Experimental study of the process of drying melon slices in a chamber-convection dryer

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Abstract. This article discusses the design features of a chamber-convective drying installation, the principle of its operation and the results of experimental studies of drying ring-shaped melon slices. Based on the analysis of the results obtained, recommendations are given for the use of a drying plant in farms and dehkan farms specializing in the cultivation and processing of melons.

1 Introduction

The natural and climatic conditions of Uzbekistan make it possible to grow and cultivate various varieties of vegetables, fruits, grape and melons. One of the conditions for extending the consumption of these products is the process of drying them. It is known that drying food products ensures the preservation of their quality indicators, but in some cases also contributes to their improvement. Therefore, being one of the main and oldest methods of processing agricultural products and the main branch of the modern processing industry, drying has not lost its relevance at the present time. The choice of drying methods, design of drying installations and rational process modes should be based on scientific and theoretical foundations: from the study of the physical and biological properties of the dried product as an object of drying, to the choice of highly efficient methods of energy supply that ensure the intensity of the process [1-4].

When drying agricultural products in industry, the convective drying method has become widespread. The comparative design of convective dryers is determined using heated air, which is at the same time a drying agent, a heat transfer, a desiccant and a dehumidifier. The design and technological schemes of convective type drying installations are varied and developed considering the physical, biological and thermophysical properties of the material being dried. Dryers with an oscillating operating mode, which involves changing the direction of coolant flow, are energy efficient.

The authors of this article have developed and tested a two-chamber drying installation for drying ring-shaped melon slices [5-6].

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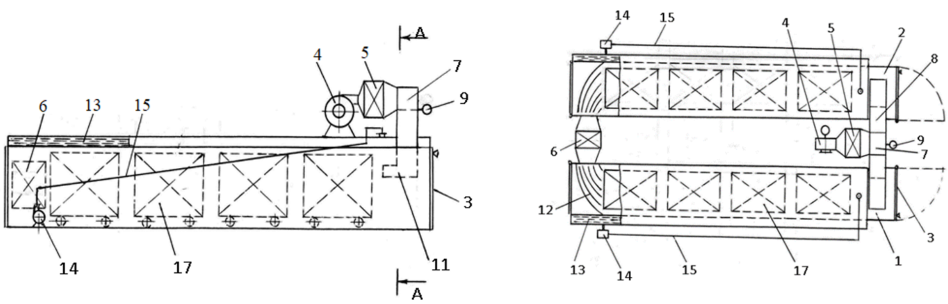
2 Research object

The object of the study is the chamber-convective drying installation developed for drying ring-shaped melon slices. The conditions for rapid loading and unloading of dried melon slices were taken into account (Figures 1-3) [7-8]. The drying installation contains two parallel rectangular working chambers 1 and 2 with doors 3, a fan 4, main 5 and intermediate 6 electric heaters and an air distribution manifold 7. The latter consists of two mirror-arranged hoses 8, descending with their lower ends to chambers 1 and 2, respectively, and the top ones are adjacent to the distribution box, while at the point where the hoses 8 converge, a rotary vane damper 9 is installed and windows 10 are provided, communicating with the pipe 11 for discharging the spent drying agent.



a) b)

Fig 1. Two-chamber convective drying installation for drying ring-shaped melon slices (a - side view; b - plan view).

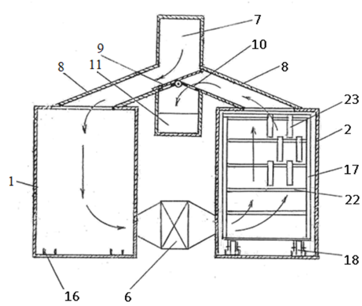


Fig. 2. Section A-A in Figure 1.

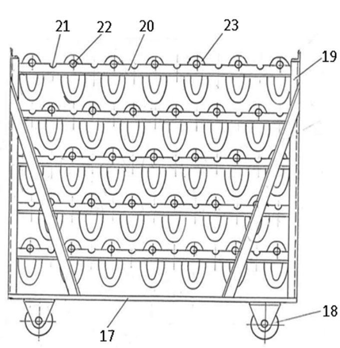


Fig. 3. Grocery cart (side view).

