International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

IJIEMR Transactions, online available on 25th Feb 2021. Link : https://ijiemr.org/downloads/Volume-10/Special

DOI: 10.48047/IJIEMR/V10/I03/51

Title: **RESEARCH OF THE PROCESS OF APRICOT FRUIT DRYING WITH INSTANT PRESSURE RELEASE**

Volume 10, Issue 03, Pages: 219-226.

Paper Authors
Rustamov E.S.[1], Djuraev Kh.F.[2], Gafurov K.Kh.[3]

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.o

RESEARCH OF THE PROCESS OF APRICOT FRUIT DRYING WITH INSTANT PRESSURE RELEASE

Rustamov E.S.[1], Djuraev Kh.F.[2], Gafurov K.Kh.[3]

[1]doctoral student PhD, [2]doctor of technical sciences, professor,

[3]candidate of technical sciences, associate professor,

[1,2,3] Department of machinery and equipment for the food and chemical industries. Bukhara Engineering-Technological Institute,

e-mail: kgafurov@yahoo.com **e-mail:** relyor@inbox.ru

e-mail: djuraev_xf@mail.ru

Abstract. The article covers the task of rational drying of fruits (on the example of apricot) using the method of high-pressure exposure to product with its sharp release; the analysis of structural changes of dried material at the moment of drying under high pressure; research of kinetics of material drying in zone of instantaneous pressure release.

Local apricot variety (*Subhoni*) was the subject of the research. Fruits of this variety contain up to 25% sugar (sucrose, fructose and glucose). Organic acids are mainly malic and citric. Fruits are rich in mineral salts, trace elements, organic acids, pectin substances, and various vitamins: *A, C, B1, B2, PP*. Initial humidity makes 80-85%.

Results of research of drying apricot fruits process by the so-called thermo mechanical method are given. In this method product is subjected to simultaneous infrared heating and pressure treatment above atmospheric pressure for several minutes in a special chamber, followed by instantaneous pressure release and subsequent convective drying. Theoretical basis of increase of moisture removal rate at instantaneous pressure release is given. The rational value of pressure, at which the rate of preliminary moisture removal is greatest, is determined. Research carried out on the example of drying apricot fruits show that the proposed drying technology has a number of advantages:

- Decrease in duration of the completely drying process by almost 2.0 times compared to the traditional convective mode,

- Accelerated process of moisture removal from the dried object is developed,

- Reduction of power consumption due to reduction of drying time
Keywords. apricot fruits, thermo mechanical treatment, infrared heating, pressure, instantaneous pressure release, humidity, porous structure.

I. Introduction.

The preservation of fruits and vegetables by drying is one of the oldest types of conservation. Humidity of dried fruits and vegetables is 8-25%, which ensures their long storage. Drying not only extends the shelf life, but also provides high preservation of quality and nutrients of the raw materials. In addition, the mass of the product decreases by 75-80%during drying, which significantly reduces transportation costs.

There are various drying methods; however, a necessary requirement for all methods is to ensure the high quality of the dried product at the lowest production costs.

Production of agricultural products is increasing every year in Uzbekistan, for example, 9 945.5 thousand tons of vegetables, 1 922.2 thousand tons of melons and gourds, 2 739.6 thousand tons of fruits and berries and 1 595.2 thousand tons of grapes were harvested in 2019 (UzDaily.uz.2020).

However, currently only 20% of these products are industrially processed. Therefore, the development and implementation of new drying methods that ensure high quality of the final product at low costs is relevant.

In this article we consider the problem of rational drying of fruits (on the example of apricot) using the method of high-pressure exposure to product with its sharp release; the analysis of structural changes of dried material at the moment of drying under high pressure; research of kinetics of material drying in zone of instantaneous pressure release.

Analytical review of the literature. Scientific and technical literature gives an analysis of the combined thermo mechanical method of drying materials: heating the wet material under the influence of pressure with its subsequent release. So, in the work of (Lashkov and Kondrashov, 2011), a review of studies on this subject is given, where it is said that dehydration at the expense of thermal energy accumulated by material was first used in the works of V.V. Yagov et.al. in the process of drying by pressure “release”. Physical basis of this method is the maximum use of the effect of intense molar transfer of steam that occurs after pre-heating the wet material under pressure and its subsequent rapid decline. The value of the initial pressure determines the depth of heat treatment of the material.

In other works positive experimental results were obtained on the application of this method for drying wood (Kozhin and Gorbachev, 2011) and dispersed materials (zeolite, lignin, and peat) (Slijuk and Akulich, 2015). Thus, in the work (Slijuk and Akulich, 2015), the application of the combined drying method for zeolite using microwave heating allowed to reduce the drying time by 1.5 times compared to the convective method at the same temperature conditions.

