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THEORETICAL AND PRACTICAL ELABORATION ON THE COMBINED METHOD OF DEHYDRATION OF PEACH FRUITS

253.05 PROCESSES AND APPARATUS IN THE FOOD INDUSTRY

Doctor of Engineering Science Dissertation Summary

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CUPRINS

Conceptual milestones of the research

The dynamic development of the food industry is carried out by profound changes in technologies and techniques. Currently, technical progress in the food industry is based on scientific investigations. From a theoretical and applied point of view, ensuring the stability of food quality from fruits through the dehydration process presents a problem of major importance. Dehydration of fruits is a technological process by which an amount of water is removed up to aw < 0.6, thus leading to the destruction of microorganisms, the inactivation of enzymes and the reduction of the rates of chemical reactions in the final product, (Rockland et al., 2020; Tatarov 2017). The classic, traditional dehydration technique and technology has various disadvantages: that is why a series of theoretical and experimental researches were carried out in order to obtain new knowledge about processes that allow obtaining quality dehydrated fruits. One of the perspective directions in ensuring the stability of fruits presents the method of preserving them by dehydration in a high-frequency electro-magnetic field. In order to modernize the technological and technical systems for drying fruits and vegetables, scientific research was carried out by several scientists from different countries, including the Republic of Moldova, scientists such as: Carajia V., Lupașco A., Bernic M., Carabulea B., Țislinscaia N., Ghendov-Moșanu A., and others, who brought a significant impact in solving problems related to food dehydration. Currently, the valorization and optimization of the assortment of dehydrated fruits is a permanent concern of specialists in agriculture and the food industry. Peach plantations occupy the third place in terms of area and volume of production in the Republic of Moldova. In recent years, predominantly in the southern area, enormous amounts of peaches have not been picked, they have been altered, due to the fact that they are perishable fruits. Currently in the Republic of Moldova as well as abroad, dried peaches would present a strategic new product on the dried fruit market. A strategic product because it would be competitive and would not have competition with other dried fruits.

The actuality of the theme: it consists in the priority direction of renewal and application in the food industry of modern technologies and equipment, processes and systems for manufacturing quality food products with low energy content.

Research hypothesis: *Reducing energy consumption and improving product quality in the process of removing free water and physico-chemically bound water from fruits during the drying process can be achieved by the combined method, which includes forced convection and electromagnetic field microwave treatment.*

The purpose of the research: Theoretical and practical elaborations of the process of obtaining quality dehydrated fruits by applying the combined drying method: dehydration of fruits by forced convection in combination with the treatment of fruits with microwaves oriented perpendicular to the drying object and the determination of physico-chemical and sensory changes of dried peaches obtained by the combined method.

The objectives of the work: designing and elaborating the research installation; description of the construction and verification of the operation of the installation; assessment of the influence of the physical characteristics of the air on the dynamics of changes in the humidity of peaches during the drying process; analysis of the kinetics of the peach dehydration process; determination of energy consumption in the process of drying peaches; determining the physical, physico-chemical and sensory changes of peaches in the drying process; mathematical modeling of the peach drying process according to quality parameters of the finished product.

The research methodology includes theoretical investigations of mass and heat transfer in the peach dehydration process; physical, chemical and physico-chemical experimental methods of the drying process by the combined method, physico-chemical and sensory methods for assessing the quality of dried peaches.

Scientific novelty and originality. It consists in the theoretical argumentation and practical achievements of the effectiveness of the combined method of drying peach fruits with the application of forced convection and microwave treatment, estimated on the basis of elaborated mathematical models, which reflect the rational consumption of energy, while protecting the quality of dried fruits from caramelization and oxidation.

The scientific problem solved: it was demonstrated that in the process of dehydrating cut fruit in the form of a plate with limited resignations, the speed of moisture diffusion from the center to the surface of the samples depends on the temperature and the size of the cut fruit, following the action of microwaves with a frequency of 2450 MHz, in the regime of pulses with a duration of 7 - 10 seconds and a pause interval of $\Delta\tau$ = 23 - 20 seconds.

The applicative value of the work. There have been submitted 2 patent applications regarding the process of dehydrating peaches by the forced convection method, no. 2424 of 10.04.2023 and with the application of microwaves no. 2423 of 10.04.2023.

Implementation of scientific results: The laboratory installation for drying fruits and vegetables was designed and developed, patent MD.1295 Z 2019.07.31. The results obtained were also implemented for the modernization of a drying facility in Edineț district.

Approval of the work at scientific forums. The results obtained during the realization of the work were presented and discussed at conferences, symposiums and invention salons: Euroaliment, Inventcor, Euroinvent, Inventica, Proinvent, Ugalinvent, Infoinvent, etc.

Summary of thesis chapters: The work is presented on 116 basic text pages and includes the following chapters: annotation in Romanian, Russian and English, introduction, 4 chapters, conclusions and bibliography with 207 titles, the work is illustrated with 83 figures and 15 tables.

In the introduction, the method as a research object, the actuality and importance of the theme, the purpose and objectives, the scientific hypotheses, the research methodology, the theoretical importance and scientific innovation, the applied value of the obtained results and the summary of the thesis chapters are revealed.

Chapter 1. Modern theoretical aspects of the peach drying process, mass and heat transfer theory, microwave treatment, physico-chemical changes in the drying process, improvements in the drying technique and technology, peach research as an object of study.

Chapter 2. Materials and research methods, the raw material, reagents and laboratory materials, the experimental stand, the method of measuring the mass drop and temperature, environmental parameters are described, the method of drying peaches by convection, with the application of microwaves and combined is described, the methods of determining the quality indices of peaches are described, the simulation of the flow of the fluid through the drying chamber was elaborated.

Chapter 3. Researching the kinetics of the peach dehydration process, fluid flow simulations are developed, the spread of the temperature field when applying microwaves is determined, the kinetics of the peach drying process by convection, microwaves and combined is described; energy consumption was determined, mathematical models were developed.

Chapter 4. The influence of drying processes on the quality of peach fruits, the organoleptic analysis of dried peach samples was carried out by different energy inputs, the mathematical modeling according to the quality parameters of the finished product, the sugar content was determined using the convection method, the polyphenol content and the antioxidant activity of dried peaches were determined for different thermal regimes.

Keywords: Convection, SHF, combined method, kinetics, mathematical model, polyphenols, quality.

