DOI: 10.5281/zenodo.3713368
CZU 66.047.75

DRYING INSTALLATION FOR GRANULAR PRODUCTS IN THE SUSPENSION LAYER

Mihail Balan*, ORCID ID: 0000-0002-7788-345X,
Mircea Bernic, ORCID ID: 0000-0001-6166-6947,
Natalia Ţislinscaia, ORCID ID: 0000-0003-3126-5792

Technical University of Moldova, 168, Stefan cel Mare bd., Chişinau, Republic of Moldova
*Corresponding author: Mihail Balan, *mihail.balan@pmai.utm.md*

Received: 01. 09. 2020
Accepted: 03. 18. 2020

Abstract. One of the main problems of wet plant products drying processes is the long duration of thermal tartarization, which consequently leads to the diminution of the quality indices. This problem is exacerbated in the case of oil products drying, high in fatty acids receptive to oxidation processes. For such products, especially granulation, as grape seeds are, drying in a suspended layer with microwave application is beneficial. This method allows automatic selection of already dried particles from the seed table and removing them from the heating zone, thus ensuring a maximum reduction of heat treatment time, so also favorable conditions for oxidation of fatty acids. The paper presents the construction of a laboratory installation for the study of the kinetics of drying processes in suspended layer with microwave application. The installation allows the online recording of the temperature, speed and humidity of the air in oilseeds and out and periodic recording of the mass decrease of the product.

Introduction

Taking into account that grapes contain up to 7% seeds, after their processing, in the Republic of Moldova annually approx. 18-20 thousand tons of grape seeds are obtained. The industrial processing of grape seeds reflects a number of specific technological operations including drying [4, 6, 16].

At the moment there are many researches in the field of drying process optimization of plant seeds, including grapes, through various methods of energy input: convection, in the microwave field, with the application of ultrasound, infrared rays, etc. Convection drying is one of the simplest and most commonly used methods, but which is accompanied by a long duration of the process, and as a consequence, diminished quality of the finished product (appearance of microflora, creation of oxidation conditions, etc.) [6, 13, 14].

Application of electromagnetic fields of different wavelengths (microwave, infrared, etc.) essentially intensifies the process, ensuring a much higher quality of dry seeds. Particular effects in order to obtain an optimal correlation between quality and energy consumption are observed when applying convection in combination with the energy of the electromagnetic fields [9, 10]. The application of ultrasound is an efficient source of intensification of the drying process of the plants of porous capillary structure highlighted but weaker to the seeds, however this method ensures a certain degree of sterilization "in the cold" [11, 15, 18].

Discussions, often contradictory, also take place in view of the state of the product layer upon drying (fixed bed, sliding bed, vibrating bed, fluidized bed, etc.) [12]. Although drying in mobile bed (fluidizing, vibrating or suspended) creates a better contact of the seed surface with the air and reduces the influence of the border layer, thus ensuring an intensification of the mass exchange between the product and the environment, however, most authors are skeptical about this method because of the risk of crack formation in the seed bark, caused by the mechanical impact between them or between the seeds and the walls of the drying chamber. However, we believe that the mobile bed can be successfully used in drying processes, but for this it is necessary that the velocity of the air flow is also determined due to the fact that the kinetic energy transmitted to the seeds is insufficient for the creation of cracks at collision.

In this case, one of the methods of the grape seeds drying process intensification can be considered to dry in a suspended layer with internal heat sources application - microwaves. This method increases the quality of the dry product and reduces the energy consumption due to the selective application of drying time for each particle, so that, once humidity is reached to the final value, the particle is eliminated from the heat treatment area. In order to research the above mentioned drying process, a laboratory installation has been developed which is described in the present article.

I. Materials and methods

Air flow and speed in the experimental drying plant have been determined based on the mass balance equation. The intensity of electromagnetic field required for the product lifting has been determined on the basis of heat balance equation, the constructive elements of the installation were selected through calculation of resistance. All these calculations were performed taking into account *MathCad 15* software.

The *3D SolidWord* 3D design software was used to design the installation.

The simulation of the kinematics and dynamics of the mixture of air (drying agent) and grape seeds was performed using the *ANSYS software*, applying the laws of numerical methods.

As the internal heating source was accepted *2450 MHz* frequency microwaves generated by a magnetron *2M210-M1 Panasonic* type rated power of *900 W*.

