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THE PROCESS OF DRYING GRAPE SEEDS IN SUSPENDED LAYER

253.05 Processes and apparatus in the food industry

Summary of the PhD thesis in engineering sciences

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C U P R I N S

Research conceptual guidelines

Actuality and importance of the topic

At present, a well-developed society, both economically and socially, cannot exist without an energy efficient system, but it can manage this system, keeping the vector to the efficiency of production technologies and their implementation in practice. The efficient management of the agro-industrial complex can be ensured both by modernizing the existing technological processes and by developing and implementing new processing methods based on high efficiency. However, research and development effort is still needed to study new drying processes. An effective method of storing oilseeds, such as grape seeds, is drying. The drying process takes place until the storage moisture is reached in the product, and involves the evacuation of moisture from the product, thus preventing the development of microorganisms. In addition to the stagnation of the development of microorganisms, the drying process also has the role of increasing the shelf life of the product. One of the main problems of the drying processes of oil products is the long duration of their heat treatment, which as a consequence, leads to a decrease in quality indices. This problem is exacerbated by the drying of oily products, which are rich in fatty acids and are susceptible to oxidation processes. For such products, especially horticultural seeds, such as grape seeds, it is beneficial to dry in a suspended layer with the application of microwaves. The application of high frequency currents essentially intensifies the process, increasing the quality of dry seeds.

The purpose of the paperwork was to dry the grape seeds in a suspended layer, the mathematical modeling of the drying process, the design and elaboration of the installation, the study of the kinetics of the drying process.

In order to achieve the stated purpose, the following **main objectives** have been set:

Objective 1: Analysis of new directions and techniques for drying agri-food products.

Objective 2: The study of grape seeds as a research object.

Objective 3: Elaboration of the mathematical model for the suspended layer grape seeds drying process.

Objective 4: Computerized 3D simulation of grape seeds suspended layer drying process.

Objective 5: Study of the kinetics of the drying process for grape seeds.

Objective 6: Design and development of suspended layer drying equipment.

Research hypothesis. In classical methods drying processes, microcracks appear on the surface of grape seeds, which contribute to the oxidation of the lipid fraction. Grape seeds suspended layer drying leads to a decrease in drying duration and prevents the appearance of microcracks due to their self-separating effect from the heat treatment area.

Synthesis of the research methodology. The research methodology included the following: computerized 3D modeling, installation design in Solid Works software, assembly of suspended layer drying equipment in laboratory and industrial conditions (S.C. AZAMET-GRUP S.R.L.), study of drying kinetics in order to optimize the process and physico-chemical and analytical methods of product quality analysis. As methodological support served the research carried out within the projects:

1. ***15.187.05.04F*** "Increasing the efficiency of dehydration processes of vegetal products using non-traditional methods of energy intake", project manager, dr. hab., prof. univ., Mircea Bernic.
2. ***16.80015.5807.208T***. "Implementation of innovative grape pomace processing technology to obtain a non-waste production in the wine industry", project manager, dr. hab., prof. univ., Mircea Bernic.

3. ***19.80012.50.14A.*** “Computerized mathematical simulation of transfer phenomena in wet vegetal products using microwave treatment”, project manager, dr., conf. univ., Guțu Marin.
4. ***20.80009.5107.09*** “Improving food quality and safety through biotechnology and food engineering”, project manager, dr. hab., prof. univ., Sturza Rodica.
5. ***2 SOFT/1.2/83*** “Intelligent valorification of industrial agri-food waste (INTEL-WASTES)”, project manager, dr. hab., prof. univ., Sturza Rodica.

Approval of results. The results obtained in the thesis were presented and discussed at international scientific conferences and symposia in the country and abroad: International Symposium and Conference "Euro-Aliment", 2017 and 2019, Galati, Romania; “InventCor” International Symposium, 2020, Deva, Romania; International Symposium "Infoinvent", 2017, 2019 and 2021, Chisinau, Republic of Moldova.

Summary of thesis chapters.

The paperwork is structured in four chapters, introduction, general conclusions and recommendations, bibliography and annexes.

In the **Introduction** are presented the actuality and importance of the approached topic, the scientific novelty of the paper, the theoretical and applied value of the obtained results; the purpose is indicated and the research objectives and issues are formulated.

Chapter 1 - Theoretical aspects of the suspended layer drying process analyzes the theoretical aspects of the drying process of seed horticultural products - on the one hand, and studies the new drying techniques and technologies - on the other hand.

There are presented aspects related to the technological process of drying seed horticultural products; different views of scientists on the dehydration process; arguments are reported, which confirm the efficiency of the drying process in order to preserve the dehydrated product for a long time.

Modern techniques and technologies for drying grape seeds are presented, various hybrid drying methods are described, which introduce new directions to improve the dehydration processes.

Chapter 2 - Research materials and methods describe the materials and methods for determining the aerodynamic properties of grape seeds and their physical and mechanical properties; the experimental stand for the determination of the aerodynamic properties, for the study of the kinetics of the drying process in suspended layer is described; methods for analyzing the quality indices of grape seed and extracted oil are described.

Chapter 3 - Suspended layer drying grapes process optimization. In this chapter we analyzed the movement of grape seeds in a suspended layer, we used mathematical modeling and 3D simulation; The suspension drying process of grape seeds was mathematically modeled, which served as the basis for the 3D simulation of the suspended layer drying process and the study of the distribution of the temperature field in the drying area.