Inside the working chambers 1 and 2, in the areas of transition of the drying agent from one chamber to another, after the intermediate electric heater 6 located between the chambers, curved air fairings 12 (ailerons) are built in. The outer side walls of the working chambers and their ceiling parts are made with water jackets 13 and are equipped with circulation circuits equipped with pumps 14 and pipelines 15. For better absorption of solar radiation, the surface of the water jackets 13 is painted with black enamel (Kuzbass varnish). Inside chambers 1 and 2, grocery trolleys 17 are installed on channel guides 16 on feathered wheels 18. The trolley is made of an angle profile in the form of a spatial parallelopiped by welding, to the four posts 19 of which longitudinal crossbars 20 are welded. On each crossbar with a certain pitch, semicircular recesses 21 are made, where poles 22 are placed with melon slices 23 strung on them. The poles are also made with boring 24 (fillets). The boring step is determined by technological requirements, depending on the type of melon being dried.

The checkerboard arrangement of melon slices in the volume of the cart promotes turbulization of the drying agent, which intensifies the mass exchange process. Working chambers 1 and 2, fan 4, main 5 and intermediate 6 electric heaters, air distribution manifold 7 constitute a single closed system for the movement of the drying agent. When changing the position of the rotary vane damper 9, the drying unit can operate in oscillating mode.

2.1 Description of the operation of the drying unit

23 carts 17 loaded with melon slices are rolled into working chambers 1 and 2 through door 3. Having filled both chambers with carts, close doors 3 tightly and turn on the air and heat supply system: fan 4 and electric heaters 5 and 6. At the same time, outside air is pumped by fan 4 through the main electric heater 5, in which it is heated to a given temperature ($t = 70 - 80^0C$) and through the distribution box, depending on the position of the rotary vane damper, it enters through one of the hoses, respectively, into the working chambers 1 and 2, in which it blows the product placed in the carts. Upon entering the chambers, the air flow is evenly distributed over the entire cross-section of the chamber and blows over the melon slices placed on the trolley. In this case, convective heat exchange occurs between the hot air and the melon slices, during which the moisture evaporates and the air temperature drops. Next, the air passes through the air fairings 12 and the intermediate electric heater 6, is again heated to the required temperature and enters the working chamber 1 and 2, alternating in an oscillating mode, in which the further process of drying the product takes place. The exhaust air is removed to the outside through one of the hoses 8, windows 10 and pipe 11.

It is known that the oscillating mode intensifies the process of removing moisture from the product, since the gradients of changes in temperature and moisture content coincide and are always directed from the deeper layers of the body outward. The oscillation period for slices of dried melon is selected depending on the physics and biological properties of the melon: sugar content, consistency of the pulp and the thickness of the cut ring-shaped slices. For many melon varieties, the oscillation time is about 50-60 minutes. The automatic control system for the rotary vane damper 9 is controlled by a timer and an electric actuator and can be assembled from known electrical automation elements. The drying installation is additionally equipped with a water jacket 13, located on the sides of chambers 1 and 2 and their ceiling parts, which accumulates incoming heat from solar radiation. To avoid the formation of stagnant zones in the corner sections of the water jackets of chambers 1 and 2, circulation circuits are provided on both sides, including centrifugal pumps and pipelines.

For the experimental setup, commercially available standard equipment and instruments were used:

- electric heaters PGS-018B, installed capacity $P = 10\ kW$; fan performance $V = 4000\ m^3/h$;

- recording multipoint electronic potentiometer KSP–4, number of controlled points–8;
- thermocouples THK-III (Chromel-copel, $t = 0 - 100^0 C$);
- vane anemometer ASO –3.

More than 1000 kg of high-sugar melon varieties were used as the research material: Ak-urug, Ich-kzyl, Kukcha and Assate, cut into ring slices 15, 18, 21 mm wide [9].

2.2 Experiment description

The experiment can be described as follows:

- weighing and identification of carts complete with wooden poles, the latter must be painted at the ends with different paints;
- stringing slices on poles with an average weight of 3.5-4.0 kg, weighing them and loading them into carts with the given numbering;
- loading the carts into the chambers in a certain order and starting the installation: measuring the temperature of the heated air, speed and recording the start of the experiment;
- weighing the mass of the carts every four hours and determining the amount of evaporated moisture.

