-3}$m).*

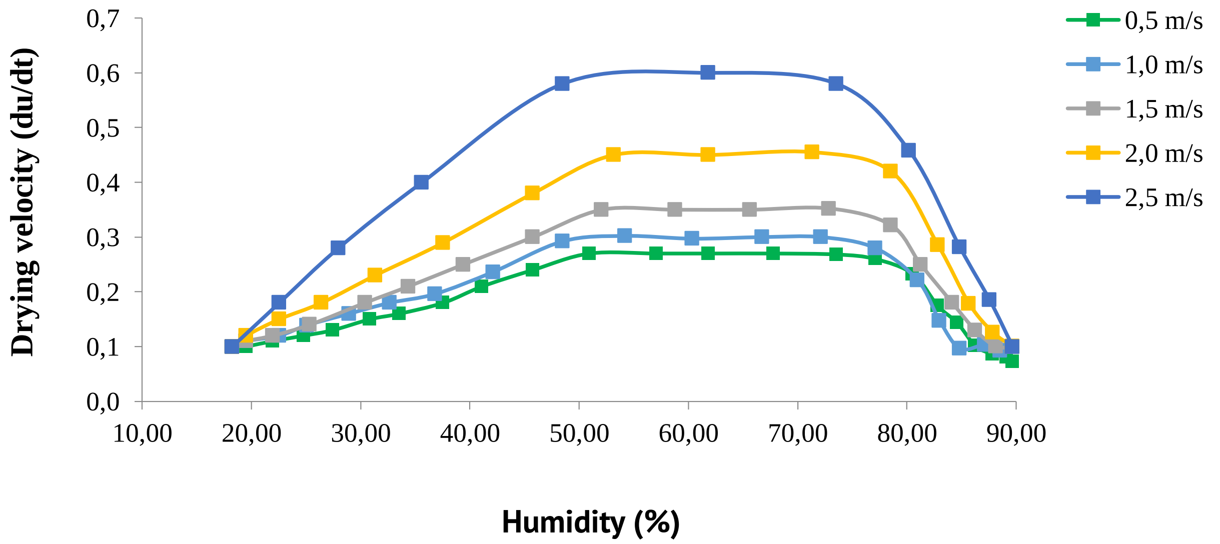


Figure 9. Peaches different thermal agent velocities drying velocity curves *(Thermal agent relative humidity 65.0%, thermal agent temperature 60°C, slices thickness $3 \cdot 10^{-3}$m).*

The following results were obtained from the analysis of Figure 8 and Figure 9: at the speed of 0.5 $m \cdot s^{-1}$, a drying time of 440 min was obtained, at 1.0 $m \cdot s^{-1}$ – 380 min., at speed of 1.5 $m \cdot s^{-1}$– 340 min., at of 2.0 $m \cdot s^{-1}$– 280 min., and for 2.5 $m \cdot s^{-1}$ for 200 min.

According to Figure 10, the dependence of the drying time of the thermal agent speed ($t = f(v)$) in the range of 0.5÷2.5 m· s⁻¹ is linear Eq. (4)

$$\tau(v) = -0{,}0085 \cdot v + 4{,}291, \quad R^2 = 0{,}987 \tag{4}$$

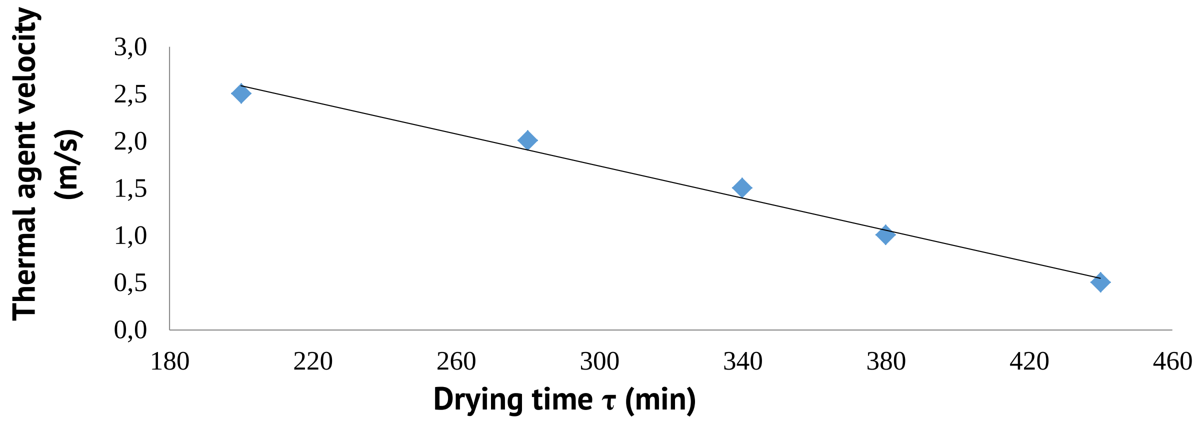


Figure 10. Correlation between peaches drying time and thermal agent velocity *(Thermal agent relative humidity 65.0%, thermal agent temperature 60°C, slices thickness 3·10⁻3m).*

During the kinetics research of the peach drying process, such varieties as SPRINGCREST, CARDINAL and REDHAVEN were studied. Both drying and drying velocity curves have the same character, indicating that small differences in physical, mechanical and thermal properties of different varieties have little influence on the transfer phenomena in the drying process. The drying times of different varieties differ in average by ±10÷15 min., which is 8÷6% (Figure 11).

