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REDUCING OF ENERGETIC COSTS FOR DRYING PROCESS FOR CANDIED PEARS PRODUCTION

The article investigates changes of temperature conditions for the drying process in the candied pears production. Experimental study on heat transfer and candied pears drying kinetics under different temperatures was conducted. Feasibility of the candied fruits drying process under temperatures equal to the temperature of the hot thermal agent is experimentally confirmed. 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.

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ЗМЕНШЕННЯ ЕНЕРГЕТИЧНИХ ЗАТРАТ ПРОЦЕСУ СУШІННЯ У ВИРОБНИЦТВІ ЦУКАТІВ З ГРУШ

Досліджено зміни температурних режимів процесу сушіння у виробництві цукатів з груш. Проведені експериментальні дослідження з теплообміну та кінетики сушіння цукатів з груш за різної температури. Експериментально підтверджено доцільність проведення процесу сушіння за температур цукатів, що дорівнюють температурі гарячого теплового агенту. Згідно з тепловим балансом розраховано кількість енергії, накопиченої шаром груші, та необхідної енергії для випарювання вологи. Встановлено, що зменшують енергетичні затрати на сушіння досушуванням цукатів за температури навколишнього середовища.

Ключові слова: груша, цукат, сушіння, температурні режими, кінетика, тепловий баланс.

Formulation of the problem. Production of new foods that have high biological value and can be produced from local raw materials can be included in the priorities of Ukraine's food industry. Candied fruits are such useful products and their consumption is growing every year.

Candied fruits – a product that is made from fruits, berries and vegetables matured in sugar syrup and dried to a specific moisture [1–3]. As food they have several advantages over other confectionery thanks to content of beneficial for the human body substances, mineral salts, minerals, pectin, vitamins, etc. At Ukrainian market candied fruits are represented mainly by products from tropical and subtropical fruits that come from foreign countries.

Today in Ukraine we can observe growth of interest to production of candied fruits from domestic raw materials. For example widespread domestic pear is a source of useful components. It contains sugar, starch, volatile, flavonoids, organic acids, dietary fiber, starch, tannins. Also pear contains vitamins A, B, C, K, E, H, PP, beta carotene and folic acid. Due to this search of new and improvement of existing technologies of candied fruits is an urgent task.

Analysis of recent research and publications. The most common candied fruits technology is proposed by the authors [4, 5]. According to it preparation of raw materials is needed, saturation in sugar syrup 50–75 % (wt.) until solids content of 40 % (wt.), separation from syrup and drying to residual moisture of 20–25 %. Sugar saturation occurs at temperatures below the boiling syrup temperature. Authors [6] offer the following technology of candied pears manufacturing: materials preparation, cutting in slices or pieces of certain shape 8-20 mm size, 8-15 min blanching, holding in a solution of citric acid at a temperature of 25–65 ° C, 2–3 times holding in boiling syrup, drying.

Candied fruits drying technology, considered by the authors [7], is performed by convective – thermoradiative way of power supply with pulsed infrared radiation under temperature of heat agent 40–90 ° C and the dryer unit load 0,5–50 kg / m2, with density of heat flow from 1 to 4,7kVt / m2. Authors [8] proposed the following method: soaked in sugar syrup at temperatures of 60–70 ° C candied fruits are placed on a sieve for syrup draining, dried in a closed desiccators at 40 ... 45 °C. The analysis of many literature sources of allows to conclude that there are no unambiguous approach to production technology and drying of candied fruit, so solving of this problem requires detailed experimental studies aimed at reducing of energy costs and improving of candied fruits quality.

The purpose of the work. The aim of this work is study of kinetics of experimental drying of candied pears and establishing the nature of change in temperature of the thermal agent under a layer of hot (80 ^{0}C) and cold (20 ^{0}C) candied fruits. Calculate heat balance and theoretically confirm proposed way of reducing of energy costs for drying, using experimental data.

The main material and discuss the results. The object of the study were the fruits of “Beurre Bosc” pear. Fruits were above average size or large – 150–190 gr., some – 220–245 gr., elongated. The skin was thin, pale yellow with golden hint. The pulp is white or yellowish, juicy, tender, buttery, sweet, with a light sourness and pleasant almond smell, high taste value. Sort of autumn ripening period, can be stored until November, in cold rooms – January – February. Table. 1 shows the average amount of nutrients of “Beurre Bosc” pear per 100 grams of product.