Chapter 4 - Kinetics of grape seed drying process in a suspended layer presents the kinetics of the process of drying the grape seed with the application of convection and with the application of microwaves (SHF), the kinetics of the process of suspended layer drying with the application of convection and the kinetics of the process of drying in a suspended layer with the application of microwaves (SHF); subsequently, the quality indices of grape seed and extracted oil were analyzed; the technical realization of the suspended layer drying installation of the grape seeds and the economic effect of the implementation are argued.

Thesis content

Chapter 1. Theoretical aspects of the suspended layer drying process

The pressing problems faced by the wine industry of the Republic of Moldova are the efficient recovery of waste obtained from grape processing, such as: yeast, wine stone, pomace, grape seeds, etc. [1]. The processing of this waste makes it possible to obtain a wide range of valuable products (natural oenomelanin [2], natural anthocyanin dye [3], grape seed oil [4], grape seed flour [5], antioxidant proanthocyanidin [6], alcohol ethyl [7], bioethanol [8], natural acidifiers [9], natural absorbents [10], tannins [11], etc.) for various branches of the economy: pharmaceutical, cosmetology, food industry, etc. The problem can be solved by creating non-residual technologies, which ensure ecological stability and added value for companies in the field [12].

Of particular interest are the grape seeds. In most cases, their processing initially involves their drying. The degree of preservation of valuable substances depends on the technological parameters of the drying regime. Traditionally, in the drying process, the fluid inside the working chamber serves as a thermal agent and transports the moisture from the product, evacuating it from the installation, quite different is the case of drying in a suspended layer, where it has the function of forming and maintaining the suspended layer for suspending the grape seeds at a certain height, in an air flow, with a constant value of the floating speed. The process of drying seed horticultural products, such as grape seeds, has been extensively studied by scientists: Licov A.V., Rudobashta S.P., Kalashnikova N.V., Voljentsev A.V. and others [13].

Drying is an indispensable process in many food industries. The development of modern drying technologies is stimulated by the increased demand on the international market to produce quality products. Improving the quality of most foods translates into a significant increase in their market value. The recent development of new hybrid drying technologies to improve food quality is in line with the current trend of improving quality with low environmental impact. Numerous emerging technologies have been listed and discussed in detail [14].

Potential areas for application of these hybrid drying technologies in improving product quality have been identified. It is well known that the dehydration process directly influences the quality of the final product. At present, research in the field is focused on improving drying technologies, both economically and qualitatively, in order to produce better quality products in a short period of time and with low energy costs respectively [15].

In recent years, the engineering focus has been on optimizing the process of design and operation of dryers to obtain dried food product with the desired characteristics. Although several steps have been taken in the development of drying technology, much remains to be done in the study of new hybrid systems through which drying technologies can be combined with each other to develop new generation drying systems. This subchapter describes some recent developments in hybrid drying technologies of interest to the food industry. In the following we will list and discuss new emerging hybrid drying technologies [16].

Although the main purpose of drying agri-food products is to preserve them, depending on the drying technology used, the raw material may differ, with significant variations in product quality. Therefore, more attention should be paid to the choice of a suitable drying equipment, given the correlation between the final product and the dryer. Losing the connection between the product and the drying technology would result in undesirable consequences, which would often lead to considerable financial losses [17].

Chapter 2. Research materials and methods

Grape seed accounts for about 15% of the solid waste produced in the wine industry and is recognized as a product that requires further analysis of its value [18]. The seeds of red varieties grapes, retrieved from pomace obtained after the primary processing of technical grape varieties (Cabernet Sauvignon, Merlot, Pinot Noir, Moldova, Isabella, etc.) were used as objects of study. Chapter two describes the methodology for determining the aerodynamic properties of grape seeds. Keeping the grape seeds in a suspended layer (fig. 2.1) requires that the ascending speed of the air in the tube to be equal to their floating speed [19].

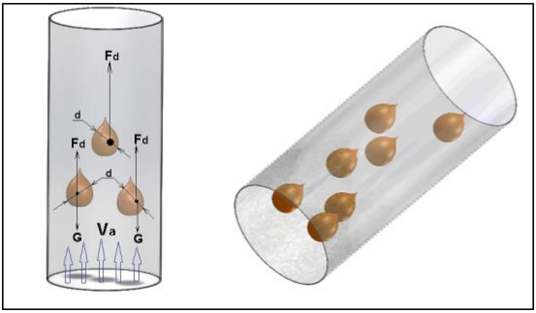

Fig. 2.1. The forces acting on the suspended grape seed

Neglecting Archimedes' force, two forces will act on the seeds: the force of gravity G and the force resulting from the pressure of the air on the particle F_d.

At the same time, the methodology for determining the physical and mechanical properties of grape seeds was described, as drying in a suspended layer of grapes seeds causes mechanical shocks, due to the continuous movement in a layer, where the collision between seeds and the walls of the drying tube appears. The crushing force to which the seeds are subjected in the drying chamber to the continuous movement was determined experimentally, with the help of the experimental laboratory stand, model MYP-100-2, which is intended for testing materials for stretching and compression [20]. After the drying process, the grape seeds were subjected to microscopic analysis to identify microcracks on their surface. This was possible with the VEGA TS 5130 electron microscope, which was used to analyze the surface of the dried grape seeds by the classical method and in a suspended layer. The analysis of grape seed surfaces was performed at a scale of 1 mm and 200 μm [21]. For the comparative study between the classical drying process and the suspended layer one, a series of researches of the kinetics of the drying process were performed at the tunnel installation (fig. 2.2).