The content of the thesis

1. Theoretical aspects of the peach fruits dehydration process

In the given chapter, the basic principles of the theory of mass and heat transfer in the drying process of products with a capillary-porous structure were analyzed. In this context, a study was carried out for the porous capillary bodies to which peaches also refer, a strategic fruit for the Republic of Moldova due to the favorable growing conditions in this area. A particular interest for this type of products is the diffusion of moisture through these capillaries which was studied based on the research carried out by the Russian engineer Luikov, (Luikov 1975). On the world level, an important contribution in the description of the transfer phenomena were engineers Bird, Stewart, and Lightfoot, (Bird et al., 1960). The transfer mechanism in the drying process of porous products is investigated by multiple scholars using different methods and simulations in a wide spectrum of applications (Kumar et al., 2012; Bonnet et al., 2019; Tartakovsky et al., 2019; Rosti et al., 2020).

The development of a mathematical model capable of predicting the transfer behavior through porous structures is due to the French engineer Henry Darcy who proposed a direct relationship between the flow rate and the pressure difference. In recent years, more complex theories have been developed to describe the process of simultaneous heat and mass transfer at the microscopic scale, based on diffusion theory (Tartakovsky et al., 2019), capillary flow theory (Ismail, N. et al., 2019) and evaporative condensation theory (Bonnet et al., 2019). The Whitaker model has become a popular approach for the theoretical modeling of drying of porous products, especially for food products that represent a porous hydroscopic medium (Plumb et al., 1985; Nasrallah et al., 1988; Constant et al., 1996; Di Blasi, 1998; Quintard et al., 2000). The Whitaker model was supplemented with the notions of porosity and equivalent water saturation for various particular cases such as the frying and cooling process of tortilla chips, (Yamsaengsung et al., 2002), for frying potato chips; (Feng et al., 2001), drying apples; (Ni et al., 1999), microwave drying (Dincov et al., 2004; Datta, et al., 2002, 2007), for bread baking (Datta, 2001; Zhang, et al., 2005, 2006). An important concretization was made by Halder Amit, Ashim Datta, Roger M. Spanswick (Halder et al., 2011), during drying water moves simultaneously in two ways: extracellular (via pores and capillaries) and intercellular (via cell membranes). The transfer phenomenon at the cell level can be characterized by several internal mechanisms: the transport of water through cell walls and membranes in the intercellular space – diffusion between the membranes of the intercellular space and the local release of water through the membranes due to the pressure difference; free water transport from cell to cell – diffusion within the cell matrix and release of water between cells from local pores in the cell structure (Whitaker et al., 1969; Marinos-Kouris et al., 2006; Silva, et al., 2012; Onwude et al., 2016).

Some modern aspects of microwave treatment have been studied, the need to use them, the polarization phenomenon has been described, determining the necessary power of microwaves in the process of drying wet vegetable products is at the moment a current problem (Feng et al., 2002; Tang et al., 2002; Tang, 2005; Sipahioglu et al.

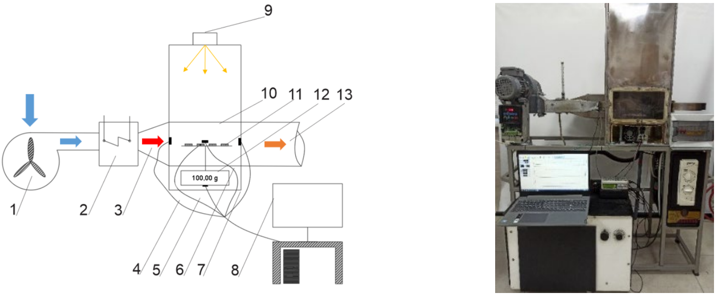
Physico-chemical changes that occur during the dehydration of fruits were analyzed, such as the browning effect, types, causes of appearance, intensification factors, etc., (Garcia et al., 2002; Gonzalez-Aguilar et al., 2005; Tatarov, 2017).

The technique and modern technology intended for the dehydration of fruits in particular were researched, the emphasis was placed on the combined drying methods, after the analysis some directions of perspective were identified, the hybrid methods, Eco-Friendly, etc., (Wang, et al., 2006; Germer et al., 2010; Golisz et al., 2013; Ahmed, 2014; Moses et al., 2014; Maican, 2015, Gîdei et al., 2016; Johnson et al., 2016; Movagharnejad et al., 2017; Schraud et al., 2021).

Peaches served as raw material for dehydration because they are the third fruit tree species, as a cultivation perspective, depending on the area and production volume after apple and plum. Peaches are appreciated for fresh consumption, being also used in processed form in compotes, nectar, jam, etc. (Rajarathnam, 2011; Davim et al., 2015), The high nutritional value of peaches is due to the complex and balanced composition of water (87 - 90%), total dry substances (10 - 12.5%), sugar content (8.4g / 100g of product), titratable acidity (0 .5%) and the pH (4). (Emadi et al., 2011; Pérez-López et al., 2014; Espinoza et al., 2015).

2. Research materials and methods

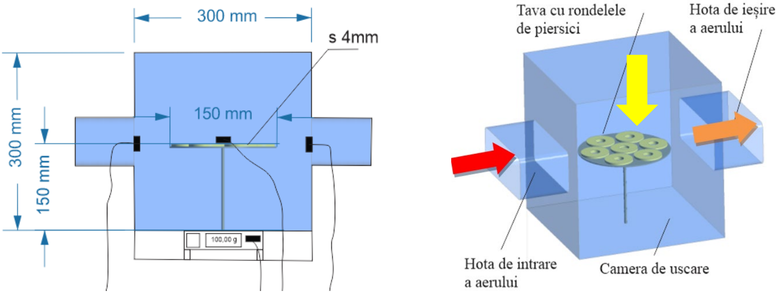
In the research, the Springcrest, Cardinal, Redhaven varieties of peaches, harvested from the Republic of Moldova between 2015 and 2022, with an initial moisture content of around 88-90%, weight around 90-110g, firmness around 0.8-1.2 Kgf/cm2 and pH around 3.5 (Popa, et al, 2016) were used, reagents and laboratory materials were chose in the research, conforms to the ISO standard. The peach dehydration process research took place at the facility designed, developed and patented at UTM, patent MD 1295 Z 2019.07.31, figure 2.1.



a) b)

Fig. 2.1. Research installation, a) functional model, b) actual view

To measure the technological parameters during the drying process (temperature, humidity, air speed) the research stand was equipped with sensors, (DALLAS 8820 – error ±0.1OC) and (DALLAS 8820 – error ±0.5%), figure 2.2.



a) b)

Fig. 2.2. Drying chamber, a) dimensions, b) working principle

The sensors and the scale were connected to an electronic device, through it and the IgiCOM software, all indicated parameters can be monitored and recorded on the computer, figure 2.3.

a) b) c)

Fig. 2.3. a) Temperature sensors, b) humidity sensor, c) Software, IgiCOM &UTM Dryer –V.2.0

For dehydration, the peaches were washed under a stream of water at room temperature, wiped with a dry napkin and examined visually and tactilely for traces of mold, foreign bodies, traces of injuries, after which they were cut in half to remove the pit, then they are cut into rounds of well-determined thickness, 2 - 4 mm. A portion of the rounds is selected and weighed so that the weight reaches 100 ± 0.1 g and arranged on the support in the drying chamber, after which drying begins.

