EFFECT OF DIFFERENT DRYING PROCESSES ON LYCOPENE RECOVERY FROM TOMATO PEELS OF CRYSTAL VARIETY

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The aim of this work is to analyze the effect of three drying processes (oven drying, vacuum oven drying, and hot air drying) of tomato peels from Crystal variety in terms of moisture content and lycopene recovery. The drying process is performed for 5 h, at temperatures between 50 °C and 120 °C. The highest moisture is observed at oven-dried tomato peels, while the lowest value is found in hot air-dried tomato peels. The highest amount of lycopene, 34 mg/100 g fresh tomato peels (329 mg/100 g dried tomato peels), is extracted from tomato peels dried in hot air, at the temperature of 80 °C.

Keywords: tomato peels, oven drying, vacuum oven drying, hot air drying, lycopene content

1. Introduction

Tomatoes are one of the most consumed vegetables in the world, being used both fresh and processed [1]. A regular consumption of tomatoes is associated with a decrease in cardiovascular disease and cancer [2], as being shown also by epidemiological studies [3]. Tomatoes contain many bioactive compounds such as ascorbic acid, vitamins A, C, and E, phenolic compounds, flavonoids, and carotenoids [3-5]. Due to the synergistic effect of these bioactive compounds, they are characterized by antioxidant, anti-inflammatory, and anti-cancer activities [6]. Carotenoids are pigments with yellow, orange, and red color, present in plant and animal world, being synthesized only in plants. The most important carotenoids found in tomatoes are lycopene, α-, β-, and γ-carotene [7]. The main carotenoid compound responsible for the red color of tomatoes is lycopene. Lycopene comprises 80-90% of the total carotenoid amount from tomatoes and varies depending on the raw material between 1-20 mg/100 g of fresh tomatoes and 43-295 mg/100 g of dried tomatoes [8,9]. Lycopene is known as the most effective natural antioxidant, with activity twice higher than β-carotene and ten times higher than α-tocopherol [8,10]. Due to this antioxidant activity, epidemiological studies revealed that lycopene from tomatoes decreases

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the risk of occurrence of six common different types of cancer like prostate, cervical, stomach, rectum, pharynx, and esophageal [11] as well as prevents cardiovascular and coronary heart disease [12]. Since lycopene is not produced by human body, it must be introduced in human organism from dietary supplements or regular food. Thanks to its antioxidant activity, lycopene can be used as a dye in common foods and in anti-aging products [13,14]. Although lycopene is found in many fruits such as watermelon, apricot, papaya, pink grapefruit, and rosehip [14], vegetables, algae, and fungi, tomatoes and their products are the main sources of lycopene in the human diet [15]. The highest amount of lycopene (between 72-92%) is found in tomato peels, the outer pericarp of the tomato. Tomato peels contains a larger quantity of lycopene and polyphenolic compounds compared to the pulp, the amount of lycopene being five times larger. Several studies report recovery of about 12 mg lycopene/100 g fresh peels and and 3.4 mg lycopene/ 100 g fresh tomatoes [4,8,9,14,16]. The quantity of lycopene from tomatoes is influenced also by the variety of tomatoes [14,16], the agricultural techniques [14], the environment factors like soil type [17], temperature, humidity, and light [14,17]. Recovery of lycopene from tomatoes is made by different extraction techniques and depends on the moisture of tomato sample subjected to extraction [4,9] and the preservation techniques such as harvesting, handling, and storage [17].

The fruits and vegetables contain a high percentage of their fresh weight as water and have a high metabolic activity which continues after harvesting, making them perishable [18]. Water accounts for 90% of the total weight of a fresh tomato, being responsible for the size of the fruit. The huge amount of water from fresh tomato peels makes them perishable being susceptible to microbial degradation and spoilage [17]. To prevent degradation of tomato peels they need to be preserved to extend their shelf-life [6,11,16], to enhance their storage stability [6], to reduce their volume [11], and to prolong time without significant loss of product quality before extraction of valuable compounds [16,19]. Moreover, it is known that fresh tomatoes have a smaller amount of lycopene than those that have been subjected to a heat treatment [14]. Vitamins are known to be heat-labile compounds, while carotenoids and phenolic compounds are more resistant to thermal processing [20] and they can be separated by extraction from dried samples. Drying is the most common process used for preservation of tomatoes that keeps the desired product qualities for a longer period. Using this method, the water is removed from the solid material to certain moisture content at which microbial spoilage is avoided [11,19]. Different drying processes (sun-drying, air-flow drying, oven-drying, vacuum-oven drying, freeze drying, infrared drying) have been reported, with their advantages and disadvantages regarding lycopene recovery from vegetable sources [6]. Major disadvantage of drying is thermal degradation by increasing temperature and drying time, causing serious damage to flavor, color, and quality of dried products [15,21].