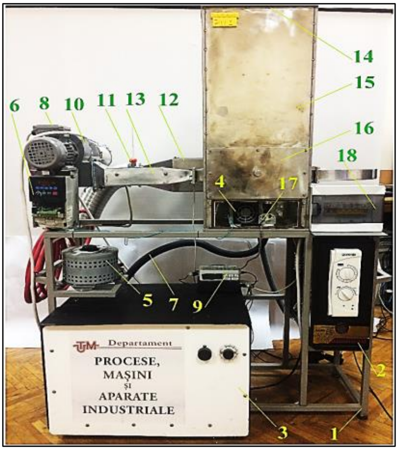

Fig. 2.2. Tunnel drying plant

In order to determine the quality indices of grape seeds, a series of preventive operations were carried out for their preparation. Initially, using the sieve, the grape seeds were separated from the remnants of bunches and other impurities. After separation, they were subjected to the drying process, using 4 methods: convection drying, the classical method; drying with the application of SHF, the classic method; convection drying in a suspended layer and drying with the application of SHF in a suspended layer. A series of physico-chemical methods for determining the quality indices of grape seeds and for analyzing the oxidative stability of the oil extracted from them have also been described. The mathematical modeling of the experimentally obtained data was performed according to the Brandon method by applying Fisher's approximation criteria.

Chapter 3. Suspended layer drying grapes process optimization

In order to ensure the drying process of the grape seeds in a suspended layer, it is necessary to deeply analyze the characteristic of the movement of the seeds in the drying chamber, which is in the form of a tube. In order to optimize this process, two mathematical models were developed, based on which 3D simulations were performed. The first mathematical model describes the aerodynamics of the grape seed in a suspended layer.

$$v_{\alpha = 77^0 \text{ model}} = 8{,}05 \cdot (10^{-5} \cdot L^2 - 0{,}0071 \cdot L + 1{,}7936) \cdot (-0{,}66 + 1{,}77 \cdot 10^{-5} \cdot P) \quad (3.1)$$

This model (3.1) allows us to determine the speed acting on the grape seed in the suspended layer, being dependent on the length of the tube, and the pressure in it. Based on the first mathematical model, the 3D simulation of the air flow behavior for eight tubes of different shape and geometric parameters was performed, shown in Figure 3.1 and 3.2.

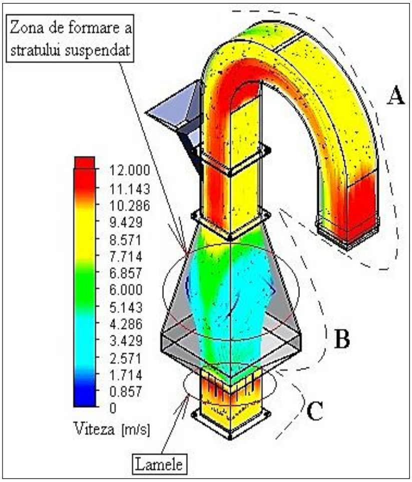

Fig. 3.1. 3D simulation of the air velocity field through the aerodynamic tube 4.

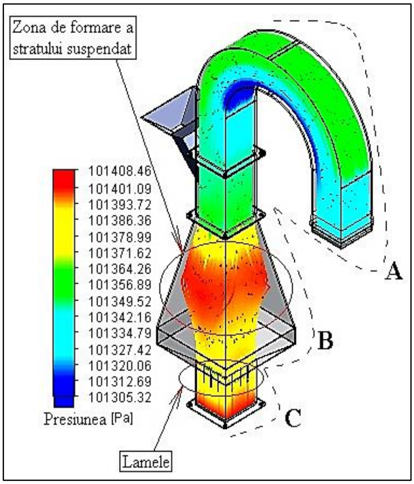

Fig. 3.2. 3D simulation of the air pressure field through the aerodynamic tube 4.

In each tube was analyzed the speed (fig. 3.1) and the air pressure (fig. 3.2), where it was established that tube 4 has the optimal shape to keep the suspended layer stable, to be subsequently made in laboratory conditions and mounted in the installation. The second mathematical model (3.2) describes the process of drying the grape seed in a suspended layer, by the criterion equation, described by Newton's criterion (Ne), which was developed based on the parameters dependent on the force acting on the seed in the tube.

$$Ne = c\, Eu^k {C_a}^y \cdot {C_{\Delta p}}^z \cdot {C_d}^\gamma \qquad (3.2)$$

Subsequently, based on the second mathematical model, two 3D simulations were performed. The first refers to the process of drying grape seeds in a suspended layer with the application of high frequency currents (microwaves), fig. 3.3, and the second simulation reflects the drying of grape seeds in a suspended layer with the application of convection, fig. 3.4.

