Drying Conditions for Tomato Processing in Solar Dryer

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Abstract: A solar dryer composed of solar collector, drying room and auxiliary heating system was constructed. Drying conditions, "The combination of dryer construction, dried product state during the process and drying medium state during the process", which lead to quality dried product, were investigated. Test runs with the dryer were carried out during the summer period at many locations across the country, using tomato slices as dried product. The correct operational drying conditions, reached by fieldwork activities, are proposed.

Keywords: Food drying, Solar dryer, Tomato.

1. Introduction

According to botany, natural science concerned with the study of plants, tomato is a fruit. However, in the common language of the people it is vegetable, primarily because it is defined as a culinary term. So, the answer is that a tomato is the fruit of the tomato plant, but it's used as a vegetable in cooking.

Hundreds of tomato varieties are grown for either fresh consumption or processing.

Tomato is delicious food mostly eaten row, but it is also used as a dried product, [1]. Nowadays, there is a great demand for dried agricultural products all over the world, with tendency for permanent increasing.

Tomato is a nutrient-dense, nice to the taste food, used as moderate source of vitamin A and C. An ordinary tomato consists of 95 % water, 4 % carbohydrates and 1% fat and protein. The appearance, texture, flavors and processing characteristics of tomato depends on the variety, growing method, local climate and local soil. The consumption of tomato is enormous. Based on world production quantities, tomato is two times more popular food, even than apple (tomato 182.000.000 tonnes, and apple 83.000.000 tonnes, in 2017), [2].

In North Macedonia, in 2017, 160.000 tonnes of tomato are produced, [3]. It is one of the traditionally basic elements in the local nutrition.

Drying of agricultural products is the most widespread preservation method in the world. Various constructions of solar dryers are developed for fruits and vegetables processing, but theirs optimal operational conditions are rarely published.

Low quantities of tomato to be dried and the price of energy, favor the use of small or farm solar driers, in the regions with high solar insolation. During the past decade, the introduction of low cost and locally manufactured solar dryers was encouraged by the researchers from the Faculty of Mechanical engineering and the Faculty of Agricultural Sciences and Food, of "Ss. Cyril and Methodius" University, in Skopje, [4], [5], [6].

Tomato is dried to provide long time availability as stabile product, to enlarge the list of its popular uses (juiced tomato, canned tomato, pasted tomato, baked tomato and stewed tomato), enhance the product quality, and ease the product handling, storing and transportation.

Tomato is dried from initial moisture content wet basis of up to 95 %, to final moisture content wet basis up to 8 %. Dried tomato is used in the form of tomato slices, tomato pulp or tomato powder, [7], [8].

In order to increase the drying surface and to reduce the moisture path from the dried product interior toward the drying surface, tomato is cut in planes at an angle of 90^{o} to its stalk, and so it is formed into rings.

The method of tomato harvesting is important for the quality of the fresh product. Shaking the tree or the use of harvesting machines can provoke invisible wounds at the place where the tomato is pressed.

The quality of dried tomato is influenced by the variety, maturity and the used pre-treatment and posttreatment, [9]. The number and shape of liquid caverns in one tomato variety, has great effect on ring thickness selection and the intensity of dried product sticking on the plastic support. The optimum ring thickness is determined by laboratory drying tests.

Once put into the drying room, tomato ring state depends on drying conditions. It is under the influence of air temperature, air relative humidity and air flow. The air temperature level is crucial for dried product quality. Generally, in drying technology, the use of higher temperature means shorter drying time, but in the dryer the permitted drying air temperature cannot be surpassed. The permitted drying air temperature is only one element of the drying conditions and it can be determined by drying tests.

Air flow was estimated by experience and laboratory measurements.

This type of dryer is interesting for farmers, which have small quantities of fruits and vegetables, and intend to apply it for on-farm drying. The dryer is constructed using locally available materials.

The tomato state change was continuously controlled during the drying process. The examination procedure contained measurements, visual evaluation and test judging.

Three groups of measurements were done: 1. initial, modular and final drying medium state (temperature, relative humidity and flow), 2. initial, modular and final dried material state (moisture content and temperature), 3. dryer (drying time and fuel consumption for additional energy). Weather characteristics, at the dryer location, were also recorded (cloudiness, direction and intensity of wind). Digital thermometers, hygrometers and anemometers were applied to control the temperature, relative humidity and flow of air. Ventilated hygrometers were also used, for determining of air conditions in the atmosphere.

Dried product moisture content was inspected by taking representative tomato samples and their laboratory analysis.

The solar dryer, developed by the Institute for Thermal Engineering at the Faculty of Mechanical Engineering in Skopje, was successfully tested under field conditions at five locations with different climate, for drying fruits and vegetables. Collected experience in the solar drying processes of apple, pear, plum, fig, raspberry, tomato, carrot, paprika, onion and zucchini, is very valuable for the next research works. For example, the temperature level of 60 ^{o}C was evaluated as sufficient for all dried fruits and vegetables.