Convection drying – the centrifugal fan and the electric dryer are used, as the heating agent the air from the room with the initial temperature 20-25°C, relative humidity 55-60%, normal atmospheric pressure is used, for research the dehydration took place at different temperatures 50 – 90° ± 0.5°C, at different air velocities from 0.5 – 2.5 ± 0.1m/s, and at different thicknesses of the product 2 , 4, 6, 8, and 10 mm., in the drying chamber with dimensions 300 x 300 ± 0.5 mm. (Zhu et al., 2014; Vișanu, 2018; Karaaslan et al., 2021).

Microwave drying – the centrifugal fan and the microwave with the magnetron with the total power of 600 W are used for research, different regimes of 120 – 490 W have been established; for the 900 W – 180 – 360 W magnetron. The heating agent is room air with a temperature of 20 - 25°C, relative humidity 55 - 60%, normal atmospheric pressure, 760 mmHg and a speed of 2.0 ± 0.1 m/s, washer thickness 4 mm, the drying chamber has the overall dimensions 300 x 300 ± 0.5 mm (Wang , et al., 2006b; Roknul et al., 2019; Vișanu, 2022).

Combined drying – round slide peaces thickness 4 mm and air speed 2 ± 0.1 m/s were established; ambient air temperature of 20-25°C, relative humidity of the ambient air around 55-60%. For convection, the drying temperature of 60 ± 0.5°C was chosen, and it was combined with the microwave treatment method, with the optimal drying regimes, 180, 225, 270 W, after which the combination of the 225 W regimes and the convection temperature of 50, 60 and 70 ± 0.5°C were investigated, as optimal drying regimes and parameters, (Mas kan, 2001b; Ismail, et al., 2017; Țislinscaia et al., 2021).

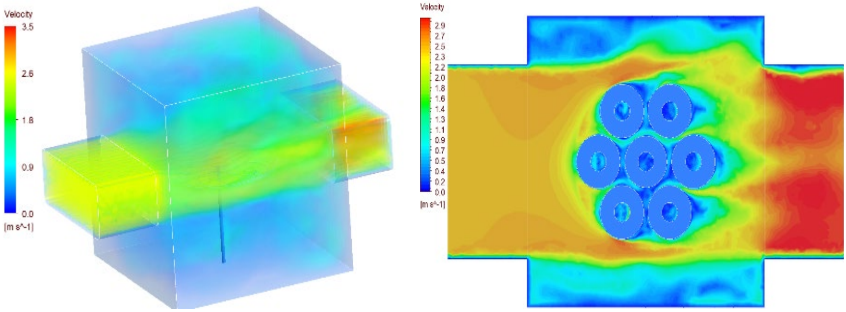
After the dehydration process, the content of dry substances was determined using the Atago refractometer, PAL-1; firmness - the penetrometer

FT-327; moisture content – gravimetric method; titratable acidity, pH – pH meter TESTO 205; for the determination of titratable acidity, the SM SR ISO 750:2014 protocol was used, fruit and vegetable products; the organoleptic analysis was performed - according to (HG1523/2007 f.a.), (Coșciug et al., 2007), indicators such as shape, surface, color, smell and taste were evaluated; the content of polyphenols was determined - using the photometric method Folin

Ciocalteu Reagent; the antioxidant activity was determined - by the free radical colorimetry method. Simulations of the flow of the fluid through the working chamber during the drying process were developed - the Ansys software was used. All the experiments carried out in the research were at least triplicated, the statistical limit was chosen: $P \leq 0{,}05$.

3. Researching the kinetics of the peach dehydration process

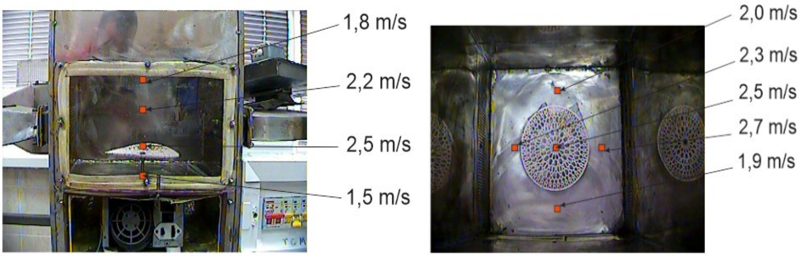
In order to determine the optimal location position of the tray with the product, the simulation of the flow of the air flow with the speed of 2 m/s was elaborated, it was observed that the areas where the value of the flow is reduced increased, the speed losses due to the opposite resistances, etc. were identified, figure 3.1, 3.2. and comparing the actual results figure 3.3. and 3.4.



a) b)

Fig. 3.1. Fluid velocity distribution, a) in volume, b) section

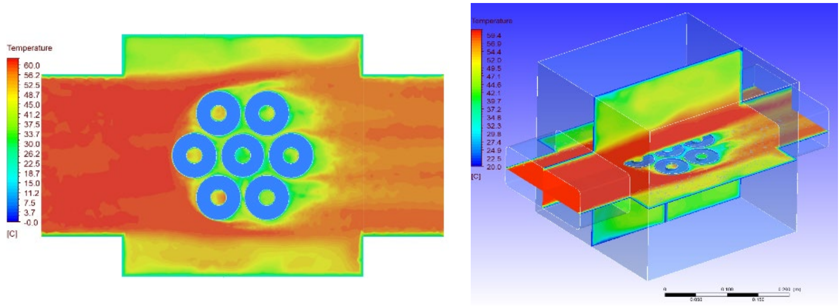
In order to compare the veracity of the results obtained from the simulations, the air speed was measured with the TESTO wire anemometer at different points in the drying chamber according to which the similarity of the results can be confirmed in 95%, figure 3.2.



a) b)