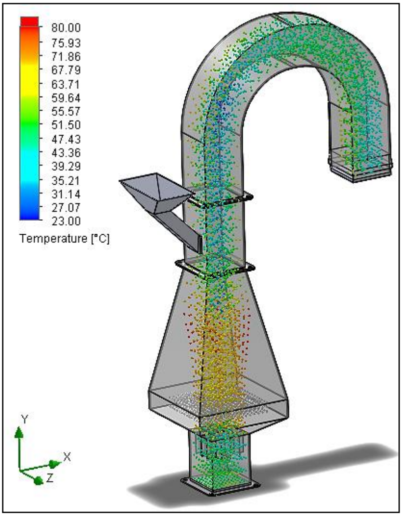

Fig. 3.3. 3D simulation for microwave-assisted suspended layer drying process

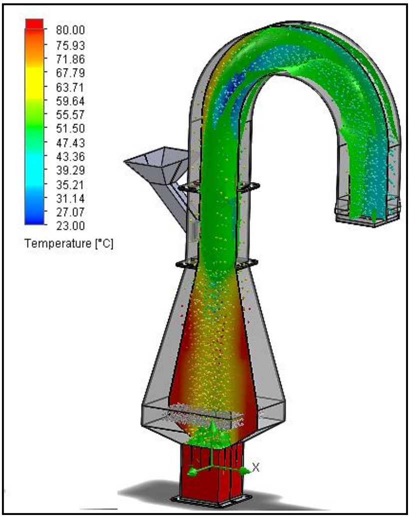

Fig. 3.4. 3D simulation for convection-assisted suspended layer drying process

As a result of the analysis of the temperature field in the simulations of both methods, it was established that the shape of the tube 4 is the most optimal to be developed and installed in the drying plant. The installation described in this chapter was created first as a sketch, then as a 3D concept [22], after which it was designed in 3D (fig. 3.5), using the SolidWorks software version 2018, then it was made in laboratory conditions. - presented in (fig. 3.6) [23].

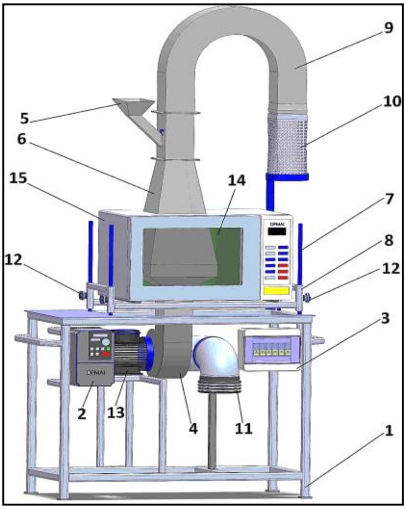

Fig. 3.5. Grape seed drying installation, 3D model [24]

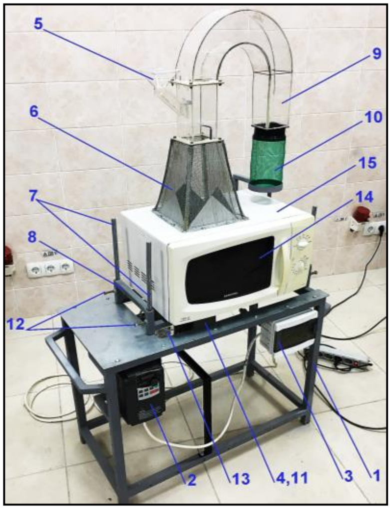

Fig. 3.6. Grapes seeds suspended layer drying installation, laboratory model

During the elaboration of the drying installation in suspended layer, the physical-mechanical, physico-chemical and aerodynamic properties of the grape seeds were taken into account. It was these characteristics that determined the design and technical parameters of the installation in Figure 3.5 and 3.6.

In order to avoid the crushing effect of grape seeds and the subsequent appearance of cracks, the critical crushing force of wet and dry seeds was compared with the crushing force to which wet and dry seeds are subjected inside the aerodynamic tube, which is also the drying chamber. It was found that the critical crushing force for both non-dried (wet) and dry seeds is much higher than the crushing force to which they are subjected in the drying chamber. It was shown that during the process of drying in a suspended layer, the appearance of microcracks on the surface of grape seeds, due to their continuous movement and collisions between them, was excluded.

Chapter 4. Kinetics of grape seed drying process in a suspended layer

To study the kinetics of the process of suspended layer drying of grape seeds with the application of convection, the installation described in Chapter 3 was used. Figure 4.1 shows the drying curves in a suspended layer of grape seeds, with convective application of heat. The temperature of the applied thermal agent had the values of 60, 70, 80, 90 and 100 ºC.

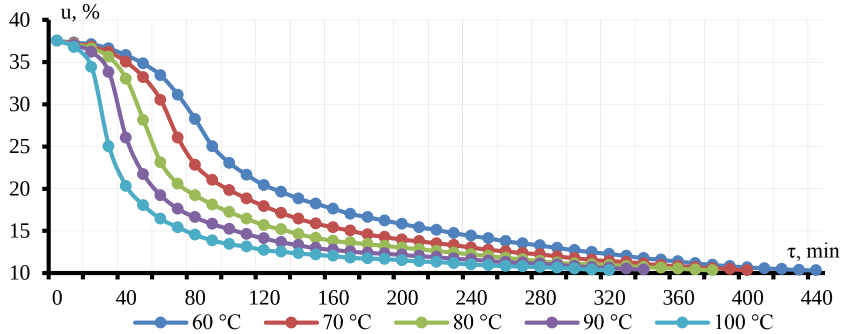

Fig. 4.1. Moisture content diminution curves, suspended layer convection-assisted drying

It was found that the duration of the drying process in a suspended layer with the application of convection depends on the temperature of the thermal agent (fig. 4.1). Thus, the use of the thermal agent with a temperature of 60 ºC, increased the dehydration of the product from the initial moisture content - 37.5%, to the final one of 10.3%, it lasted 440 min. Respectively for the temperature values 70, 80, 90 and 100 ºC, the duration of the dehydration process was 400, 380, 340 and 320 min. Although the same drying regimes were applied as in the case of convection by the classical method, the use of convection in the drying system in a suspended layer definitively excluded the effect of carbonization on the surface of the dried seeds. This was possible due to their constant state of motion during the process. Moreover, the self-separating effect of grape seeds, throughout the process of drying in a suspended layer, ensured the individual heat treatment for each seed separately [25].