Traditional sun-drying (TSD) is a cheap, slow process, which requires 7 to 12 days. It may lead to considerable quality losses due to high moisture content, color degradation during storage, microbial growth, and dependence of weather conditions. By this method, a product with an inferior quality and with 12% to 24% moisture content is obtained [22,23]. Hot air drying (HAD) is a widely used process in which heat is transferred to the product through heated air by convection [11]. This process is preferred in tomato drying because gives quality products in hygienic conditions, without significant losses [23]. Vacuum oven drying (VOD) processes are characterized by fast drying at low temperatures and large mass transfer rate. Due to reduced pressure environment, the boiling point of water decreases, which increases the evaporation rate. This process is usually used to dry materials with high porosity and low apparent density [6]. Different authors reported changes of lycopene content and antioxidant activity in thermally processed tomato (sauces, waste [9,14], slices [6,11], halves [19], dices, peels [4] or juices [13]) based on different varieties of tomatoes, pretreatments, drying methods, temperatures, and time. The most common drying techniques applied on tomato products are open and solar sun-drying [3,5,21], air drying [15-19,21-23], oven and cabinet drying [10,14,24], vacuum oven drying [3,6], freeze drying [1,3], infrared drying [24] at temperatures between -50 and 140 °C and osmotic dehydration as a pre-treatment for tomato drying in order to reduce the drying time and to concentrate and protect the nutrients [15,21].

The objective of this study is to investigate the influence of drying method, temperature, and time on lycopene recovery from peels of Crystal tomato, a very cultivated variety in Romania. Also, the quality of the dried peels (color, moisture) was monitored during drying process and optimum drying temperature was established. Peels samples were dried at temperatures of 50-120 °C by oven drying, vacuum-oven drying, and hot air drying for 5 h.

2. Materials and methods

2.1. Reagents

Lycopene, acetone, and hexane used in this study are of analytical grade, from Sigma-Aldrich, Germany.

2.2. Experiments location and time

The experiments of tomato peels drying and lycopene extraction were conducted in the laboratory of the Department of Chemical and Biochemical Engineering and in the laboratory of the Department of Organic Chemistry "Costin NENITESCU" of the Faculty of Applied Chemistry and Materials Science, during the year of 2018.

2.3. Preparation of tomato peels

Tomatoes of Crystal variety were purchased from a local Bucharest market. Tomatoes were farmed in Colibași, Giurgiu county and harvested in October 2018. Fresh and ripe tomatoes, 65-80 mm average diameter and 160 g average weight, were washed with distillated water to remove soil and dirt and then were manually peeled. About 8 g of peels per tomato was obtained. After peeling, 45 samples of 30 g of fresh peels were prepared and stored at -20 °C until their use, and did not undergo any further pretreatments.

2.4. Drying equipment and drying methods

In this study 15 experiments of tomato peel drying were done using three drying methods: oven drying (OD), vacuum oven drying (VOD), and hot air drying (HAD). In all of the drying experiments, tomato peels were placed in a thin layer on a watch glass with a diameter of 150 mm. OD and VOD experiments were performed in a vacuum oven (RAYPA, model EV-50), whereas HAD tests were conducted in a oven with ventilated air (ITM AMIRO, model E 50.2). In VOD experiments, the pressure was 0.9 bar. For each experiment, 30 g of fresh tomato peels was dried for 5 h at temperatures of 50, 70, 80, 100, and 120 °C. The tomato peels were continuosly monitored in order to see how the aspect changes. The mass of the tomato peels was measured every 30 min (during this operation, fresh air was introduced into the oven). An analytical balance (Shimadzu Corporation, model AW 220) was used. Each drying experiment was done in duplicate. The wet and dry basis moisture contents of dried tomato peels were determined with the method presented by Mercer [25].