Fig. 3.2. Fluid velocity distribution, a) in volume, b) section

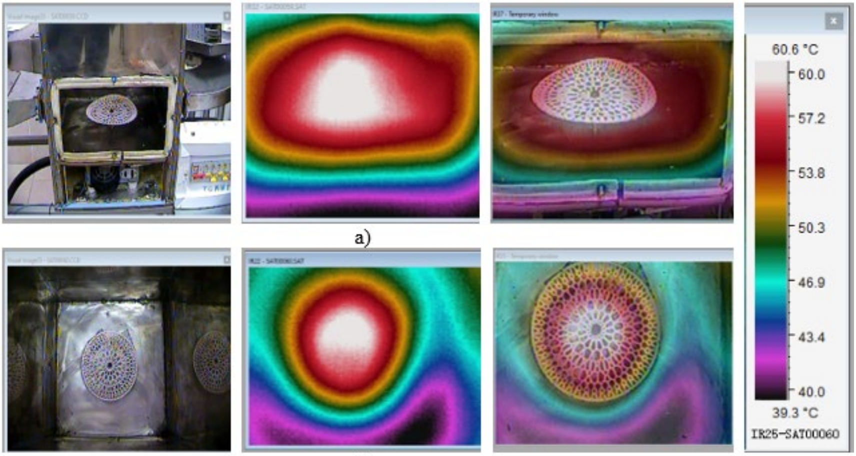
The flow of the fluid with the speed of 2 m/s and with the initial temperature of 60°C was also analyzed and simulated, where the spread of the temperature field can be observed, figure 3.3.



a) b)

Fig. 3.3. The temperature field, a) in the x-y plane; b) section x–y– z

Following the simulation, this spread was investigated at the experimental installation in real conditions, according to figure 3.4 the tray for placing the product is oriented in the optimal position, in the center of the temperature field.



a)

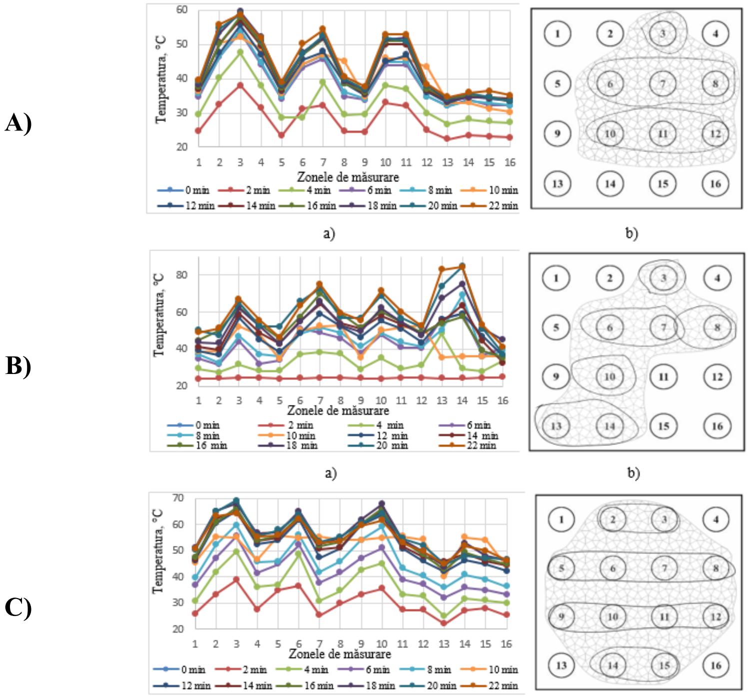
b)

Fig. 3.4. Temperature field in the drying chamber (horizontal and frontal)

When drying with the application of microwaves, a current problem is determining the spread of the temperature field inside the drying chamber, following the experiences, the efficiency of the operation of the microwave guides was presented, figure 3.5 and 3.6.

a) b) c)

Fig. 3.5. Magnetron: a) without guide; b) with a guide; c) with two guides



a) b)

a) b)

a) b)

Fig. 3.6. A) Use of magnetron without reflection guide, B) Use of magnetron with one reflection guide, C) Use of magnetron with two reflection guides, temperature field distribution, a) graphical interpretation; b) zonal interpretation

Following the experiences, we conclude that thanks to the use of reflectors the temperature field is more evenly distributed. The correct use of propagation guides with a correct construction and placement position would lead to reduced energy expenditure due to the exclusion of auxiliary drive mechanisms to rotate the tray or microwave reflectors, (Li et al., 2011; Hazervazifeh et al., 2021; Jeon et al., 2022; Shen et al., 2022).

In order to determine the optimal heat treatment method and parameters, the drying kinetics of peaches was developed and studied. Kinetics of the convection drying process: at different air temperatures - figure 3.11, different product thicknesses - figure 3.12 and for different air speeds - figure 3.13.

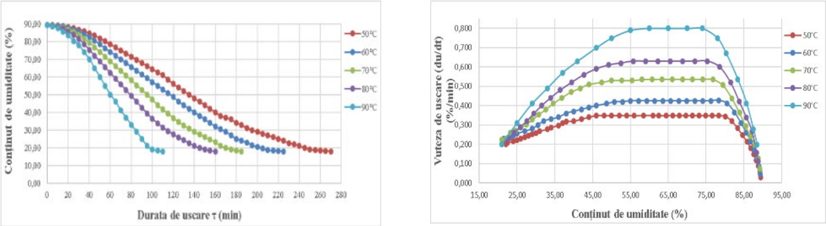


Fig. 3.7. Convection drying curves of peaches at different temperatures

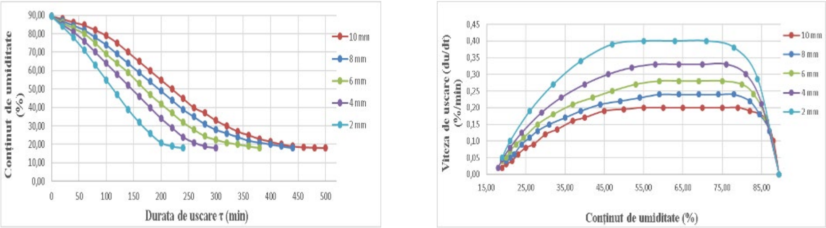


Fig. 3.8. The drying curve of peaches at different thicknesses of the washers

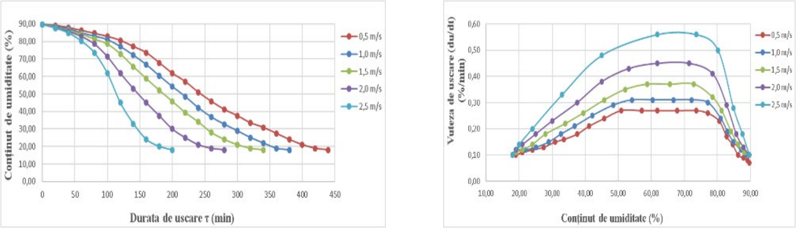


Fig. 3.9. Peach drying curve at different air speeds

The kinetics of the peach fruit drying process using electromagnetic waves with a frequency of 2450 MHz, at different magnetron powers of 600 W - figure 3.9 and 900 W - figure 3.10, (Bernic, 2008; Bernic, et al., 2011; Ţislinscaia et al., 2020).