The process of drying in a suspended layer with the application of microwaves was ensured by an air flow equal to 430 ± 0.2 m^3/h, which developed a constant speed with the value of 11.4 ± 0.1 m/s.

These parameters ensured the stability of the suspended seeds layer during the drying process. Suspended layer drying curves of grape seed using microwaves (Fig. 4.2) describe five working modes of the magnetron with the following power values: 200, 300, 450, 600 and 750 W.

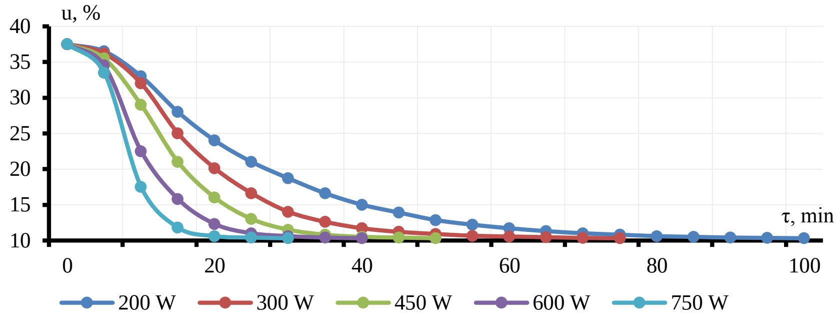

Fig. 4.2. Moisture content diminution curves, suspended layer SHF-assisted drying

It has been shown that the duration of the drying process in suspended layer with the application of microwaves depends to a large extent on the applied power of the magnetron. Thus, the application of the power of 200 W, made possible the drying in a suspended layer of the seeds from the initial humidity content of 37.5%, to the final one of 10.3%, in 100 min. Respectively for the power values of the magnetron 300, 450, 600 and 750 W, the duration of the dehydration process was 75, 50, 40 and 30 min respectively. From the above it results that the duration of the process of drying in a suspended layer of grape seeds with the help of microwaves decreases with the increase of the magnetron power, approximately 3.3 times. The application of microwaves to the drying in a suspended layer of grape seeds reduces their heat treatment time by 4.4 times compared to the drying in a suspended layer with the application of convection.

A very important aspect in terms of the quality of the oil obtained from grape seeds, is its sensory analysis. The results of the analysis of the sensory characteristics of the oil extracted from grape seed are presented in Table 4.1. A number of characteristics were analyzed: transparency, smell, taste and color. These were studied and compared with GD No. 434 of 27.05.2010 on the approval of the technical regulation “Edible vegetable oils” [26].

Table 4.1. The results of the sensory analysis of the oil extracted from dried grape seeds by different methods

№	Sensory characteristics / Oil extracted from grape seeds	Transparency	Smell	Taste	Color
1.	Oil extracted from **dried** grape seeds by **convection**, the **classic method.**	**Transparent fără sediment.**	Pleasant smell. Slightly fried oil.	Oily taste, no odor and foreign taste.	Dark yellow
2.	Oil extracted from **dried** grape seeds with the **application of SHF**, the **classic method**.		Pleasant smell. Slightly fried oil.		
3.	Oil extracted from **dried** grape seeds by **convection**, in a **suspended layer**.		Nice smell, no foreign smell.	Oily taste, no odor and foreign taste.	Light yellow
4.	Oil extracted from **dried** grape seeds with the **application of SHF**, in a **suspended layer**.		Nice smell, no foreign smell.		

According to Table 4.1, for oil extracted from dried grape seed samples in a suspended layer with the application of convection and dried in a suspended layer with the application of microwaves, there was no slight fried smell, which indicates that during the heat treatment the seeds were in continuous motion, moreover the effect of their self-separation due to the equivalent diameter differed from one seed to another. The drying of the grape seeds in a suspended layer increases the quality of the oil obtained and makes their heat treatment more efficient.

For the innovative method of drying grape seed in a suspended layer, which ensured the uniform heat treatment of the seeds and led to a considerable reduction in the process time, the energy consumption of the drying system in a suspended layer was calculated in relation to the classic drying method. (conventional). According to (tab. 4.2) it is observed that the difference in cost for drying in a convection-assisted suspended layer, compared to the conventional drying method with the application of convection was 12.5%. The application of the SHF-assisted suspended layer drying method, compared to the conventional drying method with the application of SHF, resulted in a 31% cost difference.

Table 4.2. The difference in energy consumption between the suspended layer and the conventional driers

No	**Drying method**	**Drying cost for one liter of oil, lei/L**	**Cost difference between the suspended layer drying method and the conventional method, %**
1.	**Suspended layer** drying with convection.	637	It is **12.5% cheaper**, than the conventional convection method.
2.	**Suspended layer** drying with microwaves..	91	It is **31% cheaper**, than the conventional microwaves method
3.	Convection drying.	728	It is **12.5%** more expensive than the convection-assisted suspended layer drying method.
4.	Microwaves drying.	132	It is **31%** more expensive than the microwave-assisted suspended layer drying method.