The work (Patent China CN102417286B. 2011) implements a method for instant drying of fruits, including pre-heating the fruits, pressure release in the drying hopper, repeating the step followed by vacuum drying, until the mass humidity of fruits and vegetables reaches 10-25%. However, existing pressure release drying technologies cannot be used for our local raw materials. Therefore, the determination of rational operating parameters of drying with pressure release calculated on local raw materials is relevant.

The purpose of the work is to research the process of removing moisture from the capillary-porous layer (of half of apricot) using a combined thermomechanical drying method to produce a dried product.

In accordance with the purpose of the study, the following objectives were set:

- research of influence and instantaneous release of air pressure as drying agent during treatment,

- analysis of structural changes of the material to be dried at moment of high-pressure treatment;

- research of material drying kinetics in the zone of instantaneous pressure release.

Material and methods of research. The object of the study was selected local variety of apricot (*Subhoni*). The fruits of this variety contain up to 25% sugar (sucrose, fructose and glucose). Malic and citric acids mainly represent organic acids. Fruit is rich in mineral salts, trace elements, organic acids, pectin, and various vitamins: *A, C, B1, B2, and PP*. The initial humidity makes 80-85%.

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

Apricot is a plant mainly aimed to be dried, and is widely used in drying (Baymetov et al., 2011).

From the fruits uryuk (dried apricot fruit with a seed), kaisu (dried completely apricot fruit without a seed), kuraga (half slices of apricot) are prepared. For our case, kuraga with the final moisture content of 18-20% were obtained.

Before drying apricots have been washed, cut into two halves with the separation of seeds and processing the material in a solution of citric acid.

Laboratory installation was created to study the combined drying method using pressure release and infrared (IR) heating, (Fig.1).

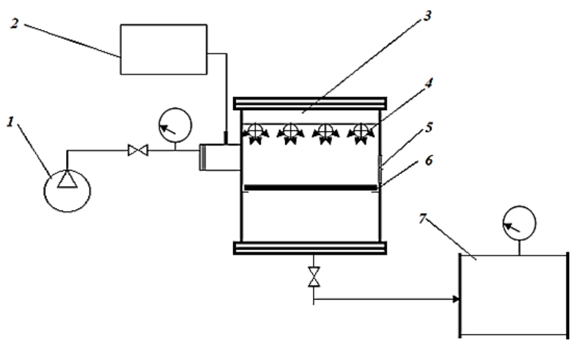

Fig. 1. Scheme of the experimental laboratory setup:

1 - compressor; 2 - automatic data collection system using a personal computer; 3 - hermetic chamber for thermomechanical processing of product samples; 4 - IR emitters;

5 - window for feeding a tray with product samples; 6- tray with a product; 7 - receiver.

The base of the installation is a hermetic special chamber, in which the tested samples of material are placed. The tray for material is a container with a mesh bottom (dimensions of cells is 6x6 mm, wire diameter is 0.6 mm); a hinge of apricot halves with thickness of 8-10 mm was placed in the tray. The tray is placed on silenced stands. IR generators for material heating are above the tray. The chamber has a quartz glass window.

Chamber is equipped with compressed air supply system with automatic support of preset pressure. The unit has a special valve and receiver for moisture removal by pressure release. The installation allows heating the sample under pressure to 0.8 MPa and pressure release. The sample is heated using 1 kW infrared sources.

The installation is equipped with a control system and automatic data collection of indicators of the heating process and pressure release. The main indicators that allows controlling and managing the process are temperature are humidity of the material and pressure in the chamber.

The source material first processed in a hermetic chamber by pulsed infrared radiation and pressure with instant pressure release, and then subjected to simple convective drying in a drying chamber.

Moisture content of the material was defined in accordance with State standard 33977-2016 (Interstate standard. Products of processing of fruit and vegetable. Methods for determining the total content of dry matter. Fruit and vegetable products. Methods for determination of total solid content).

Modern methods of mathematical design of the experiment, methods of study of the moisture content of apricot in the initial, intermediate and final points of the drying process have been used in the work.

Results of the research and their discussion. Number of theoretical and experimental studies were carried out to solve the problems set. The physical basis of the proposed method of fruit drying is a concept according to which by increasing the pressure and heat treatment the possibility of changing the temperature of the material is created, which, in turn, allows the maximum use of the effect of intensive molar transfer of steam, which ensures the transition of moisture to a free state. Due to this, the boundary between bound and free moisture during pressure release shifts to the region of lower moisture content. At moment of pressure release throughout the entire volume of the product, a rapid advance of moisture occurs; a pressure drop between the center and the surface of the processed material is created, which contributes to the formation of a moisture stream directed to the surface of the particle in the form of steam. On its way, the vapor-air mixture carries liquid droplets and pushes to the surface (Lashkov, 2011; Potapov et al., 2013).