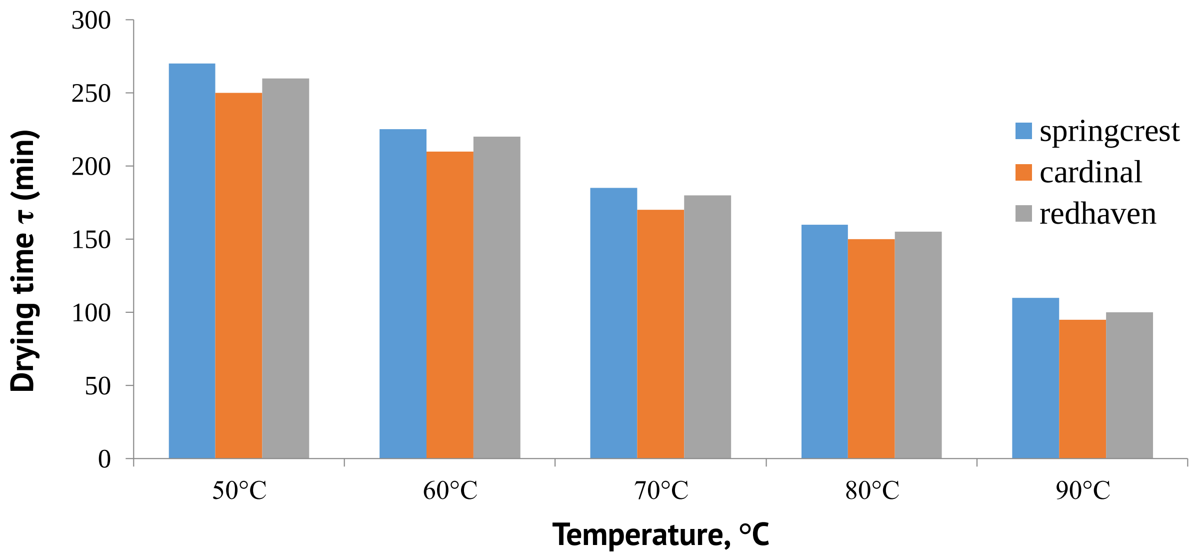
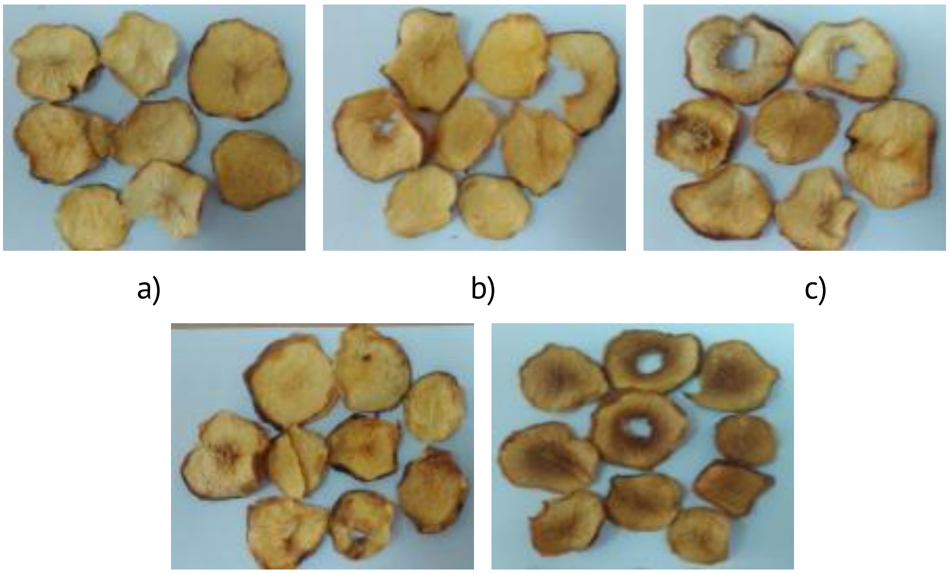


Figure 11. Correlation between peaches variety and drying time *(τ = f (variety)).*

As a result of drying process kinetics study, dry product samples were obtained for different temperatures and speeds of the thermal agent, and different thickness of the rounds. Of particular interest is the external appearance of dried peaches at different temperatures, since drying, as a thermal process, may be accompanied by various unwanted effects such as sugar caramelization, browning polyphenols, etc. Figure 12 shows SPRINGCREST dry peach samples with a thickness of $3.0 \cdot 10^{-3}$ m, the drying being carried out by convection at different thermal agent temperatures at a speed of $2.0\ m \cdot s^{-1}$ and a relative humidity of 60%.



a) b) c)

d) e)

Figure 12. SPRINGCREST peaches aspect dried using: thermal agent 2.0 m/s velocity and 60.0% relative humidity: *a) 50°C; b) 60°C; c) 70°C; d) 80°C; e) 90°C temperature*.