II. Results and Discussion

In order to obtain a stable seed bed, an air velocity corresponding to that of the floating particles it is required in our case 8.5 m/s, which cannot be modified. Thus, the variation of the productivity of the drying plant can be achieved only by changing the diameter of the aerodynamic tube in which this suspended bed is created, so the air flow is directly proportional to the productivity, and constitutes for grape seeds 430 $m^3/(h \cdot kg)$. Obviously, with an increased air flow and taking into account that not all the heat will be transmitted from the air to the product, the convection heating of the seeds in a suspended bed becomes unprofitable, it is accompanied by essential heat losses with the air used. In order to reduce the heat loss, the thermal energy released in the product (seeds) was accepted as a result of the electromagnetic fields - microwaves acting. Microwaves only possible to heat the product, excluding heat losses removed from the workroom with drying agent (air) and reducing them to the minimum from walls environment. At the same time, the given method of applying the heat energy allows the localization of the heating (drying) process only in the area of formation of the electromagnetic field, which coincides with the one of suspension (floating) of the wet granules, thus ensuring a good self-selection of the dry particles.

The drying system consists of the carcas 1 (figure 1) on which the construction elements are mounted, namely: the power supply unit consisting of the lock 5 driven by the electric motor 12; the drying system (air) supply system, consisting of the fan 4 operated by the electric motor 13 and the air filter 11; the aerodynamic tube 6 with a conical shaped section on which the drying chamber 8 is fitted, equipped with the magnetron 7; the exhaust system consisting of the exhaust pipe 9 and the cyclone 10.

The system is equipped with temperature sensors and humidity of the air mounted at the inlet and outlet of the aerodynamic tube 6. The air speed is controlled within the limits *0...20 m/s* by changing the fan speed 13 using the frequency converter 2, which allows us to ensure the suspended bed not only for grape seeds with other granular products that have a much higher floating speed. The temperature of the product in the microwave heating zone is measured with the *EC060V* type thermoset., measurement error ± *0,99ºC*. The mass decrease of the product is determined by the periodic extraction of samples from the drying area and their subsequent weighing on the electronic scale type *JJ2000B*, measurement error ± *0,01g*.

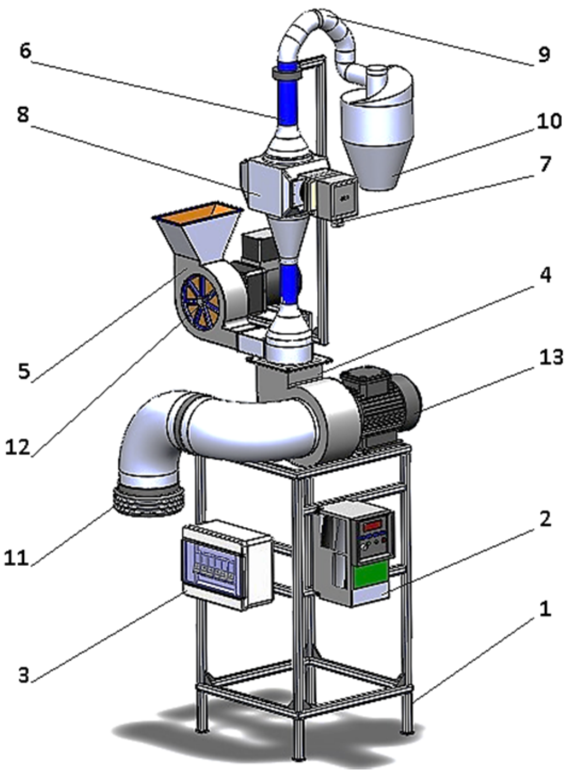

Figure 1. General view of the drying plant in suspended layer: 1 - carcase; 2 – frequency converter; 3 – control panel; 4 - fan; 5 - sluice; 6 – aerodynamic tube; 7 – magnetron; 8 – drying room; 9 – outlet pipe; 10 - cyclone; 11 - filter; 12 – electric motor; 13 – electric motor.

As mentioned above, the stability of the bed suspended by the seeds was ensured by the air speed being consistent with the speed of the floating seeds., but at the same time this is due to the specific shape tability of aerodynamic tube 6, which shows two truncated cones (a speaker and a biasing) overlay. The area of formation of the bed is in the place of overlap of these two geometric figures, in which the air velocity is maintained, corresponding to the speed of seed drift.