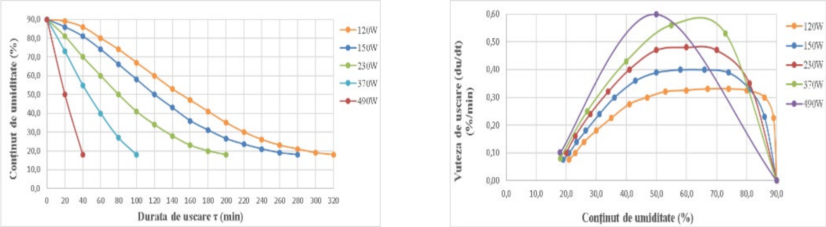


Fig. 3.10. Peach drying curve with 600W magnetron

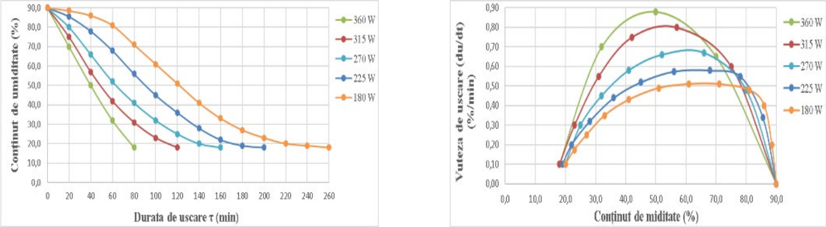


Fig. 3.11. Peach drying curve with 900W magnetron

As a drying method, the simultaneous combination of convection and microwaves was established (Demirel et al., 2017; Hii et al., 2021; Țislinscaia et al., 2021), air temperature 60°C and microwaves at 180W, 225W and 270W, figure 3.27.

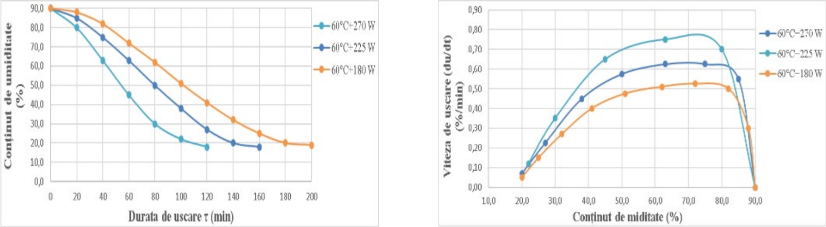


Fig. 3.12. Peach drying curve by the combined method, convection + SHF

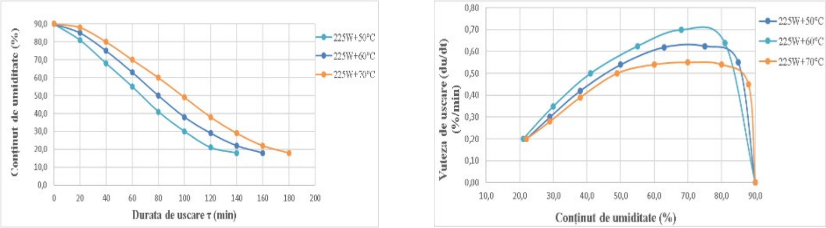


Fig. 3.13. Peach drying curve by the combined method, SHF + convection

After carrying out the drying process of peaches, the consumption of electricity was determined for drying by convection, microwaves and the combined method, the air speed of 2.0 m/s and the thickness of the product of 4 mm, are maintained for all methods, figure 3.14 – 3.17.

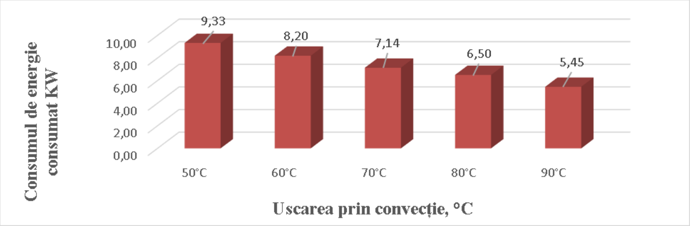


Fig. 3.14. Convection drying energy consumption

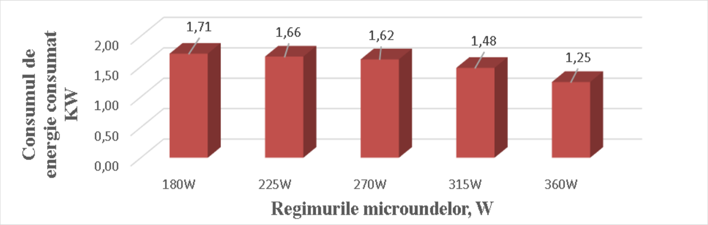


Fig. 3.15. Energy consumption for microwave drying

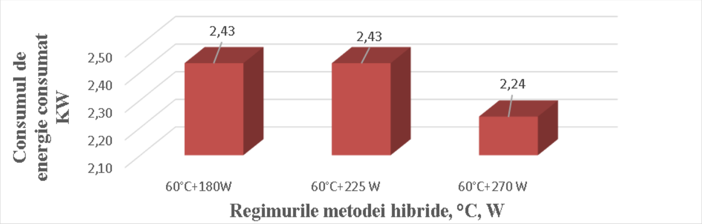


Fig. 3.16. Energy consumption for the combined method

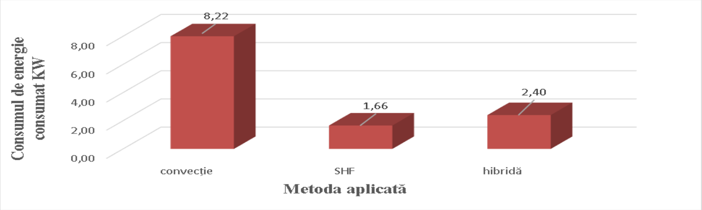


Fig. 3.17. Energy consumption for convection, SHF and combined

There were elaborated 2 mathematical models:

model I shows temperature and humidity transfer in microwave installations equation 3.1 and 3.2.