As we know, the temperature during an adiabatic compression process in the compressor is related to pressure (Ginzburg, 1973):

$$t_{out} = (t_{in} + 273)\left(\frac{P_1}{P_0}\right)^{\frac{q-1}{q}} - 273, \quad (1)$$

where t_{out}- compressor outlet temperature, ^{0}C; t_{in} - compressor inlet temperature, ^{0}C; P_0- compressor inlet pressure, Pa; P_1- compressor outlet pressure, Pa; q- adiabatic exponent for air (q=1,4).

The calculations performed according to this formula showed that with increase in pressure from 0.2 to 0.4 MPa, the temperature at the outlet of the compressor increases slightly, that is, from 40 to 42°C. This means that the process in the installation is polytrophic and q<1.4; accordingly, the temperature of the vapor-air mixture at the outlet is almost unchanged.

The adiabatic conditions of moisture evaporation, depending on the purpose of the process, lead to a decrease in the temperature of the material, change in the concentration of liquid in the volume of the dried material, or modification or destruction of its structure.

It should be noted that drying with sharp reduction of pressure in adiabatic conditions due to positive temperature gradient significantly increases efficiency of moisture removal from capillary-porous materials. By pressure release in the chamber, an overpressure inside the material corresponding to the temperature of the liquid in the layers of the material is formed, as a result of which a positive overpressure gradient is created along the cross-section of the dried particle. Accordingly, when external conditions change, pressure relaxation can be achieved (Lashkov and Condrasov, 2011; Potapov et al., 2013).

In the proposed installation, the microcapillaries containing water molecules are destroyed in the process of increasing the pressure of the drying agent in the structure of the material to be dried, and in case of sharp reduction of pressure, the intensive movement of the water molecule from the inner layers of the material to the surface layers is distinguished. At the same time, the product is placed in a hermetic system, in which pressure up to 0.8 MPa is created via compressor. The material is treated for 4-6 minutes, then the pressure is released and the vapor-liquid mixture is removed from the system. The results of the analyses showed that in this treatment method air as a drying agent fully uses its potential, at the same time 8-14% of moisture of its total amount is removed depending on the pressure created. Then the material is subjected to simple convective drying till moisture content is equal to 19-20%.

Drying speed determines one of the most important technological parameters - the rate of evaporation of moisture from the material m, which is expressed by the amount

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

of moisture evaporated from a unit surface of the material F per unit time.

$$m = \frac{W}{F \cdot \tau} \qquad (2)$$

Pre-weighed apricot halves were taken for the experiments; the thickness of the material layer on the pallet was $\delta = 4$ mm. The material is subjected to heat treatment using infrared emitters with a radiation flux density $q = 1.5$ kW/m^2. The choice of the radiant flux density in the range of 1.5 kW/m^2 is due to the fact that a decrease in the radiant flux density leads to an increase in the duration of the heat treatment process, and an increase in the radiant flux density leads to overcooking of the material layer surface (Patent RUz No. IAP 03373, 2007). Heat treatment is performed in intermittent irradiation mode. The radiant flux density and processing time, for various pressures, remained unchanged. The initial moisture content of the material is $W_i = 78.0 \pm 1.0\%$.

Material was exposed to IR heat treatment at pressures P_1= 0,4 MPa, P_2= 0,6 MPa and P_3= 0,8 MPa for 6 min, followed by instantaneous pressure release till atmospheric one. The residual moisture of the material after each pressure was W_{res1}=70%; W_{res2}=67%; W_{res3}=64%. Thus, the moisture removal rate at P_1= 0.4 MPa is 1.33%/min, at P_2= 0.6 MPa is 1.83%/min, and at P_3= 0.8 MPa is 2.33%/min

From this it can be concluded that the pressure created in the chamber is more affected by the removal of preliminary moisture from the material. This means that due to the creation of a certain pressure and its instantaneous release, there is an intensive movement of moisture between the center and the surface of the processed material in the fruits. This, in turn, determines the possibility of accelerated movement of moisture from the inner layers of the material to the surface. As a result, the process of moisture removal is accelerated by 1.75 times, if we compare the rate of moisture removal at P_1= 0.4 MPa and P_3= 0.8 MPa.

Further, the material is subjected to simple convective drying at the same temperature conditions.