The geometrical shape of the aerodynamic tube 6 was developed using the computer simulation of the kinetics and dynamics of the air-seed mixture flow through it from the considerations of obtaining in the drying area a stable seed bed in suspended state (figure 2). Thus, the areas A and C is the maximum speed of the mixture (*aprox. 15 m/s*), so the particles travel through them without being noticed, and in zone *B* (consisting of a diffuser and overlapping confuser), due to the slow enlargement of the diffuser's diameter, the air velocity decreases to the value of the flowing of the wet seeds. (*8,5 m/s*) [3, 4]. Due to the inertia forces, the area in which the air velocity is set equal to that of the wet seed float was obtained in the second half of the confounder. This is where the product is heated in the microwave field. With the drying (mass reduction) of the particles, the floating speed also decreases, so that the already dried particles are driven by the flow of air and moved from the heating zone. Due to the further narrowing of the conical area, the air velocity increases, which ensures a better entrainment of the dry granules, which is further eliminated from the aerodynamic tube due to the increased mixing speed in zone *A* [5].

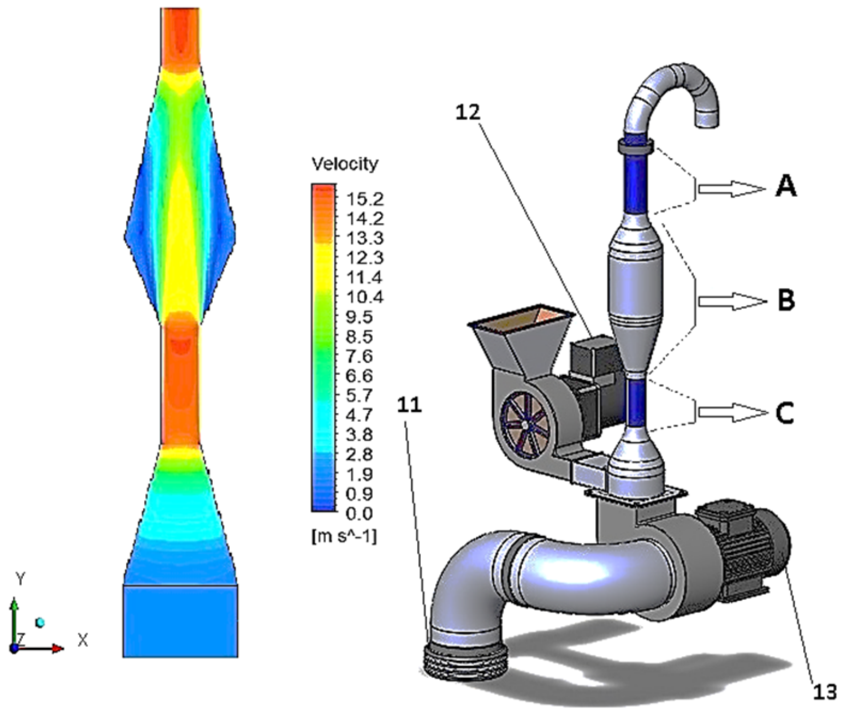

Figure 2. Variation of linear speed over the entire section of the tube with three zones.

Drying plant operates in the following way. The wet granules are charged through the lock *5* in the lower area of the aerodynamic tube, where they are taken by the air flow carried by the fan *4*. In zone *B* (in the middle of the confounder) the wet granules stop and go into a state of suspension, being in a Brownian state of motion. In the present area an electromagnetic field is formed, which subjects to volume heating air blown granules, drying them. The dry granules, losing weight, rise in the upper area of the confuser where they are driven by the air flow with increasing speed and through tube *A* they are conveyed in cyclone *10* where the separation of the dry product takes place.

Conclusion

The proposed laboratory installation for kinetics research of wet granular products drying process in a suspended layer and subjected to heat treatment with microwave application allows to obtain a stable suspended bed. The air speed can be adjusted within the range 0 - 20 m/s, which allows the installation to be used for a wide range of granular products, the floating speed within the given range. The possibility of regulating the temperature of the product within the limits of *20 – 100* ^{0}C is sufficient to research drying processes of wet granular products of plant origin. The installation allows online recording of temperature, speed and humidity of the air in and out and periodic recording of product mass decrease.