2.5. Soxhlet extraction of lycopene from tomato peels

Soxhlet extraction of tomato peels was carried out to extract lycopene. The extraction process comprises of four steps: preparation of tomato peel cartridge, extraction from tomato peel cartridge for 6 h, evaporation of solvent from the extract, as well as collection and storage of tomato peel extracts.

Extracts were prepared according to the procedure described by Nobre [26]. One fresh tomato peel sample and 15 dried tomato peel samples were subjected to Soxhlet extraction with 100 cm^3 acetone:hexane mixture in 1:1 volume ratio. After extraction, the solvent was removed from the extract using a rotary evaporator (Hahnvapor, model HS-2000NS) and the extracts were stored in Eppendorf tubes until analysis. Each Soxhlet extraction was done in duplicate.

2.6. Lycopene quantification from tomato peel extracts

The lycopene from tomato peel extracts was quantified by UV-Vis spectrometry in a Helios UV–Visible spectrophotometer (Helios beta, Thermo Spectronic), using a standard curve of pure lycopene dissolved in acetone:hexane mixture in a 1:1 volume ratio, in concentrations ranging from 0.5 to 10 µg/mL. The level of lycopene from the extracts, c_L (g/mL) was calculated by applying Eq. (1), obtained from the standard curve, where A_{505} is sample absorbance at 505 nm wavelength.

$$c_L = \frac{A_{505}}{0.2532} \times 10^{-6} \quad (1)$$

For each sample, 0.001 g of extract was dissolved in 10 cm^3 of acetone:hexane mixture in a 1:1 volume ratio and the absorbance at wavelenght of 505 nm was measured. Each analysis was done in triplicate. The results were expressed as mg of lycopene/100 g of tomato peels.

3. Results and discussion

The drying process is influenced by the properties of the product and of the dryer. The characteristics of the material include the shape, the size and thickness, the composition, structure and porosity, the initial moisture content, the surface characteristics, the surface available for water loss and the variety of the material. The properties of the dryer include the type of dryer, the drying temperature, the drying time, the volumetric air flow rate, the linear air velocity, the uniformity of air flow, and the variation in weather and air conditions [25]. From all these factors, in the drying experiments conducted, the following factors linked to the dryer properties were considered: the type of the dryer (OD, VOD, HAD), the drying temperature (50-120 °C), and the drying time (0-5 h). Regarding to the characteristics of material, the shape (peels), thickness (thin layer), and variety (Crystal) of the tomatoes were analyzed.

Fig. 1 presents the results of the drying experiments for tomato peels, Crystal variety. The left diagrams show the change of the mass of the sample during oven drying (OD, top), vacuum oven drying (VOD, middle), and hot air drying (HAD, bottom). Each diagram includes results of drying experiments performed at different temperatures. (see it on the next page).

The right diagrams show the change of sample moisture (dry basis), M_{db} (g/g), defined by Eq. (2), where m_w (g) is the mass of water in the sample and m_s (g) the mass of solid in the sample.