Suspended layer drying is based on a very strong potential in terms of the variety of its applicability. This potential refers to the possibility of drying more granular products of agri-food origin.

The only constructive element that needs to be adapted to the drying system in a suspended layer, for dehydration of other granular agri-food products is the aerodynamic tube, the geometric shape of which is specific for each raw material.

General conclusions and recommendations

A major importance for the advancement of the national economy is the design and implementation of new technologies. One of the methods of preserving the functionality of agri-food products is the drying process. As technology advances to new frontiers, the method of preservation by dehydrating products is constantly evolving. The research carried out within the thesis allowed the formulation of the following conclusions:

1. New techniques for drying agri-food products require their intelligent combination to make product quality more efficient and reduce energy consumption. The hybrid microwave-assisted fluidized bed dryer ensures uniform drying of the product and reduces the heat treatment time and energy consumption, respectively. The valorification of grape seed using suspended layer drying depends on a number of factors, such as seed density, equivalent diameter and floating speed.

2. The mathematical model was developed according to the Brandon method, which allowed the determination of the floating speed of the seeds in the suspended layer depending on the height of the tube and the angle of inclination of the upper surfaces of the working chamber. The process of drying the seeds in a suspended layer is described by criterion equations obtained based on this mathematical model. The computerized 3D simulation of the suspension drying process of the grape seeds allowed the establishment of the geometric shape of the aerodynamic tube and the identification of the optimal geometric parameters.

3. Crushing grape seed testing has shown that the critical crushing force (59.4 N) for both wet and dry seeds significantly exceeds the crushing force to which the seeds are subjected in the drying chamber (0.098 - 0.100 mN). This excludes the possibility of microcracks due to collisions during the drying process in a suspended layer, which reduces the likelihood of lipid oxidation.

4. The analysis of the kinetics of the process of convection drying in a suspended layer in relation to the drying by convection in steady state (60 - 100 ºC) showed a reduction of the drying time by 12% and an increase of the speed of the drying process by 10%. At the same time, it was established that the seeds of grapes dried by convection in a steady state are subjected to an uneven heat treatment, which leads to the appearance of microcracks, which increases the probability of oxidation of lipids.

5. The analysis of the kinetics of the drying process of grapes in a suspended layer with the application of microwaves in relation to the drying with the application of microwaves in steady state (200 - 750 W) showed an increase of the drying process speed by 20%, which led to reducing the heat treatment time by 31%. The application of microwave treatment (SHF) in a suspended layer reduces the drying process by 77% and increases the speed of the drying process by 72% compared to the application of convection by the same method.

6. The application of the method of drying grape seed in a suspended layer ensures the uniform distribution of temperature and moisture transfer, which prevents distortion of the product, caused by the variation of the equivalent diameter. This effect is due to the continuous movement during the drying process of the grape seeds in a suspended layer, which ensures the uniformity of the heat treatment through the self-selection effect of the already dried seeds and their removal from the heat treatment area.

7. It was designed in 3D and developed the installation of drying grape seeds in a suspended layer in laboratory conditions. The techno-economic parameters of the suspended layer drying process were identified. Dried grape seed oil obtained from suspended layer with the application of convection dried grape seeds ensures reduced costs by 12.5% compared to convection dried grape seed oil in steady state. Dried grape seed oil in a suspended layer with microwave application provides 31% lower production costs compared to stationary microwave dried grape seed oil.

8. The results obtained were implemented when designing the grape seed drying plant of S.C. AZAMET-GRUP S.R.L. In industrial conditions, it was found that the quality indices of the oil obtained from dried grape seeds in a suspended layer correspond to the requirements of GD 434 of 27.05.2010 regarding the approval of the technical regulation “Edible vegetable oils”.

Recommendations

1. It is recommended to dry the grape seeds in a suspended layer with the application of SHF, which ensures a drying time - 100 min with the speed of the dehydration process - 2.5% / min.

2. Increasing the extraction mass of the oil fraction requires the application of the following drying regimes:

- microwave drying after conventional method, drying mode: 750 W magnetron working mode, drying time 40 min;
- drying in a suspended layer with the application of microwaves, drying mode: 750 W magnetron working mode, drying time 30 min.

3. The reduction of the acidity index and the acidity of the oil requires the application of the following drying regimes:

- drying in a suspended layer with the application of convection, drying regime: thermal regime 60ºC, drying duration 440 min;
- drying in a suspended layer with the application of microwaves, drying mode: magnetron working mode 200 W, drying time 100 min.

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1. Articles in scientific journals

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3.13. VIȘANU, Vitali, ŢISLINSCAIA, Natalia, **BALAN, Mihail**, MELENCIUC, Mihail, GÎDEI, Igor., ȚURCANU, Dinu, POPESCU, Victor. Procedeu de uscare a piersicilor cu aplicarea microundelor. Cerere BI nr. 2244 din 2021.09.27.

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3.15. BALAN, Mihail, ŢISLINSCAIA, Natalia, VIȘANU, Vitali, MELENCIUC, Mihail, ȚURCANU, Dinu, POPESCU, Victor. Instalație de uscare modulară. Cerere BI nr. 2245 din 2021.09.27.