The research tasks are to study the influence of the thickness of slicing melon slices on the quality of the finished product; the dynamics of drying melon slices; the influence of the density of hanging slices on the drying time; the oscillation process on the drying process.

3 Methods

Based on the objectives, the experiment involves studying changes in moisture content in slices of dried melon of different varieties and at different cutting widths. The change in the amount of moisture was determined by weighing the mass of melon slices located on one pole, and then on the entire cart. In this case, the varieties of melons were distributed evenly across all eight carts, and were identified by pole numbers, row and tier of carts. To do this, throughout the entire period of the experiment, the drying was stopped every four hours, the carts were rolled up and each pole with a complex melon was weighed, and then the mass of each cart was determined by summation. After the next weighing, the carts were rolled in and drying continued.

Thus, 6 stops and starts of the installation were made until the drying process was completely completed. Data were recorded over time in the observation log (Table 1).

Table 1. Results of drying melon pulp “Ak-urug” over time in oscillating mode.

Location of the poles	Thickness of slices, mm	Results of weighing poles with melon, g							Relative moisture
		At the beginning	Drying measurement intervals, hours						
			4	8	12	16	20	24	
Trolley 1 Tier 1	15	$\frac{3880}{3490}$	$\frac{3000}{2610}$	$\frac{1870}{1440}$	$\frac{1490}{1120}$	$\frac{1110}{830}$	$\frac{870}{780}$	$\frac{810}{730}$	21
Tier 3		$\frac{4100}{3690}$	$\frac{3290}{2810}$	$\frac{2190}{1710}$	$\frac{1810}{1330}$	$\frac{1440}{950}$	$\frac{1290}{1160}$	$\frac{780}{700}$	19

Tier 5		4080/3670	3190/2780	2120/1710	1710/1300	1300/1170	1170/1050	850/770	21
Trolley 3 Tier 3	18	4120/3710	3240/2830	1750/1340	1250/840	910/810	850/760	740/680	18
Tier 2		4040/3640	3050/2650	1740/1340	1320/1020	1170/800	1090/745	840/680	21
Tier 4		3960/3560	2980/2580	1670/1270	1190/890	830/740	750/670	673/605	17
Trolley 6 Tier 2	21	3600/3240	2810/2450	1760/1500	1320/1060	1180/810	1060/790	830/640	20
Tier 3		4020/3620	3140/2740	1790/1390	1390/910	1030/820	960/780	820/730	23
Tier 5		4100/3690	3170/2760	1680/1270	1170/760	840/670	750/640	690/620	17

in the numerator – the mass of slices before drying; The denominator is the mass of slices after drying.

Since we experimented with melon slices with different thicknesses and the measurement results differed slightly from each other, then selectively, for one cart (for example, the second), a corresponding drying "curve" over time was built (Figure 4).

4 Results and discussion

The curves (Figure 4) show that with an increase in the thickness of the slices, the drying time constant increases regardless of the type of melon being dried. It was noticed that slices with a thickness of 15 mm were dried evenly throughout the entire volume, while, as with thicker slices, the inner layers of pulp were not completely dried and led to spoilage of the product during long-term storage.

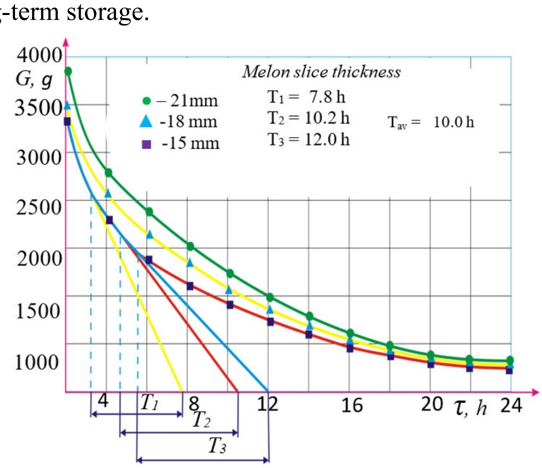


Fig. 4. Curve of change in mass of dried melon over time.

