Reducing of Energetic Costs for Drying Process for Candied Pears Production

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***Abstract* – According to calculations of the heat balance were calculated amounts of energy accumulated by pears layer and energy required to evaporate moisture. It was determined that reduce of energy costs for candied fruits drying is achieved by final drying at ambient temperature.**

Key words – candied pear, drying, temperature conditions, kinetics, heat balance.

I. Introduction

One of the priority directions of development of food industry of Ukraine is the production of candied fruits. At present, main attention in the production of candied fruits is paid to the processes of saturation of raw materials with sugar and its subsequent drying, as well as to examination of physical and chemical composition of the finished product. The most prolonged and energy–consuming stage of the production of candied fruits is drying. Ukraine is an energy–dependent state, that is why theoretical and experimental research aimed at reducing energy consumption is promising. In addition, cuts in energy consumption positively influence the cost of the finished product and its sales market.

According to authors [1], during filtration drying, the resistance of layer of material, through which thermal agent is filtered, determines energy costs of the process. That is, hydrodynamic processes in a layer significantly influence the course of heat mass exchanging processes. The formation of a layer with maximum possible specific surface and the same equivalent diameter over entire height will reduce hydraulic resistance of the layer. However, in the case of drying polydisperse materials, such uniformity is impossible to achieve. Only the layer, systematically formed out of particles of the same size and shape, will make it possible to reduce hydraulic resistance.

The research into fluid motion through the cubic, semi–cubic, trapezoidal, parabolic channels prove significant influence of the shape of channel, washing perimeter, and equivalent diameter on the consumption and speed of fluid [3]. It was proven that the cubic section has the lowest hydraulic resistance, which reduces energy expenses for the process.

So the filtration method of drying appears to be interesting, the essence of which lies in the filtration of gas flow in the direction of "stationary layer of candied fruits – perforated partition". Its advantage is, first of all, a large area of contact of the candied fruits particles with thermal agent. This approach to the methods of the formation of a layer of candied fruits and solution to the problems of hydrodynamics during filtration of gas flow through the formed layer of candied fruits has both practical and theoretical interest.

II. Page Setup

Preparation of the raw material was realized as following: pears was washed peeled of rind and film, cut in whole pieces with height ≥ 20 mm. With the help of matrix the cubic particles with equal sizes (20x20) were formed. The layers 3 were formed of the received particles in containers (Fig. 1).

The general container of cylindrical form for the study of hydrodynamics consisted of four containers with height 30 mm, each of them corresponds to the scheme, presented on the Fig. 1. Containers 1 and perforated barriers 2 are made of fluoroplastic 4D.

Prepared candied fruits were divided into two halves. The first half was left in the syrup with temperature 80^0C, the second half - in the cooled syrup with temperature 20^0C. After separation from the liquid phase hot (80^0C) and cold (20^0C) candied fruits were dried separately. Slices were spread out in a container made of Teflon (Fig. 1) on four perforated partitions 30 pieces per each. Drying was performed thru filtration of hot heat agent (100^0C) at a speed of 6 m/s, according to the methodology set in [2].

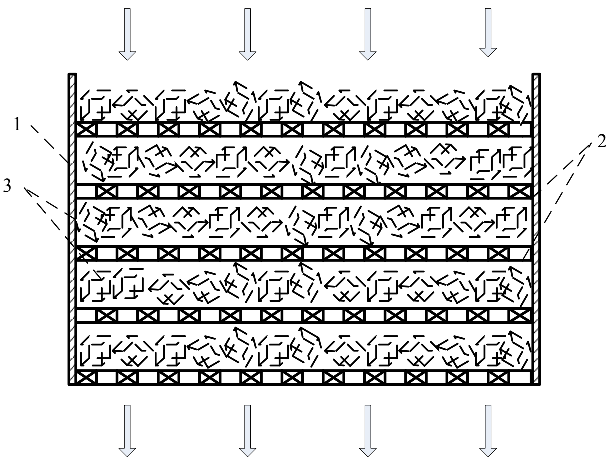

Fig. 1. Scheme of container for candied fruits drying

Hot candied fruits still need 500 sec more for final drying until final moisture content (Fig. 2), cold candied fruits need 1000 sec (2 times more) for final drying.

Studied material doesn’t have period of intense surface evaporation of free moisture. The rate of drying in this case is determined by the rate of diffusion in the middle of the material. In the middle of plant material occurs transfer of moisture in liquid form through pores and cracks in the cell walls to the intercellular space and from it to the surface of the plant material. This liquid mass transfer is done by internal molecular diffusion. From the surface of candied fruits slices moisture evaporates in the heat agent in the form of steam.

Lower speed and, therefore, a longer drying time of cold candied fruits depends primarily from thermodiffusion transfer of moisture inside the particles under the influence of temperature difference on the surface, which is approximately equal to the temperature of the thermal agent and middle of the particles, that are warmed slowly. Thus, a significant temperature gradient becomes an opposition for movement of water from the depths to the surface of the material where the temperature is higher than in the inner layers. After heating of particle throughout the whole volume moisture from the middle of the particle diffuses back to the surface.