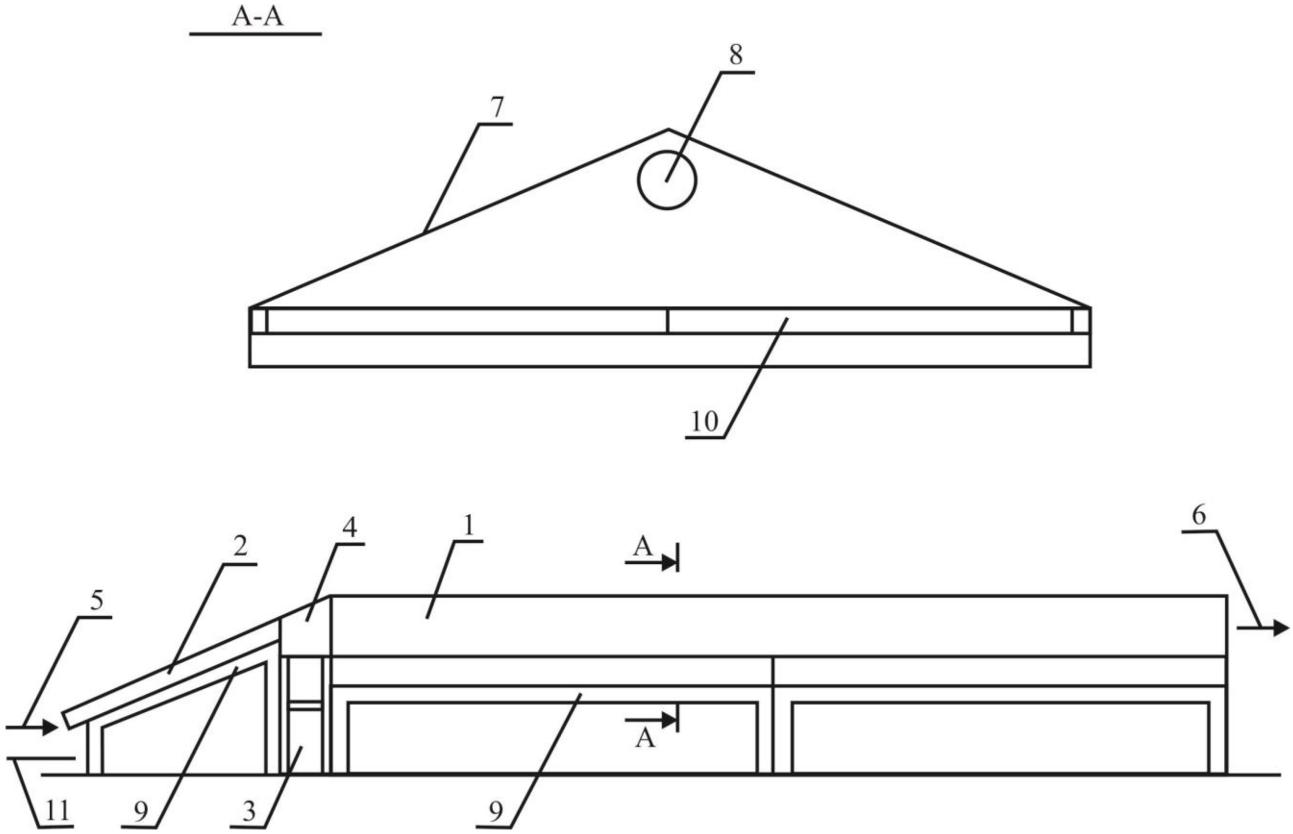
2. Equipment - Solar Farm Dryer

The starting point for the drier construction was the old-time simple dryer with only one element, horizontal flat support for dried product. A tent model dryer was developed, to protect the dried product from direct solar radiation, to reduce heat losses and also to protect the dried product from wind, dust and rain. To increase the drying capacity of natural convection dryer, solar collector is connected to the drying room. The air inlet in the solar collector, and the air outlet from the drying room, are covered by plastic net to protect the dried product from insects. At the solar collector entrance, damper is inserted, to stop the air flow during the night or for occasion of violent weather. At the drying room entrance, mixing section is inserted, to reduce the flow of heated air from the solar collector, during the periods of extreme solar insolation, when the air temperature, at the solar collector exit, exceeds 60 ^{o}C. The second mixing component is air from the atmosphere. To intensify the air flow into the solar collector and drying room, axial fans are used. Gas burner is installed as auxiliary heating device. Additional heating is realized by the use of liquefied petroleum gas.

Functional draft of solar farm dryer is shown in Figure 1.