The pictures show that dried peaches at temperatures between 50°C and 60°C are more attractive than those dried at temperatures of 70°C, 80°C and 90°C, indicating that at the given temperatures the undesirable caramelization phenomena and peach browning do not take place yet.

Conclusion

The study of peaches convective drying kinetics at the temperature of the thermal agent in the range of 50÷90°C, speed of $0.5 \div 2.5\ m \cdot s^{-1}$ revealed that the increase both thermal agent temperature, speed and decreasing the thickness of the rolls from 10 to $1 \cdot 10^{-3}$m, leads to an intensification of the process. However, temperatures above 60°C cause an acceleration of the undesirable sugar caramelization and browning phenomena, Figure 12. Therefore, for the convective drying of peaches, the temperature of 60°C with the speed of the heating agent $2.0\ m \cdot s^{-1}$ and the thickness of the rolls $3\ 10^{-3}$m are recommended for getting an optimal drying process. The character of the drying curves is classical and does not differ from that of the fruits and vegetables described in the specialized literature [14-16, 19-22].

Bibliography

Books:

1. Popa S., Braghiş A., Manziuc V., Cumpanici A. *Manual tehnologic Producerea piersicilor*. Chişinău 2016. pag. 5, 7, 10 - 13, 173;
2. Tatarov P. *Chimia produselor alimentare*. Chişinău 2017. pag. 5-12, 48-50, 64-66, 200-215, 313-316;

Web references:

- Nutrition information of fresh peaches:

3. https://skipthepie.org/fruits-and-fruit-juices/peaches-raw/;

4. https://dieta.romedic.ro/aliment/piersici;
5. http://cesamancam.ro/valori_nutritive_fructe.html;
6. https://www.nutrition-and-you.com/peaches.html;
7. https://draxe.com/peach-nutrition/;
- Health benefits of peaches:
8. https://www.nutrition-and-you.com/peaches.html;
9. https://www.medicalnewstoday.com/articles/274620.php;
10. https://draxe.com/peach-nutrition/;
11. https://www.stylecraze.com/articles/benefits-of-peaches/#gref;
- Health benefits of dried peaches:
12. http://montagudriedfruitnuts.co.za/7-health-benefits-of-cling-peaches/
13. https://nuts.com/driedfruit/peaches/jumbo.html
- Studies of peaches drying process
14. https://www.researchgate.net/publication/275650176_Different_Drying_Methods_Their_Applications_and_Recent_Advances
15. https://www.researchgate.net/publication/292947307_Drying_studies_on_peach_and_strawberry_slices
16. https://www.researchgate.net/publication/275650090_COMPARATIVE_STUDY_OF_EFFECT_OF_DIFFERENT_DRYING_METHODS_ON_NUTRITIONAL_QUALITY_OF_PEACH_CULTIVARS_DURING_STORAGE

Symposia volumes:

17. Țislinscaia N., Bernic M., Malezhyk I., Buleandra A. *Mathematical model of drying process velocity factor*. / Proceedings of the International Conference "Modern Technologies in the Food Industry-2016", Chișinău" Bonus Offices", 2016. p. 99-104.;

Journal published papers:

18. Agricultura Republicii Moldovei. Departament statistică şi sociologie al Republicii Moldova - Statistica Moldovei, 2003.;
19. Golisz1 E, Jaros M, Kalicka M. *Analysis of convectional drying process of peach*. Faculty of production engineering, Warsaw University of life sciences. Received 21 July 2013; accepted 27 October 2013; available on line 15 November 2013.;
20. Naseer A., Jagmohan S., Rajkumari K., Parshant B., Anisa M., Harleen K., Harmeet C., Prerna G., *Comparative study of effect of different drying methods on nutritional quality of peach cultivars during storage*. Special issue, vol. vi: 01-06: 2014 an International quarterly journal of environmental sciences, ISSN: 0974 – 0376;
21. Bernic M., Răducan M., Ciobanu E. *Drying Kinetics of Sunflower Seeds using Pulsed UHF Energy Intake*. TEM Journal, 2(4), November 2013, pp. 305-308.;
22. Bernic M. *Aspecte teoretice ale fenomenelor de transfer în procesele de uscare*. // Meridian Ingineresc. – Chişinău: UTM, 2008. – Nr. 2. – p. 32 – 35.