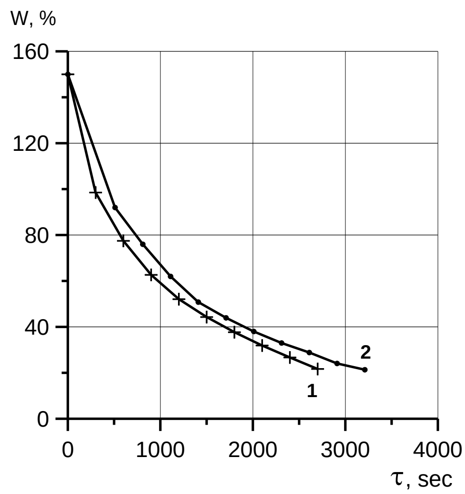

Fig. 2. Kinetic curves of drying of hot (1) and cold (2) layers of candied pears

III. Page Setup

During drying of hot candied pears layer vast majority of energy is expended on evaporation. Therefore, the rate of cold candied fruits drying is 1.3 times lower, than for hot.

Candied fruit drying process is long and, as a result, energy-intensive. Therefore, authors proposed a way to reduce energy costs of candied pears drying process. For this authors analyzed cost of heat spent in the drying process, which is described by the equation:

$$Q_{t.a.(\tau=n)} + Q_{dry1.(\tau=n)} + Q_{water(\tau=n)} = \\ = Q_{evap.(\tau=n+1)} + Q_{t.a.(\tau=n+1)} + Q_{dry1.(\tau=n+1)} + Q_{water(\tau=n+1)} \quad (1)$$

Using heat balance equation (1), lets calculate the amount of heat accumulated by layer of pear:

$$Q_{layer} = Q_{dry1.(\tau=n)} + Q_{water(\tau=n)} + Q_{dry1.(\tau=n+1)} + Q_{water(\tau=n+1)} \quad (2)$$

Than amount of thermal agent heat in time moment τ :

$$Q_{t.a.} = G_{t.a.} \cdot c_{t.a.} \cdot (t_{t.a.in} - t_{t.a.out}) \cdot \tau \quad (3)$$

Amount of heat used for moisture evaporation in time moment τ

$$Q_{evap} = G_{evap} \cdot r \cdot \tau \quad (4)$$

For the hot candied fruits at time 1800 sec we have energy accumulated by layer of pears – Q_{layer} = 62,64kJ while for moisture evaporation (to achieve a final moisture content of 25%) material needs Q_{evap} = 28.82 + 25.82 = 54.64 kJ. This means that for 1800 sec. moment, the amount of energy accumulated by pears layer will be sufficient to evaporate moisture, which must be removed in the next 500 sec.

For cold candied fruits on time moment 2310 sec. amount of energy accumulated by layer of pears - Q_{layer} = 49,94 kJ while for moisture evaporation (in order to achieve final moisture content) material needs Q_{evap} = 20.62 + 23.60 = 44.22 kJ. As we can see, at 2310 sec, the amount of energy accumulated by layer of pears will be enough to vaporize residual moisture from material.

According to the obtained experimental and calculated data the authors assumed that after reaching drying time of 1800 sec. for the hot candied fruits and 2310 sec for cold it is expedient to apply thermal agent with a temperature of 20^0C and pursue drying to final moisture by cold thermal agent. Thus saving of thermal agent heat, as shown in Tables 2 and 3, will be:

for hot candied fruits $Q_{t.a.} = 20.12 + 17.44 = 37.56$kJ,

for cold candied fruits $Q_{t.a.} = 16.098 + 15.43 = 31.53$kJ.

Conclusion

After drying by proposed method and 6 months storage candied pears have a firm texture, found no signs of mold and fermentation, are not stuck together. The results of experimental studies and theoretical calculations found that after reaching of drying time for the hot candied fruits – 1800 sec. and 2310 sec. for cold, it is expedient to apply thermal agent with 20^0C temperature for final drying to a final moisture content. That will help to reduce energy costs of the process.

The offered experimental studies indicate the necessity of drying candied fruits in the package of systemically formed layers. Such drying method can be introduced in production after enrichment of experimental data.

The experiments prove the expedience of the candied fruits layer formation of the cubic particles of correct. Such method allows provide the insignificant hydraulic resistance of the layer and rather high speed of the gas flow filtration through this layer. It would result in the increase of heat transfer and mass output coefficients, so to the intensification of filtration drying. Such formation method also allows reduce the volume of drying equipment, shorten the time of drying.

On the base of experimental data the necessity of further calculation, modeling and optimization of the values of hydraulic resistance of the layer and the gas flow speed in it appeared.

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