Ambient air enters in the solar collector (2), passes a heat exchanger (4), and moves across the dried product in the drying room (1). Plastic cover (7) offers protection of dried product from direct solar radiation, rain, wind, dust, birds and rodents. Axial fans (8) direct and provide sufficient air flow. Dryer support (9) is strong enough to bear two and a half drying room modules. Dirt elevation from the ground can be avoided by using protective cover (11).

The dryer is designed using modular concept, for all parts of the dryer, to facilitate the montage and eventual transport. Due to the modular design, the dryer capacity usually depends on actual farmer intention of drying. Horizontal flat support, 1.5 m in width and 1 m long, defines the basic module for the drying room. The module is designed as metal frame, covered in the form of tent, with a special plastic plate, transparent for solar radiation. The plastic foil is fixed to the metal frame of the both sides of the dryer and is removed for loading or unloading of the dryer. The top surface of the solar collector is painted in black. The upper side, of



1-Drying room, 2-Solar collector, 3-Auxiliary heating source, 4-Heat exchanger, 5-Air inlet, 6-Air outlet, 7-Plastic cover, 8-Axial fan, 9-Dryer support, 10-Dried product support, 11-Protective cover

Figure 1. *Solar farm dryer*

the modules in the drying room, consists of stainless steel wire netting, elevated over the horizontal flat support to allow air flow under the dried product, and covered by plastic netting as direct support of dried product. Two trays of 700 x 900 mm are put in every module of drying room. The whole construction was designed to be lightweight, for easy transportation and montage, because the dryer is usually located in the field and also needs to be stored for the winter period.

The heat exchanger is used for air reheating at the entrance of the drying room.

3. Procedures, Results and Comments

The suitable location for the new dryer was selected as clean place, remote from any air contamination source and possible shadow. Many of the used dryers in the research were placed on meadows, but there were some located at the terraces on first and fourth floor of buildings. Being installed over the concrete mass, additional heating was exploited.

At five locations, farmers were engaged in drying tomato: Skopje, Sveti Nikole, Miravci, Ohrid and Bitola. The state of the air in the atmosphere was predicted with the help of climatic curve for summer period.

Needed horizontal area for dryer location, was evaluated at 3 x 10 = 30 square meters. Additional surface, which measures 2 x 2 = 4 square meters, under the entrance of solar collector, was required to provide clean air inlet. Usually, plastic cover was used.

The standard version of drying room, used in the experiments, contained 5 modules. The net drying surface of 6.3 m^2 was sufficient for the planed activity.

In the pre-treatment phase, damaged tomatoes were eliminated, stalks were moved out and the product was washed in water.

Cleaned tomato was cut in rings and arranged, in one row, on the plastic net support of the drying room. Thin layers of 3, 4, 5 and 6 mm were examined. Tomato rings with thickness of 5 mm were evaluated as the best. A drying room product load of 4,5 kg/m^2 was reached with such tomato rings.

Drying time, for dried tomato rings at level of 10 % final moisture content wet basis, was 70 - 110 hours, at summer weather conditions for North Macedonia region.

Because the dried tomato is highly hygroscopic material, immediately after drying, it was packed in airtight containers.

Regarding to the temperature regime, in days with clear sky, air temperatures up to 70 ^oC were realized, at noon time. In the morning and late afternoon, usually there were no extremes of temperature values. In the actual investigation, the permitted drying air temperature, at the entrance of the drying room, was 60 ^oC.

Drying progress was kept under continuous observation by measuring the product weight every 45 minutes.

The transparent plastic foil, usually was only two seasons durable.

Operational drying conditions for tomato are proposed based on the test results conducted in the summer period. Three tomato varieties were under investigation: “Heinz”, “Hamson” and “Roma”. An example of operational drying conditions for tomato is presented in Table 1.

Table 1. Operational drying conditions for tomato

Elements of drying conditions		
Drying medium		
Period of drying		15.06. - 15.09.
Air state in atmosphere		
Temperature	^oC	20 - 40
Relative humidity	%	20 - 60
Air state at the entrance of drying room		
Temperature	^oC	40 - 60
Airflow	m^3/s	0.1 - 0.4
Dried product		
Seed variety		Heinz
Diameter x height	cm	7 - 5
Weight	g	180
Initial moisture content, wet basis	%	80 - 95
Final moisture content, wet basis	%	8 - 12
Initial temperature	^oC	25 - 30
Final temperature	^oC	45 - 50
Thickness	mm	5
Dryer		
Location		Skopje
Number of drying room modules, 1.5 x 1 m		5
Number of solar collectors, 1.5 x 1 m		2

4. Conclusion

The solar dryer, developed by the Institute for Thermal Engineering at the Faculty of Mechanical Engineering in Skopje, proved to be successful in drying fruits and vegetables.

This indirect solar type of dryer, with an auxiliary heating source, demonstrated functional stability even during the periods of reduced solar irradiation or sunless periods.

Based on the test results, conducted in the summer period, operational drying conditions for locally grown tomato variety "Heinz" are proposed.

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