$$M_{db} = \frac{m_w}{m_s} \quad (2)$$

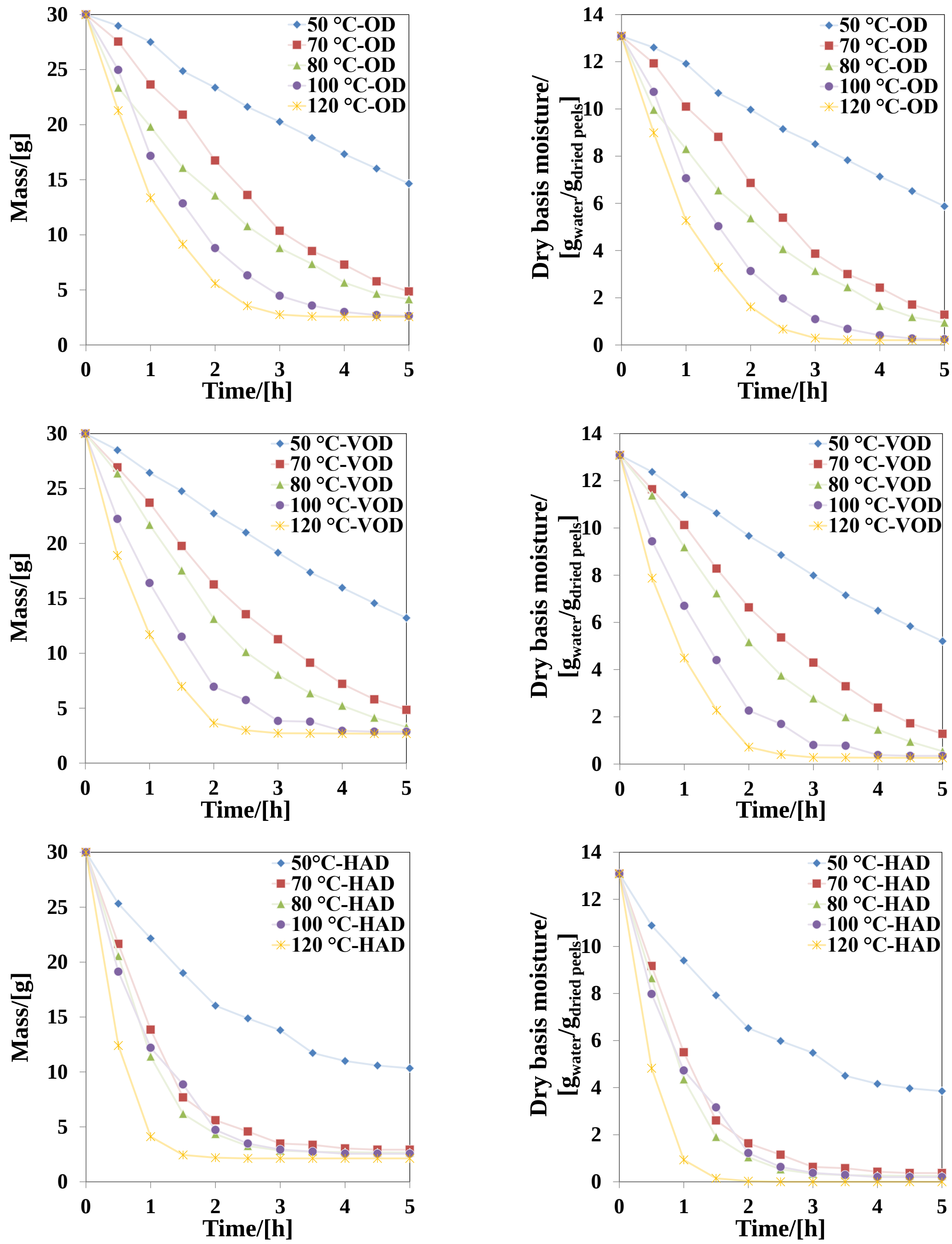

Fig. 1. Mass and moisture content of dried samples

Starting with 30 g of fresh peels subjected to drying at the highest temperature (120°C), the mass of dried peels which did not change after 3 consecutive measurements was found to be 2.57 g for OD, 2.69 g for VOD, and 2.13 g for HAD. The lowest value (2.13 g) was considered to represent the mass of solids in the sample. It should be noted that the amount of water that can be removed is limited by the partial pressure of water in the vapour phase, which cannot exceed the saturation value. Therefore, the value considered here (2.13 g) includes the water which could not be removed, at 120 °C, by contacting the tomatoes peels with air with the daily humidity. The mass of water in the sample was calculated as the difference between the mass of the sample and the mass of solids in the sample.