A comparative analysis of the experiment results on combined thermomechanical and convective drying with the above modes showed (Fig.2) that at a pressure of P= 0.8 MPa and a thickness of δ= 4 mm of the product (curve - 1), the drying process is reduced to 40 - 50 min compared with the process at a pressure of P=0.4 MPa (curve - 3). Thus, it is possible to choose a mode in which the processing pressure is P = 0.8 MPa.

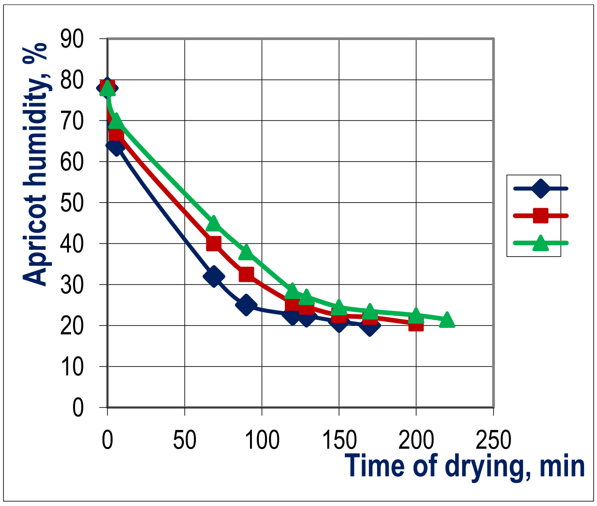

Fig 2. Kinetics of drying of apricot fruit (halves) during preliminary thermomechanical processing under pressure:
1-P=0,8 MPa; 2-P=0,6 MPa; 3-P=0,4 MPa
IR flux density q=1,5 kW/m^2.

The drying process was studied using mathematical planning methods in order to

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

obtain a mathematical dependence reflecting the dependence of the speed and drying coefficient, product moisture on influencing factors.

The experimental design for the physical dimension of factors (P, t_M, δ) and in the dimensionless expression (x_1,x_2,x_3) is presented in Table 1.(Rustamov E.S. et al. 2020)

Table 1. The experimental design for the physical dimension of factors (P, t_M, δ) and in the dimensionless expression (x_1,x_2,x_3).

No	Indicators	P, MPa	x_1	$t_м$, °C	x_2	δ, mm	x_3
1	Maximum	8	+1	65	+1	6	+1
2	Minimum	4	-1	50	-1	2	-1
3	Medium	6	0	57	0	4	0

Processing the results of the experimental data allowed to obtain the following equations for calculating the moisture content of the product *W*, the average values of the constant drying rate in the first period of the process *N*, and the drying coefficient in the second period of the process *K*.

$$W = 48{,}3 - 4{,}625x_1 - 0{,}125x_2 + 2{,}875x_3 + 1{,}375x_1x_2 + 1{,}375x_2x_3 - 0{,}125x_1x_3 + 0{,}875x_1x_2x_3$$

$$N = 0{,}97 + 0{,}088x_1 + 0{,}01x_2 - 0{,}0362x_3 - 0{,}0412x_1x_2 - 0{,}0287x_2x_3 - 0{,}00375x_1x_3 - 0{,}0212x_1x_2x_3$$

$$K = 0{,}91 + 0{,}0925x_1 + 0{,}05x_2 + 0{,}0175x_3 + 0{,}02x_1x_2 + 0{,}015x_2x_3 + 0{,}0025x_1x_3 + 0{,}01x_1x_2x_3$$

The obtained dependences adequately describe the apricot fruits drying process and allows calculating the values of *W*, *N* and *K* with error of up to ± 5.0%, that is, within the limits of the change in the parameters of the studied process.

Comparative experiments on the convective drying of apricot samples with specific energy costs approximately equal to those during drying by pressure release at *P*=0.8 MPa and with the same product thickness were conducted in order to evaluate the effectiveness of the proposed drying method. Data on moisture removal from apricot fruits are presented in Fig. 3.