Therefore, based on these judgments and considering technological requirements, a cutting thickness of 15 mm is recommended. During the experiment, the temperature of the coolant was also controlled at different points in the drying chamber [10]. It was found that the air temperature drops significantly from the beginning of the entrance to the end of the chamber and averages 20ºC.

Based on these data, the drying time constant for the entire process was calculated, which was $T_{av} = 10.0\ h$.

So, with the direct flow of hot air, its temperature dropped from 72ºC around trolley No. 1 to 54^0C at the end of the chamber. Then, due to heating in an intermediate heater to 70^0C, it entered the zone of cart No. 5 and at the outlet had a temperature of 46^0C, which characterizes an uneven drying mode. To ensure uniform moisture collection, an oscillating mode was used, i.e. reversed the flow direction. At the same time, the total temperature in the chambers was $\approx 120^0$C, which ensured uniform drying of all carts. Considering the heating time $t_{н} = 25\ min$ and the cooling time $t_0 = 20\ min$, the oscillation time is on average $t = 45\ min$.

During the drying process, the volume of the product naturally decreases. Melon slices with different cutting thicknesses of 15, 18, 21 mm, taken from different carts, were selectively examined. Since it is difficult to theoretically calculate the volume of lobules, our research was based on the theory of Archimedes - i.e. determining the volume of displaced liquid when a body is immersed. Cottonseed oil was used as a liquid as it is water-repellent. By measuring the volume of the slices before and after drying, we determined the volumetric shrinkage coefficient, which is almost the same for all samples $\delta = 0{,}94 - 0{,}946$.

Knowledge of the volumetric shrinkage coefficient is necessary when calculating the second drying period, when the porosity of hanging slices in the volume of the cart increases, and the heat consumption of the agent must be reduced.

5 Conclusion

Thus, based on the experimental studies carried out we can conclude the following.

From the point of view of obtaining high-quality dried melon, the thickness of the slices is 15-18 mm (depending on the variety and sugar content of the melon).

It was revealed that with a heating time of melon slices $t_{н} = 25\ min$ and a cooling time $t_0 = 20\ min$, the rational oscillation time is $t = 45\ min$.

It was found that the checkerboard order of hanging slices on poles ensures uniformity and better conditions for moisture collection during the drying process.

The drying unit can also be used for drying grapes, hanging bunches on poles, as well as other loose products, placing them on perforated pallets.

References

1. O. Rakhmatov, O.O. Rakhmatov, F.O. Rakhmatov, *Improving the technology of processing melons in the conditions of the Republic of Uzbekistan* (Tashkent, Fan, 2018)
2. Z.S. Iskandarov, *Increasing the efficiency of solar-fuel drying plants for agricultural products* (Tashkent, Fan va texnologiya, 2017)
3. T. V. Fonteles, M. G. Maia Costa, A. L. Tibériode Jesus, et al., Food and Bioprocess Technology **7,** 2860-2869 (2013)
4. L. Mayor, A.M. Sereno, Journal of Food Engineering **61,** 373-386 (2004)
5. Kh.F. Zhuraev, K.O. Dodaev, R.O. Boboyarov, Food industry **11,** 40-41 (2002)
6. N. Muhamad, N.A. Mohd Redzuan, Journal of Agrobiotechnology **10(1S),** 46-58 (2019)

7. *Final report for 2018 on research work on the topic: "Conducting pilot tests and introducing an effective resource-saving drying installation for fruit and melon products" under contract I -2017-2-19* (Tashkent, 2018)
8. O.O. Rakhmatov, F.O. Rakhmatov, O. Rakhmatov, et al, *Convective drying installation for drying melon slices* RUz patent for utility model No. FAP 01524 publ. B.I. No. 8 (2020)
9. G.M. Abdieva, *Justification of parameters and operating modes of a melon drying plant* (Tashkent, 2019)
10. B.P. Shaimardanov, *Technological foundations and justification of the scheme and parameters of the means of mechanization of waste-free processing of melon fruits* (Tashkent, 2000)