References

1. Ghid pentru producătorii de struguri pentru masă / elab. : *Gheorghe Nicolaescu, Panfil Apruda* - Ch.:"Iunie Prim" SRL,2007.-128 p.
2. Gracielle Johann, Maraisa Lopesde Menezes. Comparing models to Neumann and Dirichlet conditions in grape seed drying // Applied Thermal Engineering, Volume 93, 25 January 2016, Pages 865-871.
3. Moşneguţu Emilian. Contribuţii privind sortarea aerodinamică a produselor agricole, Universitatea Tehnică „Gh. Asachi" Iaşi, 2006, Facultatea de Inginerie Mecanică, Catedra Maşini Agricole.
4. Moşneguţu Emilian, Panainte Mirela, Savin Carmen. Separarea amestecurilor de particule solide în curenţi de aer verticali, Ed. Alma Mater Bacău, 2007.
5. Hong-Weili Tingwang, Changchang Binsun Wen-Penghong, Yun-Long Zhou. Multi-scale nonlinear analysis of drying dynamics in the mixed pulsed drying fluidized beds. // Powder Technology, Volume 339, November 2018, pp. 958-969.
6. Roberts J.S., Kidd D.R., Padilla-Zakour O. Drying kinetics of grape seeds. Journal of Food Engineering, Vol. 89, Issur 4, 2008, pp. 460-465.
7. Burdo O.G., Bandura V.N., Levtrinskaya Yu. O. Electrotechnologies of targeted energy delivery in the processing of food raw materials. / Journal Surface Engineering and Applied Electrochemistry. Vol. 2, Issur 2, 2018, pp. 210-218.
8. Clemente G., Sanjuán N., Cárcel J.A., Mulet A. Influence of temperature, air velocity, and ultrasound application on drying kinetics of grape seeds . *Drying Technology* 2014 , 32 (1), 68 – 76.
9. Rute Quelvia De Faria, Amanda Rithieli Pereira Dos Santos, Yvan Gariepy, Edvaldo Aparecido Amaral Da Silva, Maria Márcia Pereira Sartori, Vijaya Raghavan. Optimization of the process of drying of corn seeds with the use of microwaves. *Drying Technology* 2019 , pp.37 (14), p.1745 – 1756.;
10. Bernic Mircea. Uscarea produselor oleaginoase in camp UHF cu aport de energie prin impuls. Ch.: 2011, 271 p.
11. Gabriela Clemente, Neus Sanjuan, Juan Andres Carcel, Antonio Mulet. Influence of Temperature, Air Velocity, and Ultrasound Application on Drying Kinetics of Grape Seeds. *Drying Technology* 2014 , 32 (1), pp. 68 – 76.
12. M. A. S. Barrozo A. Mujumdar &J. T. Freire. Air-Drying of Seeds: A Review. *Drying Technology* 2014 , 32 (10), pp. 1127 – 1141.
13. John S. Roberts, Olga Padilla-Zakour, David R. Kidd. Drying kinetics of grape seeds. *Journal of Food Engineering* 2008, 89 (4), pp. 460-465.
14. S. Azzouz I. Hermassi R. Chouikh A. Guizani, A. Belghith. The convective drying of grape seeds: Effect of shrinkage on heat and mass transfer. *Food Process Engineering* 2017, 41 (1).
15. Magdalena Sledz, Artur Wiktor, Malgorzata Nowacka, Dorota Witrowa-Rajchert. Drying Kinetics, Microstructure and Antioxidant Properties of Basil Treated by Ultrasound. *Food Process Engineering* 2017, 40 (1).
16. Jun Wang, Arun S. Mujumdar, Weisong Mu, Jianying Feng, Xiaoshuan Zhang, Qian Zhang, Xiao-Ming Fang, Zhen-Jiang Gao And Hong-Wei Xiao. Grape Drying: Current Status and Future Trends. *Grape and Wine. Biotechnology. Capter 7* Editors Antonio Morata, Iris Loira, 2016 pp. 145-167.
17. G. Clemente, N. Sanjuan J. Bon, R. Peña J.V. Garcia-Perez. Grape Seeds Dehydration under Forced Convection Conditions. *Defect and Diffusion Forum* (Volumes 283-286), 2009, pp. 610-615.
18. Visanu Vitali. Peaches convective drying. DOI: 10.5281/ZENODO.2557337. CZU 664.854:634.25. 2018.