Table 1

Nourishing substance of sort “Beurre Bosc” pear

Nutrient	Mass, gr. (per 100 gr)
Fats	0.3
Proteins	0.4
Hydrocarbons	10.3
Water	85.0
Mono and — and disaccharides	9.8
Starch	0.5
Fiber	2.8
Organic acids	0.5
Ash	0.7
Calories 42.9 cCal	

Candied pear was prepared according to technology showed in literature [7]. Pears were cut into slices 20*20*20 mm size, kept for 3 hours in a solution of citric acid (pH = 3) at 25 °C, and after kept in sugar syrup (70 % wt.) with temperature 80 ^{0}C until its full cooling. Then syrup was decanted, heated to 80 ^{0}C and then again poured on candied fruits. Thus was repeated 3 times to complete saturation of candied fruits with sugar. After process candied fruits were diaphanous looking, with a firm texture.

Prepared candied fruits were divided into two halves. The first half was left in the syrup with temperature 80 ^{0}C, the second half – in the cooled syrup with temperature 20^{0}C. After separation from the liquid phase hot (80 ^{0}C) and cold (20 ^{0}C) 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 ^{0}C) at a speed of 6 m/s, according to the methodology set in [11].

After certain time intervals weight change of container was determined by e-scales AXSIS-3000 with an accuracy of 0.01 gr. Experiment continued until candied fruits achieved humidity 25 % (of dry matter). Above material and below the perforated partition were installed HC-thermocouples for measurement of thermal agent temperature using eight channel intelligent transducer PT-108. After the experiment prepared candied fruits, dried in two different ways, were kept at room temperature in a dry packs for 6 months.

The research results of thermal agent temperature change at the outlet from layer of material from time, are shown in Fig. 2.

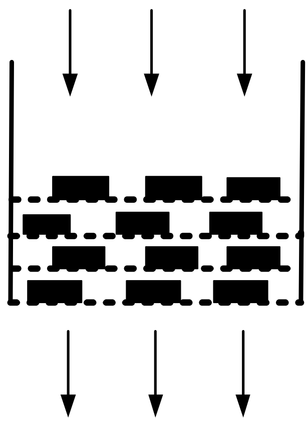

Fig. 1. Scheme of container for candied fruits drying

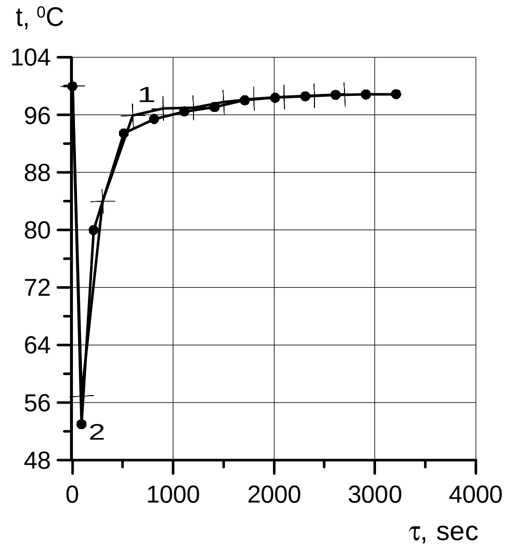

Fig. 2. Dependence of thermal agent temperature at the outlet from layer of material from time: 1 – Hot candied fruit, 2 – cold candied fruit;

As it is shown in Fig. 2, at initial time moment thermal agent temperature at the outlet from the layer is a wet thermometer temperature. At the outlet from layer of cold candied fruit it is 54 ^{0}C, and at the outlet from layer of hot candied fruits – 57 ^{0}C. Further, the temperature at the outlet from layers of cold and hot candied fruits begins to grow, and it means heating of candied fruits surface and, as a result, evaporation of moisture.

After 2000 sec. thermal agent temperature at the outlet from the layer remains unchanged and equal to the temperature of the thermal agent on the inlet to layer, this should mean a complete evaporation from both cold and hot candied fruits. However, if hot candied fruits still need 500 sec more for final drying until final moisture content (Fig. 3), cold candied fruits need 1000 sec (2 times more) for final drying.

Fig. 4 shows the drying rate curves that corresponds to kinetic curves in Fig. 3. As it is shown in Fig. 4, 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.

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 (Fig. 4).