$$T=\sum_{m=1}^{\infty}\sum_{p=1}^{\infty}C_{mp}(y)\left[\cos\left(k_{zp} * z\right)-\frac{\alpha}{\lambda_{d}k_{2p}}\sin(k_{2p}z)\right]\cdot\cos(k_{xm}x) \qquad (3.1)$$

$$U=\sum_{i=1}^{\infty}\cdot\sum_{j=1}^{\infty}A_{j}(y)\left(\cos\left(k_{zj}z\right)-\frac{\beta}{\alpha_{m}kk_{zj}}\cdot sink_{zj}z\cdot cosk_{xi}x\right) \qquad (3.2)$$

model II shows the amount of heat required in the drying process to extract a certain amount of moisture from the product, equation 3.3.

$$\begin{gathered}Q_{(70\%)}=2.0\cdot10^{9}e^{(-0.021\cdot T)}\\Q_{(50\%)}=1.9\cdot10^{9}e^{(-0.021\cdot T)}\\Q_{(30\%)}=1.0\cdot10^{9}e^{(-0.019\cdot T)}\\Q_{(20\%)}=9\cdot10^{8}e^{(-0.019\cdot T)}\\Q_{(10\%)}=8.5\cdot10^{8}e^{(-0.019\cdot T)}\\Q_{(5\%)}=4.5\cdot10^{8}e^{(-0.017\cdot T)}\end{gathered} \qquad (3.3)$$

4. The influence of dehydration processes on the quality of peaches

As raw material, 2015-2022 harvest Republic of Moldova harvested peaches were used. To establish the optimal drying conditions in terms of the quality and biological value of the peaches, the following methods were used: forced convection; the application of microwaves and the combined method (convection and microwaves) (Deseatnicova, et all., 2022).

Sensory analysis was initially performed to determine the optimal drying parameters of forced convection.

The first sample analyzed dried peach slices with different thicknesses, from 2 to 10 mm. According to the results obtained, it was found that the sample with a thickness of 4 mm obtained the very good qualification out of a maximum of 20 points with an average of 19.44 points, followed by the sample with a thickness of 2 mm, 18.0 points with a good qualification, figure 4.1.

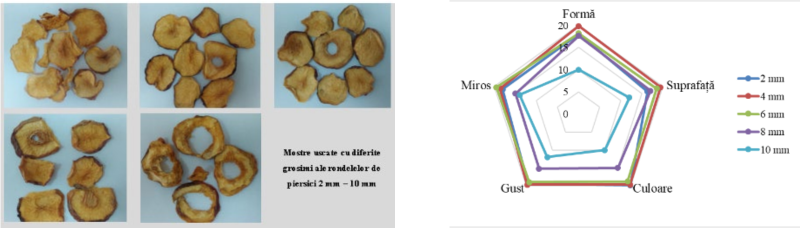


Fig. 4.1. Different thicknesses dried peaches slices

According to the sensory analysis, the dry samples at the air speed of 2 m/s obtained 19.66 points with the very good qualification, followed by the dry sample at the speed of 1.5 m/s with 18.0 points and the sample with the air speed of 2.5 m/s with the good qualification with 17.34 points. In the given case, the air speed from 1.50 - 2.50 m/s shows high qualifications, the points accumulated practically do not differ, so they can be applied in drying, figure 4.2.

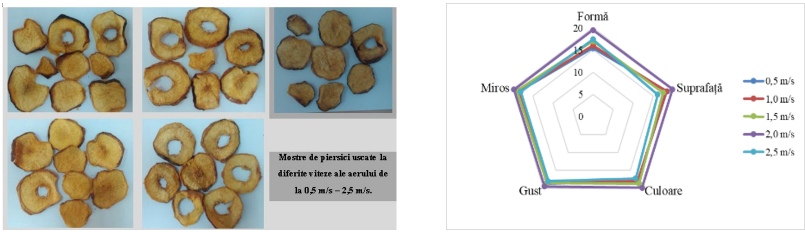


Fig. 4.2. Dehydrated peach slices at different air velocity

Following the organoleptic analysis, the sample dried at 70°C obtained the maximum value of 19.74 points, followed by a very small score difference, the sample dried at 60°C, which accumulated 19.02 points, both samples obtained the qualification of very good. The third place was obtained by the peach sample dried at 50°C with 18 points and the good qualification. In conclusion, it can be stated that the use of temperature values lower than 60°C and higher temperature values of 70°C diminishes the external appearance of the dry product, at temperatures of 80 and 90°C there is an intensification of the browning process and as a result a radical change in color, figure 4.3.

Fig. 4.3. Dehydrated peach slices at different air temperatures

According to the sensory analysis, the dry sample at the magnetron power of 270 W with a score of 19.86 points and 225 W with 19.24 points received the very good rating, practically both samples are identical in terms of shape, color, smell and taste. The dry sample at the magnetron power of 180 W scored 18 points with the good qualification. The samples obtained after treatment at the power of 315 and 360 W obtained the inadequate and unsatisfactory qualification due to a too intensive field which caused burning and damage to the product, fig. 4.4.

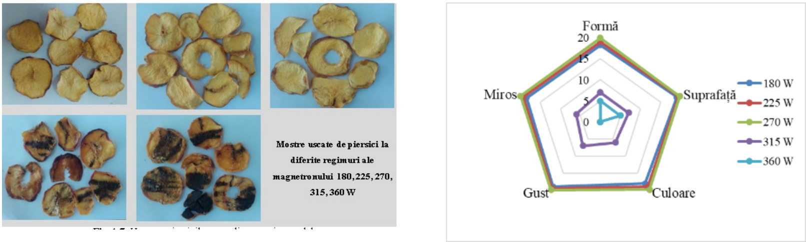


Fig. 4.4. Dehydrated peach slices at different magnetron power

Following the sensory analysis, the following results were obtained: all three samples received the very good qualification for the combined method of convection and microwaves. Peaches dehydrated at a temperature of 60°C under the action of microwaves with a magnetron power of 270 W received the maximum score of 20, for a magnetron power of 225 W – 19 points and for 180 W – 18.48 points. The very good grade was also given to the sample dehydrated by the combined method of applying microwaves and convection. At the magnetron power of 225 W in combination with drying at the temperature of 50°C, 19.20 points were obtained, while the regime with the power of 225W and the temperature of 70°C, which received the unsatisfactory qualification – 7 points, figure 4.5.