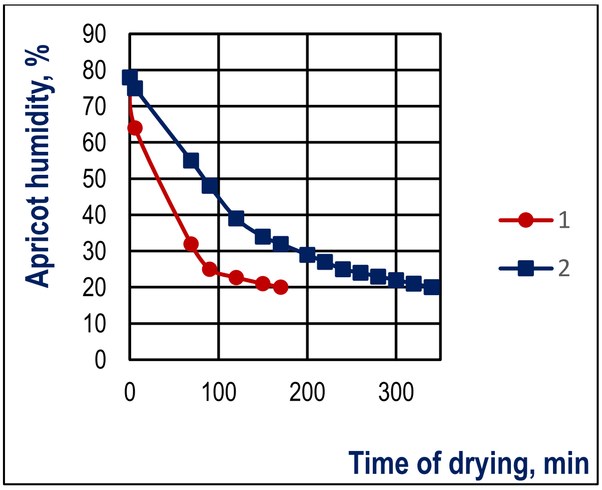

Fig. 3. Kinetics of drying of apricot samples (halves):

1 - method of combined thermomechanical drying at *P*=0.8 MPa; 2 –convective method

As can be seen from these data, the drying time of the apricot fruit halves to a moisture content of $W_к$ = 20% by the convective method makes 330 minutes, and by the thermomechanical method with pressure release and further combined drying makes 170 minutes. The application of the proposed drying method for halves of apricot fruit can reduce the drying time by 1.94 times compared to the convective method at the same temperature.

Therefore, based on the data of experimental studies, we can conclude that it is possible to intensify the process of dehydration of fruits by the method of pressure release and the use of infrared heating.

Conclusions. In the thermomechanical method, wet material is preheated in a hermetic chamber where the pressure increases. In case of rapid pressure release from the chamber due to accumulated heat, in the volume of material active vapor formation takes place. The molar vapor stream mechanically emits a portion of the moisture in the form of liquid particles (droplets), thereby reducing the energy required to remove the moisture. Organoleptic indices of dried products meet the requirements of state standard 32896-2014 (Interstate standard, dried fruit, put into force in 2016):

- appearance and shape – halves of dried fruits of regular oval shape with slightly wrapped edges;
- taste and smell – characteristic for the fruits of this kind, without extraneous taste and smell;
- color – uniform bright orange, typical for well-raped apricots.

Research carried out on the example of drying of apricot fruits show that the proposed drying technology has several advantages:

- decrease of duration of the entire drying process by almost 2.0 times in comparison with traditional convective mode,

- accelerated process of removing moisture from the object to be dried is developed,

- decrease in energy consumption at the expense of decrease of drying time.

REFERENCES

1.Baymetov K.I., Turdieva M.K., Nazarov P. Features of the cultivation of local varieties of apricot in Uzbekistan. - Tashkent, 2011. 26 p.: Received from http://www.agriculture.uz/filesarchive/abrikos-rus.pdf

2.Ginzburg, A.S. (1973). The basics of theories and techniques of food drying. – Moscow: Food Industry, 1973. -528 p.

3.Kozhin V.P., Gorbachev N.M. Application of the pressure relief method for high-temperature oscillating drying of large wood // Engineering Physics Journal. 2011. Volume 84, # 2. P. 223–229.

4.Lashkov V.A., Kondrasheva S.G. (2011). Overview of the use of the effect arising from a decrease in the pressure of a vapor-gas medium // Journal “Bulletin of Kazan Technological University, - P.210-215. Received from https://cyberleninka.ru/article/n/obzor-napravleniy-ispolzovaniya-effekta-voznikayuschego-pri-ponizhenii-davleniya-parogazovoy-sredy

5. Lashkov V.A. Hardware design of processes that occur when lowering the total and partial pressures of a combined cycle gas medium // Bulletin of Kazan Technological University. - 2011.-Vol. 14, # 8.- P.210-215.

6. Rustamov E.S., Djuraev Kh.F., Gafurov K.Kh. Kinetics of fruit crops drying with instant pressure release // The American Journal of Engineering and Technology. Volume 02 Issue 10-2020.P.45-54.

7. Patent China CN102417286B. 2011- Steam pressure relief method and device for sludge hydrothermal drying steam pyrolysis reaction kettle. Received from https://patents.google.com/patent/CN102417286B/en

8. Patent of the Republic of Uzbekistan No. IAP 03373 - 05/30/2007, "Method for drying fruits".

9. Potapov V.A., Gritsenko O.Yu., Ponomarenko Yu.O. (2013). Research of the

drying process in mass transfer modules under the influence of high pressure // Report in the collection of scientific works "Progressive Technique and Technologies of Food Production of Restaurant Facilities and Trade", Kharkov, Ukraine. P.148-153.

10. Slizhuk D.S., Akulich P.V. Kinetics of drying dispersed materials in a combined way using microwave heating // Web conference "The First International Lykovsky Scientific Readings dedicated to the 105th anniversary of Academician A.V. Lykova - Moscow 2015, P.58-62. Received from http://drying-committee.ru/dl.php?f=536

11. UzDaily.uz. (02/05/2020). Agriculture, forestry and fisheries of the Republic of Uzbekistan in January-December 2019. Received from. https://www.uzdaily.uz/ru/post/49276.