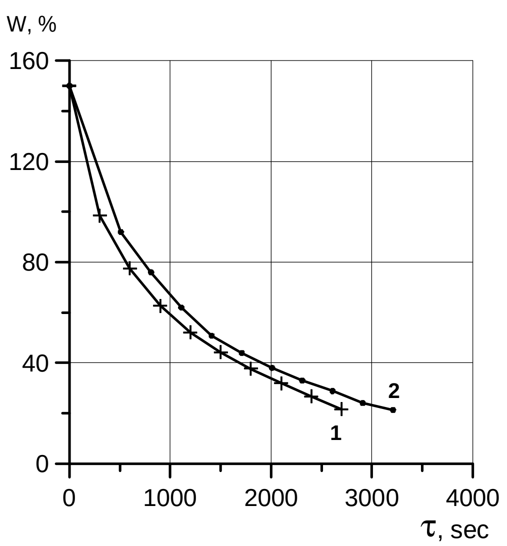

Fig. 3. Kinetic curves of drying of hot (1) and cold (2) layers of candied pears

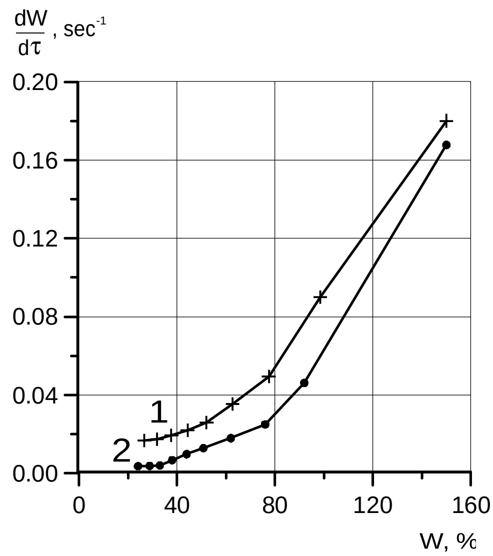

Fig. 4 – Drying rate: 1 – hot candied fruit; 2 – cold candied fruit

As it is shown in Fig. 3, 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:

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

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

$$Q_{layer} = Q_{dry\,l.(t=n)} + Q_{water(t=n)} + Q_{dry\,l.(t=n+1)} + Q_{water(t=n+1)} \quad (2)$$

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

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

The calculation results of changes of heat amount in time for the hot and cold candied fruits according to equation (2 – 4) are shown in Tables 2 and 3 respectively.

As it is shown in Table 2, for the hot candied fruits at time 1800 sec we have energy accumulated by layer of pears – Q_{layer} = 62,64 kJ 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.

Table2

Change of heat amount in time for hot candied pears

τ, sec	Q_{layer}, kJ	Q_{evap}, kJ	$Q_{t.a.}$, kJ
0	139.3	0	0
300	119.58	259.65	214.64
600	93.38	104.66	55.0
900	76.28	73.71	41.59
1200	70.61	52.72	40.24
1500	66.61	38.72	29.51
1800	**62.64**	32.72	24.15
2100	58.45	**28.82**	20.12
2400	54.994	**25.82**	17.44

Table3

Change of heat amount in time for cold candied pears

τ , sec	Q_{layer} , kJ	Q_{evap} , kJ	$Q_{t.a.}$, kJ
0	34.83	0	0
90	70.34	125.45	187.14
210	68.83	112.81	107.32
510	63.61	100.38	87.87
810	60.93	69.0	61.04
1110	59.31	52.25	46.95
1410	59.085	41.66	38.903
1710	55.94	34.03	26.16
2010	52.33	29.48	21.46
2310	**49.94**	24.92	18.78
2610	48.35	**20.62**	16.098
2910	44.3	**23.60**	15.43

Similarly from Table 3, 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 ^{0}C 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.

Conclusions. 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 ^{0}C temperature for final drying to a final moisture content. That will help to reduce energy costs of the process.

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EFFECT OF CAVITATION ON DISPOSAL OF LIQUID WASTES FROM OLEFINS PRODUCTION

It was found that effective neutralization of liquid waste production of olefins, that contain compounds of mainly arene and diene rows, is possible by processing in cavitation fields. Usages of sodium hypochlorite solutions, which are the wastes of related production, as reagents allow intensify the oxidation of organic substances. The optimum ratio between liquid waste production of olefins and sodium hypochlorite was determined according to the change of the redox potential of the reaction system. It is shown that the oxidation of organic compounds occurs through stages of their cavitational and oxidational destruction.

Key words: olefins production, liquid waste, cleaning, cavitation, sodium hypochlorite.

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ДОСЛІДЖЕННЯ КАВІТАЦІЙНОГО ЗНЕШКОДЖЕННЯ РІДКИХ ВІДХОДІВ ВИРОБНИЦТВА ОЛЕФІНІВ

Встановлено, що ефективно знешкодити рідкі відходи виробництва олефінів, які містять сполуки головно аренового та дієнового рядів, можна, обробляючи їх у кавітаційних полях. Використання як реагенту розчинів натрію гіпохлориту, які є відходами суміжного виробництва, дає змогу інтенсифікувати окиснення органічних сполук. Оптимальне співвідношення між рідкими відходами виробництва олефінів та натрію гіпохлоритом було визначене залежно від зміни величини редокс-потенціалу реакційної системи. Показано, що окиснення органічних сполук відбувається через стадії їх кавітаційної та окисної деструкції.

Ключові слова: виробництво олефінів, рідкі відходи, очищення, кавітація, натрію гіпохлорит.

Introduction. Chemical plants are belong to one of the most powerful sources of environment pollution, including the hydrosphere. This is caused by several factors, among which the most important are the output of large volumes of liquid wastes or wastewaters in chemical-engineering processes; high