A D N O T A R E

Balan Mihail, „**Procesul de uscare a semințelor de struguri în strat suspendat**”, Teză de doctor în vederea conferirii titlului științific de doctor în științe inginerești, or. Chișinău, Republica Moldova, 2022.

Structura tezei: teza este constituită din introducere, patru capitole, concluzii și recomandări, bibliografie din 228 titluri, 3 anexe, 112 pagini de text de bază, 37 figuri, 46 tabele.

Cuvinte cheie: semințe de struguri, instalație de uscare, convecție, microunde, strat suspendat, simulare 3D, cinetica procesului de uscare, ulei din semințe de struguri.

Scopul lucrării: Uscarea semințelor de struguri în strat suspendat, modelarea matematică a procesului de uscare, proiectarea și elaborarea instalației, studiul cineticii procesului de uscare.

Obiectivele cercetării: 1. Analiza direcțiilor și tehnicilor noi de uscare a produselor agroalimentare; 2. Studiul semințelor de struguri ca obiect de cercetare; 3. Elaborarea modelului matematic pentru procesul de uscare a semințelor de struguri aflate în strat suspendat; 4. Simularea computerizată 3D a procesului de uscare în strat suspendat pentru semințele de struguri; 5. Studiul cineticii procesului de uscare pentru semințele de struguri; 6. Proiectarea și elaborarea echipamentului pentru uscarea în strat suspendat.

Noutatea și originalitatea științifică: În urma cercetărilor procesului de uscare în strat suspendat a semințelor de struguri, au fost constatate următoarele: s-a redus durata de uscare a semințelor de struguri pentru convecție cu 60 min, pentru SHF cu 45 min; a fost redus consumul de energie pentru convecție cu 12%, pentru SHF cu 31%. Această metodă permite selectarea automată a semințelor deja uscate din masa totală de semințe și înlăturarea acestora din zona de prelucrare termică, micșorând astfel durata de tratare termică, și indicii de aciditate.

Rezultatele obținute: A fost elaborată metoda de tratare termică a materiei prime sământoase în strat suspendat. S-a constatat, că metoda inovativă de uscare în strat suspendat pentru semințe de struguri este eficientă din punct de vedere calitativ și energetic. A fost demonstrat, că uscarea în strat suspendat reduce maxim durata de tratare termică a semințelor de struguri; reduce indicii de aciditate ai uleiului obținut din semințe de struguri deshidratate în strat suspendat, ceea ce influențează pozitiv calitatea lui. Din punct de vedere energetic metoda uscării în strat suspendat presupune micșorarea cheltuielilor până la 31% față de metoda clasică de uscare, ceea ce prezintă un indice important pentru implementarea tehnologiei date.

Semnificația teoretică: Au fost obținute noi rezultate științifice referitor la uscarea semințelor de struguri în strat suspendat, care eficientizează procesul de uscare, prin micșorarea duratei de tratare termică și sporirea indicilor de calitate ai semințelor.

Valoarea aplicativă se referă la aplicarea metodei inovative de uscare în strat suspendat a semințelor de struguri și stabilirea parametrilor optimi ai procesului tehnologic.

Implementarea rezultatelor științifice: A fost proiectată și elaborată instalația de laborator pentru uscarea în strat suspendat a semințelor de struguri, în baza căreia au fost obținute șase brevete de invenții: MD 1249 din 15.02.2018; MD 1278 din 30.03.2018; MD 1278 din 31.03.2019; MD1481 din 07.06.2021; Hotărâre acordare brevet nr. 9901, din 15.10.2021; Hotărâre acordare brevet nr. 9902, din 15.10.2021 și au fost depuse patru cereri de brevet: nr. 2142 din 2020.11.11; nr. 2243 din 27.09.2021; nr. 2244 din 27.09. 2021; nr. 2245 din 27.09.2021. De asemenea rezultatele obținute au fost implementate pentru modernizarea instalației de uscare a semințelor de struguri din cadrul întreprinderii S.C. AZAMET-GRUP SRL.

А Н Н О Т А Ц И Я

Балан Михаил, **„Процесс сушки косточек винограда во взвешенном слое”** диссертация на соискание ученой степени доктора инженерных наукб г.Кишинев, Республика Молдова 2022 г.

Структура диссертации: диссертация состоит из введения, четырех глав, выводов и рекомендаций, библиографии из 228 наименований, 3 приложений, 112 страниц основного текста, 37 рисунков, 46 таблиц.

Ключевые слова: виноградные косточки, сушильная установка, конвекция, микроволны, взвешенный слой, 3D-моделирование, кинетика процесса сушки, масло из виноградных косточек.

Цель работы: Сушка виноградных косточек во взвешенном слое, математическое моделирование процесса сушки, проектирование и разработка установки, исследование кинетики процесса сушки.

Задачи исследования: 1. Анализ новых направлений и технологий сушки агропродо-вольственных товаров; 2. Изучение косточек винограда как объекта исследования; 3. Разработка математической модели процесса сушки косточек винограда во взвешнном слое; 4. Компьютерное 3D моделирование процесса сушки виноградных косточек во взвешенном слое; 5. Изучение кинетики процесса сушки виноградных косточек; 6. Проектирование и разработка оборудования для сушки во взвешенном слое.