Table 1 presents the mass of the sample after 5 h of drying. In all cases, the mass of fresh peels was 30 g. Table 1 also includes dry-basis moisture content, M_{db} (g/g), calculated according to Eq. (2) and wet-basis moisture content, M_{wb} (%wt.), defined by Eq. (3), where m_w (g) is the mass of water in the sample and m (g) the sample mass.

$$M_{wb} = 100\,\frac{m_w}{m} \tag{3}$$

Table 1

Dried Crystal tomato peels characteristics (mass of fresh peels: 30 g; drying time: 5 h)

Drying method	Drying temperature (°C)	Mass of dried peels (g)	Wet-basis moisture M_{wb} (%wt.)	Dry-basis moisture M_{db} (g/g)
OD	50	14.65	85.46	5.88
	70	4.86	56.18	1.28
	80	4.15	48.69	0.95
	100	2.65	19.51	0.24
	120	2.57	16.96	0.20
VOD	50	13.21	83.88	5.20
	70	4.85	56.08	1.28
	80	3.29	35.17	0.54
	100	2.87	25.69	0.35
	120	2.69	20.69	0.26
HAD	50	10.34	79.39	3.85
	70	2.92	27.13	0.37
	80	2.67	20.16	0.25
	100	2.56	16.8	0.20
	120	2.13	0.00	0.00

Note that the initial wet-basis moisture of the fresh tomato peels from Crystal variety is 93%.

3.1. Influence of drying factors on moisture content

In the following, the influence of the drying factors on the moisture of dried tomato peels is presented. Three factors that affect tomato dried samples were studied: drying method, time, and temperature. 15 samples of tomato peels, Crystal variety, were subjected to different conditions of drying and the differences are presented.

3.1.1. Drying method

Fig. 1 (left column) shows the change of the sample mass during the drying process performed in dryers of different types (OD – top; VOD – middle; HAD – bottom) and at different temperatures.

The initial mass of the sample was 30 g. In OD the mass transfer of water from solid to vapor state takes place by natural convection. Thus, complete drying is achieved in 3.5 h at 120 °C and in 5 h at 100 °C. In VOD, as the evaporation potential is increased due to the vacuum, complete drying is achieved in shorter time, namely 3 h (at 120 °C) or 4 h (100 °C). During HAD, the air flows over the solid material and drives the water vapors, improving the mass transfer rate. As a result, the method is more efficient, complete drying requiring only 2 h at 120 °C or 3.5 h at 100 °C. As expected, the drying is faster at higher temperature. When the drying is performed at low temperature (50 °C), after 5 h, the mass of dried peels is about 13-14 g (OD and VOD) and 10 g (HAD). During the initial period (about 1 h at 120 °C), the rate of water removal is constant.

Fig 1 (right column) shows the moisture content (dry basis, Eq. (2)). After 5 h of drying at 50 °C, the moisture content (dry basis) is 5.88 g/g (OD), 5.20 g/g (VOD), and 3.85 g/g (HAD). These values correspond to removal of 55% (OD), 60% (VOD), and 70% of the initial amount of water. A similar trend is observed at other temperatures.

For convenience, Table 1 presents the moisture content (wet- and dry-basis) after 5 h of drying in different conditions. Note that the mass of the sample dried in the most efficient conditions (2.13 g, HAD, 120 °C, 5 h) was taken as the mass of solids in the sample and used to calculate the moisture content.

3.1.2. Drying temperature

Drying experiments were performed at 5 different temperatures: 50 °C, 70 °C, 80 °C, 100 °C, and 120 °C for determining the optimum drying temperature in terms of the amount of lycopene which can be recovered by extraction. Fig. 2 shows the effect of drying temperature (left, 5 h drying time) and drying time (right, 80 °C) on the moisture content (wet-basis). After 5 h of drying, the moisture content of tomato peels (wet basis) decreases from 93% to 85-79% at 50 °C, 56-27% at 70 °C, 48-20% at 80 °C, 19-16% at 100 °C, and 16-0% at 120 °C.

Another important issue in drying experiments of tomato peels is the evolution of the color of the peels with the drying temperature, this aspect being associated with the nutritional quality. For tomatoes, drying conditions as temperature, time, and oxygen exposure affect the color and content of the product. Generally, a change in the color of the product is associated with degradation of lycopene [27]. Also, a low moisture content of tomato products dried at high temperatures leads to irreversible chemical reactions and structural, physical, and mechanical changes [11].