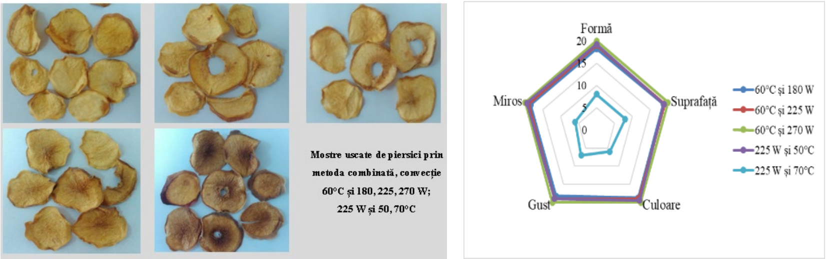


Fig. 4.5. Peach slices dehydrated by the combined method

Mathematical modeling of the peach drying process according to quality parameters of the finished product.

Three other models were determined for convection, microwave and the combined method in order to obtain qualitatively dried peaches from the point of view of external appearance.

For forced convection:

$$K_{convecția} = 0{,}765 * (-0{,}0011t^2 + 0{,}1332t - 2{,}8589) * (-0{,}1857v^2 + 0{,}52v + 0{,}8152) * (0{,}0114\delta + 0{,}956) \tag{3.4}$$

For the microwave:

$$K_{UHF} = 0{,}624 * (-9 \cdot 10^{-5} \cdot W^2 + 0{,}0424W - 3{,}2987) * (-0{,}0205\delta^2 + 0{,}1378\delta + 0{,}7262) \tag{3.5}$$

For the combined method:

$$K_{con+UHF} = 1{,}2 * (-0{,}0038t^2 + 0{,}4123t - 10{,}21) * (-6 \cdot 10^{-5}W^2 + 0{,}0258W - 1{,}883) * (-0{,}0743\delta^2 + 0{,}2296\delta + 0{,}7698) * (0{,}0236v + 1{,}0166) \tag{3.6}$$

Changes on the appearance of peach fruits according to the drying temperature

Due to the fact that fresh peach is a product rich in carbohydrates, the content of mono- and disaccharides in particular: fructose, glucose and sucrose was determined in the dehydrated samples. The influence of different temperature values on the total mono- and disaccharide content was examined. The purpose of the research was to identify the optimal temperature in keeping the maximum content of mono and disaccharides in the chemical composition of dehydrated peaches.

According to the results obtained after dehydration by the forced convection method, at the temperature of the thermal agent of 60 ± 0.5°C, the maximum summary content of mono and disaccharides was obtained, of about 67.05 g/100 g, compared to the treatment at the temperature of 50°C being 55.96 g/100 g. It is obvious that drying peaches at high temperatures such as 70 - 90°C leads to the reduction of the total content of carbohydrates in the result of the caramelization process and the Maillard reaction. At the same time, the increase in the concentration of mono- and disaccharides at the temperature of 60 ± 0.5°C presents a specific effect that requires special studies in the field of food chemistry (Tatarov 2017).

The content and antioxidant activity of polyphenols in peach fruits as a function of drying temperature

The aim of the research was to assess the influence of peach drying conditions on the biological value and antioxidant activity of the dried samples. The total content of polyphenols was determined in peaches that were dried by three methods: convection, microwave and the combined method. Initially, the total content of polyphenols in fresh peaches was determined, which was about 4.66 mg AG/g of product.

Total polyphenol content and antioxidant activity in convection-dried peaches at different air temperatures:

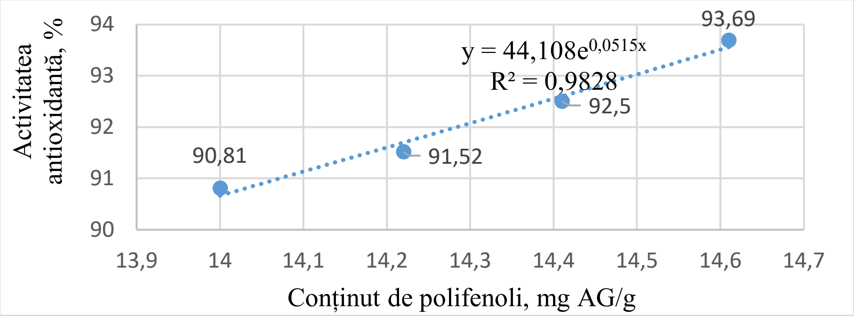


Fig. 4.6. The dependence of the antioxidant activity of polyphenols varies between 91 and 94%

Total polyphenol content and antioxidant activity in microwave-dried peaches at different magnetron powers:

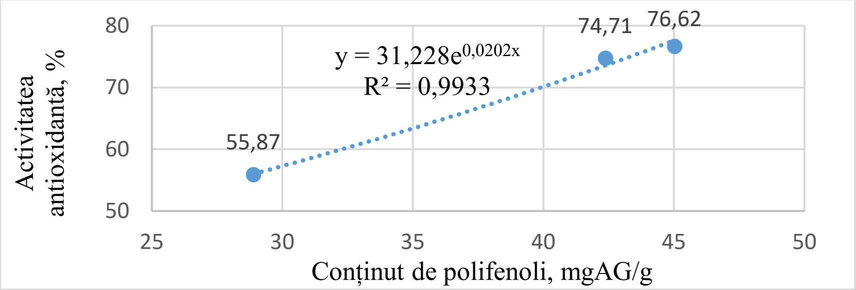


Fig. 4.7. Dependence of antioxidant activity on polyphenol content

Total polyphenol content and antioxidant activity in dried peaches by the combined method:

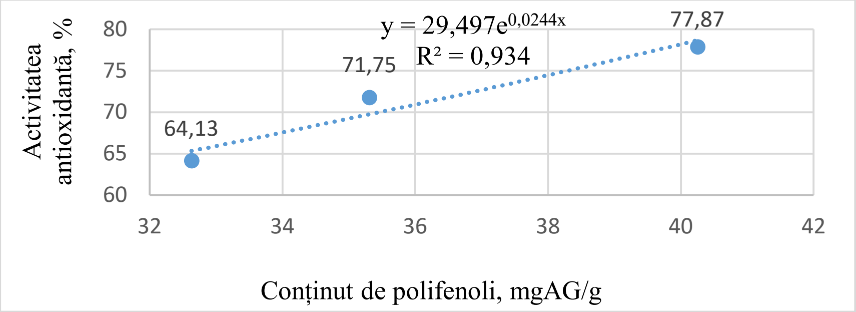


Fig. 4.8. Dependence of antioxidant activity on polyphenol content

The analysis of the correlation of the antioxidant activity and the total content of polyphenols shows an exponential dependence with the high precision of the results 0.95, 0.98 and 0.99. In turn, the content of polyphenols is influenced by the temperature and the thermal regimes of the microwaves, so that as the temperature increases, the content of polyphenols decreases, an inversely proportional dependence, table 4.7, but when applying microwaves, the dependence is directly proportional, table 4.8. The negative effect of increased temperature on the reduction of polyphenol content is described in the literature (Tatarov, 2017; Deng et al., 2020; Eyenga et al., 2020).