Новизна и научная оригинальность. В результате исследований процесса сушки виноградных косточек во взвешенном слое установлено: время сушки виноградных косточек при конвекции сократилось на 60 мин, при СВЧ на 45 мин; энергозатраты на конвекцию снижены на 12 %, на СВЧ на 31 %. Этот метод позволяет автоматически выделять из общей массы высушенные косточки и удалять их из зоны термической обработки, что позволяет сократить время термической обработки и показатели кислотности.

Полученные результаты. Разработан метод термической обработки косточек во взвешенном слое. Установлено, что инновационный способ сушки во взвешенном слое виноградных косточек эффективен с точки зрения качества и энергии. Показано, что сушка во взвешенном слое значительно сокращает продолжительность термической обработки косточек винограда; снижает кислотность масла, полученного из обезвоженных косточек винограда во взвешенном слое, что положительно влияет на его качество. С энергетической точки зрения метод сушки во взвешенном слое предполагает снижение затрат до 31% по сравнению с классическим методом сушки, что является важным показателем для реализации данной технологии.

Теоретическая значимость: получены новые научные результаты по сушке косточек винограда во взвешенном слое, что позволяет упростить процесс сушки, за счет сокращения продолжительности термической обработки и повышения качественных показателей косточек.

Практическое значение докторской диссертации относится к применению инновационного метода сушки виноградных косточек во взвешенном слое и установлению оптимальных параметров технологического процесса.

Внедрение научных результатов. Была спроектирована и разработана лабораторная установка для сушки во взвешенном слое косточек винограда, на основании которой получено шесть патентов на изобретения: MD 1249 от 15.02.2018; MD 1278 от 30.03.2018; MD 1278 от 31.03.2019; MD 1481 от 07.06.2021; Решение о выдаче патента №. 9901 от 15.10.2021; Решение о выдаче патента №. 9902 от 15.10.2021 и поданы четыре заявки на изобретения: №. 2142 от 11.11.2020; №. 2243 от 27.09.2021; №. 2244 от 27.09.2021; № 2245 от 27.09.2021. Также полученные результаты были внедрены для модернизации установки по сушке виноградных косточек в рамках S.C. AZAMET-GRUP SRL.

S U M M A R Y

Balan Mihail, **“The process of drying grape seeds in suspended layer”**, the thesis for the degree of Doctor in engineering sciences, Chisinau, Republic of Moldova, 2022.

The thesis structure: the thesis consists of an introduction, four chapters, conclusions and recommendations, a bibliography of 228 titles, 3 appendices, 112 pages of basic text, 37 figures, 46 tables.

Keywords: grape seed, drying plant, convection, microwave, suspended layer, 3D simulation, kinetics of drying process, grape seed oil.

The purpose of the paper: Drying of grape seeds in a suspended layer, mathematical modeling of the drying process, design and elaboration of the installation, study of the kinetics of the drying process.

The research objectives: 1. Analysis of new directions and techniques for drying agri-food products; 2. The study of grape seeds as a research object; 3. Elaboration of the mathematical model for the drying process of the suspended grape seeds; 4. Computerized 3D simulation of the suspended layer drying process for grape seeds; 5. Study of the kinetics of the drying process for grape seeds; 6. Design and development of equipment for drying in a suspended layer.

The novelty and scientific originality. Following the researches of the process of drying the grape seeds in a suspended layer, the following were found: the drying time of the grape seeds for convection was reduced by 60 min, for SHF by 45 min; energy consumption for convection was reduced by 12%, for SHF by 31%. This method allows the automatic selection of already dried seeds from the total seed mass and their removal from the heat processing area, thus reducing the heat treatment time, and acidity indices.

The results obtained. The method of heat treatment of the seed raw material in a suspended layer was developed. It has been found that the innovative method of drying in a suspended layer for grape seeds is efficient in terms of quality and energy. It has been shown that drying in a suspended layer greatly reduces the

duration of heat treatment of grape seeds; reduces the acidity of the oil obtained from dehydrated grape seeds in a suspended layer, which positively influences its quality. From an energy point of view, the suspended layer drying method involves a reduction of costs by up to 31% compared to the classic drying method, which is an important index for the implementation of this technology.

Theoretical significance: New scientific results have been obtained regarding the drying of grape seeds in a suspended layer, which streamlines the drying process, by reducing the duration of heat treatment and increasing the quality indices of the seeds.

The applicative value of the paper refers to the application of the innovative method of suspension drying of grape seeds and the establishment of optimal parameters of the technological process.

Implementation of scientific results. The laboratory installation for the drying in a suspended layer of the grape seeds was designed and elaborated, based on which six patents of inventions were obtained: MD 1249 from 15.02.2018; MD 1278 of 30.03.2018; MD 1278 of 31.03.2019; MD1481 from 07.06.2021; Patent granting decision no. 9901, dated 15.10.2021; Patent granting decision no. 9902, of 15.10.2021 and four patent applications were filed: no. 2142 of 11.11.2020; no. 2243 of 27.09.2021; no. 2244 of 27.09.2021; no. 2245 of 27.09.2021. Also, the results obtained were imple-mented for the modernization of the grape seed drying plant within the S.C. AZAMET-GRUP SRL.

BALAN MIHAIL

THE PROCESS OF DRYING GRAPE SEEDS IN SUSPENDED LAYER

253.05 Processes and apparatus in the food industry

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