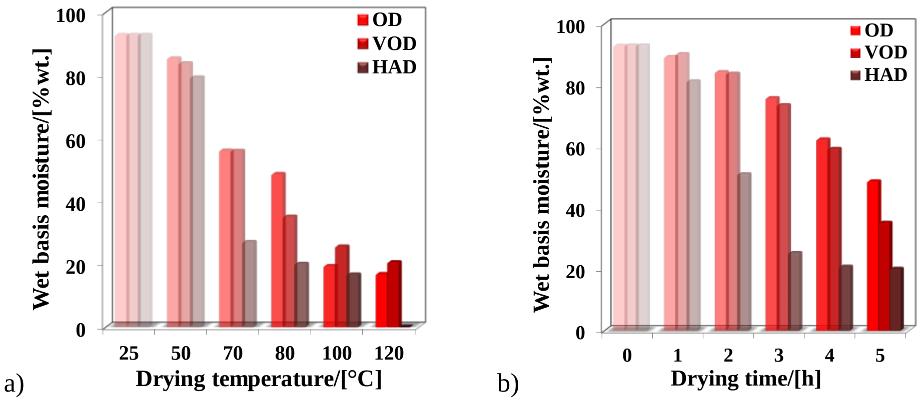

Fig. 2. Moisture during drying of tomato peels depending on: a) drying temperature at 5 h; b) drying time at 80 °C

Fig. 3 presents the aspect of the dried tomato peel after 5 h of drying at different temperatures. The dried tomato peels differ in color, texture, and odor with the temperature and the drying method.

The color varies between fresh red and brown depending on drying method and temperature. At temperatures over 80 °C (see Fig.3), color of dried peels is changed from red to brown and at 120 °C to dark brown. These changes are related to degradation of carotenoids, mainly of lycopene. The samples dried at 80 °C keep the red color for all drying techniques.

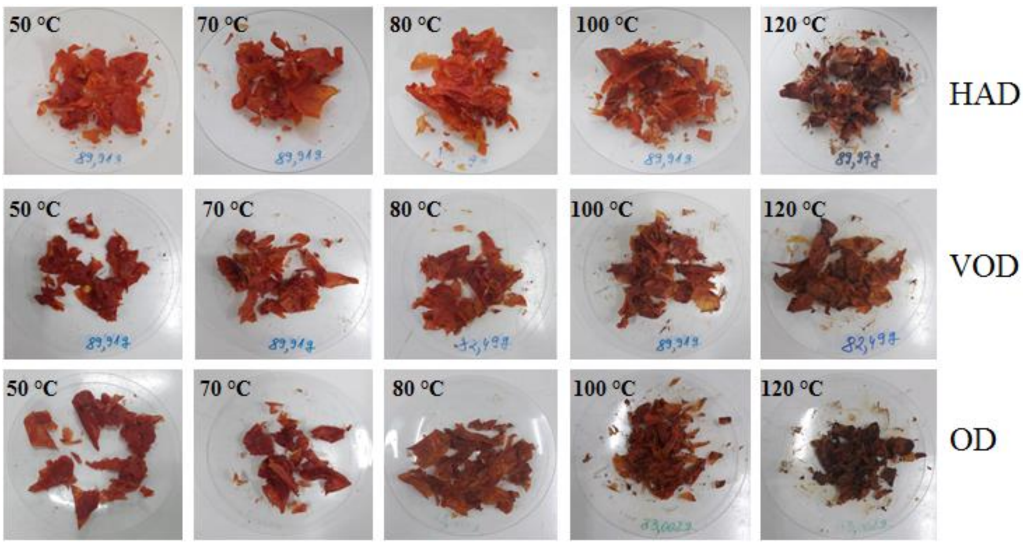

Fig. 3. The aspect of the dried tomato peels for three drying methods

3.1.3. Drying time

For each drying experiment, the mass of dried peels and the wet and dry basis moisture were determined every 30 min. Regardless of drying method, the samples lose the highest quantity of water during the first two hours (Fig. 1) when the percentage of water loss from OD and VOD peels is of 5-10%, while for HAD peels is 40% (see Fig. 2b for results concerning drying at 80°C). In the next three hours, the water loss for HAD peels is almost constant, while for OD and VOD peels is 10% per hour.