General conclusions and recommendations

Following the theoretical and experimental research carried out within the thesis, they led to the formulation of the following conclusions:

1. The installation was designed and developed for experimental research of the fruit drying process by the combined method, in an electromagnetic field simultaneously with dehydration by convection. The device is equipped with an electronic system and a software for monitoring and recording temperature, humidity, pressure, changes in fruit mass in the drying process, air speed, electromagnetic field parameters, no. of the patent MD 1295 Z 2019.07.31, subchapter 2.3 (Bernic et al., 2018).
2. The theoretical peculiarities of mass and heat transfer processes in the process of drying peaches by the combined method were determined. Mathematical functional relationships of energy consumption depending on fruit moisture and drying process parameters were established, subchapter 3.7 (Țislinscaia et al., 2021; Ivanov et al., 2022).
3. It was determined that the speed of moisture diffusion from the center to the surface of fruits cut in the form of a plate with limited resignations, arranged parallel to the air flow and perpendicular to the action of microwaves, depends on the electromagnetic field with the action of microwaves at a frequency of 2450 MHz, in the pulse regime with a duration of 7.5 - 10 seconds and a pause interval of $\Delta\tau = 20 – 22{,}5$ seconds, subchapter 3.4 (Vișanu et al., 2022).
4. It was found that the drying of peaches with the application of the combined method by convection and microwaves leads to a reduction of the drying time by 40 - 60 minutes, if the equivalent parameter of the fruit in the form of a plate, with a thickness of 4 mm, air temperature of 60 - 650C, air speed of 2 ± 0.1 m/s, treated with microwaves at a magnetron power of 180 - 270 W, results in an energy consumption of about 3 kW for drying 1 kg of peach fruits, subchapter 3.6 (Țislinscaia et al., 2021; Țislinscaia et al., 2022).
5. After assessing the quality of dried peaches by the combined method, it was found that the final humidity is 16-18%. The content of glucose, fructose and sucrose in peaches dried at a temperature of 50 - 600C is about 55 -67%. The total content of polyphenols varies within the limits of 14.0 – 14.6 mg AG/g and the antioxidant activity determined by the DPPH method was 71 -78 %, subchapter 4.3 (Deseatnicova et al., 2022; Vișanu et al., 2022).

6. The existence of the functional correlation (R2 = 0.96) between the antioxidant activity and the total content of polyphenols in dried peaches was determined. Due to this high correlation, the speed of the oxidation reaction was reduced, therefore, the surface appearance of the dried peach samples was identical to the color of the native fruits, subchapter 4.4 (Deseatnicova et al., 2022).
7. To assess the total energy consumption of the peach drying process and the quality of the dehydrated peaches, three mathematical models were developed. Model I shows the temperature and moisture transfer in the peach drying process. Model II shows the dependence of the heat consul according to the volume of water evaporation from the product. Mathematical model III shows the dependence of the quality of dried peaches on the parameters of the drying process, subchapter 3.7 (Ivanov et al., 2022), subchapter 4.2.

Recommendation

Technical recommendations regarding the research facility:

Increased energy consumption, heat loss (heat lost through the walls of the drying chamber, through the dry product, during loading/unloading operations, during recycling, with the exhaust of combustion gas): replacing electricity with another, more economical, renewable energy source; effective insulation; partial recirculation of the heat agent; the possibility of adaptation to a closed circuit; the automation of the installation, the electric skin to maintain a constant temperature; use of temperatures ≤ 70°C; use of air speeds ≤ 3,5 m/s; the space of the drying chamber to be used at 90 – 95%.

Increased manual work (when loading / unloading the product): plant automation.

Unidirectional air flow (will mean contact only from the air flow side, the other sides are only partially heated): orientation of the air flow perpendicular to the largest surface of the product or placing the product with the largest surface perpendicular to the air flow in the drying chamber.

Creation of air turbulence in the installation (distribution of an uneven temperature field): avoiding the change in the sizes and geometric shape of the air current passage sections

Lack of air/product temperature and humidity control (during drying the product is subject to tactile and visual control only): equipping with temperature, humidity, speed, air and product mass sensors, connecting to the computer, monitoring and recording momentary data.

Technical recommendations regarding drying technology:
uneven contact (uneven drying - surfaces located in the effective air stream receive a high proportion of energy and will dry faster than other surfaces): arranging the product in a single layer, choosing the right shape of the product, washers.
deformation – (where product shrinkage occurs, the surface exposed to the air current contracts first, causing deformation): choosing an appropriate thickness (for rounds 3-4 mm); the product subject to drying must be completely on the tray.
long cycle (where shrinkage occurs, the porous structure will close, slowing down the passage of water vapor): choosing varieties suitable for drying (peaches with sticky pits); the right choice of the harvest period according to the maturity period; choosing products with high firmness, peaches ≥1 kgf/cm^2.
crust formation (the surfaces, contracting, prevent the release of water vapor from the product leaving a wet mass under the crust): choosing the right speed and temperature of the drying agent - 2 - 3 m/s and 50-70°C respectively.

Technical recommendations regarding the drying methodology:
It is recommended for the peach drying process: Ripe peaches are chosen, firmness 1 - 1.2 kgf/cm2, Redhaven variety, diameter 75 – 100 mm, with the stone slightly sticking to the pulp; after preparing the peaches for drying, it is recommended to cut them into rounds with a thickness of 3 – 4 mm; drying peaches by forced convection (at a temperature of 60 – 70°C, product thickness 3 – 4 mm, heat agent speed of 2 – 2,5 m/s, final product humidity 16 – 18%); microwave drying (microwaves at magnetron power of 180 – 270 W, product thickness 3 – 4 mm, air speed of 2 – 2,5 m/s, final product humidity 16 – 18%); combined drying (convection at a temperature of 60°C, magnetron power of 180 – 270 W, slice thickness of 3 – 4 mm, heat agent speed of 2 – 2,5 m/s, final product humidity 16 – 18%).

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VIȘANU VITALI

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253.05 PROCESE ȘI APARATE ÎN INDUSTRIA ALIMENTARĂ

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