Depending on the drying method used, the moisture content of peels dried at 120 °C reaches the lowest value after 3-4 h for OD, 2-3 h for VOD, and 1-2 h for HAD. Drying temperature influences the drying time: the lowest moisture is reached after 4-5 h by drying at 70-80 °C and 2-3 h by drying at 100-120 °C.

During the drying experiments, the highest moisture content of the dried peels is observed at OD tomato peels, while the lowest moisture content is found in HAD tomato peels. Also, the drying process performed at 50 °C for 5 h is not efficient because the dried peels contain a high amount of water. This slows the extraction process (see next sections), an additional step for separating the water from the extract being necessary.

3.2. Influence of drying factors on the amount of recovered lycopene

Fresh and dried peels by the previously described drying methods were subjected to Soxhlet extraction to determine the lycopene content. 16 samples of tomato peels were monitored during an extraction time of 6 h, to see how the color of the extract from the bottom flask change. At the end of extraction time, sample cartridges and solvent from the extractors were discolored, while bottom flask extracts became more colorful, because carotenoids responsible for the color present in the sample cartridges were extracted in bottom flasks.

It was seen that the extracts from fresh tomatoes and their peels dried at 50 °C had a red brighter shade, while the extracts from tomato peels dried at 70-120 °C had a red color. After the extraction process, the solvent was removed from extracts by evaporation and samples were weighed in Eppendorf tubes. Extraction conditions and results of fresh and dried tomato peels are presented in Table 2.

Table 2

Soxhlet extraction results

Drying method	Drying temperature of tomato peels (°C)	Mass of tomato peel sample (g)	Mass of extract (g/100 g dried peels)
Fresh tomato peels	-	30.00	0.59
HAD	50	5.30	3.87
	70	2.30	10.78
	80	2.30	6.45
	100	2.40	8.04
	120	2.00	7.61

VOD	50	12.10	1.16
	70	4.30	4.85
	80	2.95	9.88
	100	2.60	7.33
	120	2.00	2.96
OD	50	13.00	1.56
	70	5.00	5.24
	80	3.90	5.29
	100	2.70	7.34
	120	2.30	6.66

It can be noticed that the amount of extract varies with the drying method and the drying temperature of the sample. The highest amount of extract was obtained at 70 °C from HAD peels (10.78 g/100 g dried peels), at 80 °C from VOD peels (9.88 g/100 g dried peels), and at 100 °C from OD peels (7.34 g/100 g dried peels).

3.2.1. Drying method

The initial lycopene content of fresh tomato peels from Crystal variety is 7 mg/100 g of fresh tomato peels, as determined by UV-Vis spectrometry analysis. Fig. 4 presents the amount of lycopene recovered from tomato peels relative to dried (Fig. 4a) and fresh samples (Fig. 4b), which varies with the drying method between 17-329 mg/100 g dried peels.

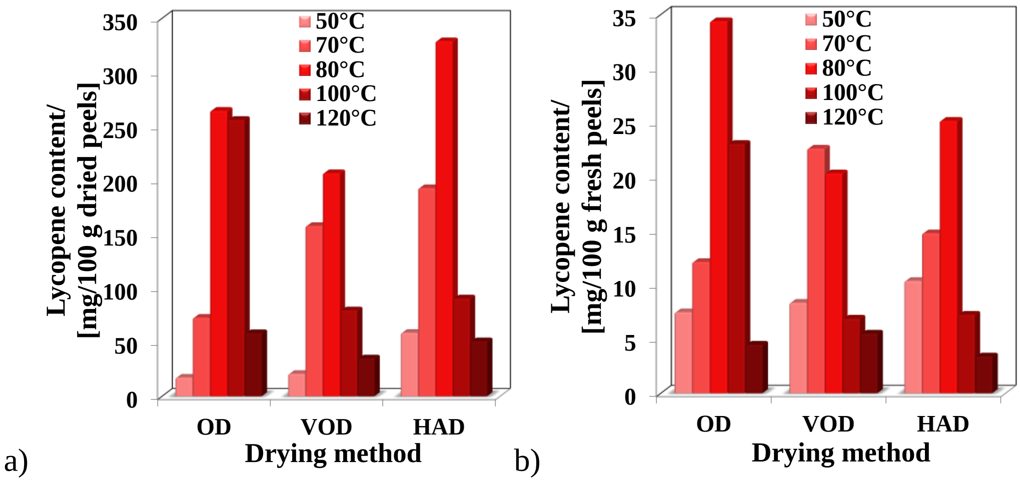

Fig. 4. Lycopene content during drying of tomato peels

For OD tomato peels the highest lycopene amount of 264 mg /100 g dried tomato peels was obtained from tomato peels dried at 80 °C, while the lowest amount of 17 mg/100 g of dried tomato peels was obtained from tomato peels dried at 50 °C. For VOD tomato peels the highest lycopene amount of 207 mg/100 g dried tomato peels was obtained from tomato peels dried at 80 °C, while the lowest amount of 21 mg/100 g of dried tomato peels was found in tomato peels dried at 50 °C. For HAD tomato peels the highest lycopene amount of 329 mg/100 g dried tomato peels was obtained from tomato peels dried at 80 °C, while the lowest amount of 51 mg/100 g of dried tomato peels was found in tomato peels dried at 120 °C. For OD tomato peels the highest lycopene amount of 34 mg/100 g fresh tomato peels was obtained from tomato peels dried at 80 °C, while the lowest content of 4 mg/100 g of fresh tomato peels was found in tomato peels dried at 120 °C. For VOD tomato peels the highest lycopene content of 23 mg/100 g fresh tomato peels was obtained from tomato peels dried at 70 °C, while the lowest content of 6 mg/100 g of fresh tomato peels was found in tomato peels dried at 120 °C. For HAD tomato peels the highest lycopene amount of 25 mg/100 g fresh tomato peels was obtained from tomato peels dried at 80°C, while the lowest content of 3 mg/100 g of fresh tomato peels was found in tomato peels dried at 120 °C.

3.2.2. Drying temperature

Fig. 4a presents also the effect of drying temperature on the amount of lycopene extracted from dry tomato peels, expressed as mg/100 g of dried tomato peels. Low amounts of lycopene are recovered from samples dried at low temperature (50 °C), because these samples have high moisture content and water acts as a barrier to lycopene extraction. Extracts obtained from dried peels at 70 °C contain more lycopene than dried peels at 50 °C, the maximum content being observed at 80 °C for each drying technique. As the drying temperature increases over 80 °C, the amount of recovered lycopene decreases, due to thermal degradation of the lycopene. This degradation was also observed from the change of the color at this temperature range.

Based on the measured amount of lycopene recovered from dried tomato peels by three drying methods, the most suitable drying temperature is 80 °C. A small difference can be observed when reporting the amount of lycopene recovered in fresh peels due to the presence of water in the samples (Fig. 4b).

4. Conclusions

All the studied factors (drying method, drying temperature, drying time) influence the moisture and the amount of lycopene recovered from tomato peels, Crystal variety. The driest samples were obtained by HAD method in the shortest time (2.13 g dried peels after 2 h). Altough the driest samples were obtained at 120 °C, above drying temperature of 80 °C, it was observed a change in color, which means that the peels were degraded. The time needed for complete drying of tomato peels varies with the drying temperature, the lowest moisture being reached at 70-80 °C after 4-5 h and at 100-120°C after 2-3 h. The process of lycopene extraction from dried peels is influenced by moisture content of peels. Thus, from samples with high moisture (dried at temperatures of 50-70 °C, with

27-85%wt.) the lowest quantity of lycopene is extracted (17-193 mg/100 g of dried peels, 7-23 mg/100 g of fresh peels). The highest lycopene amount (329 mg/100 g dried tomato peels, 34 mg/100 g fresh tomato peels) was recovered from tomato peels, Crystal variety, dried at 80 °C using HAD method. When peels drying is performed at temperatures higher than 80 °C, the lycopene content decreses due to the thermal degradation.

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R E F E R E N C E S

[1]. *R. K. Toor and G. P. Savage*,"Antioxidant activity in different fractions of tomatoes", in Food Research International, **vol. 38**, no. 5, Jun. 2005, pp. 487-494

[2]. *C. H. Chang and Y. C. Liu*,"Study on Lycopene and Antioxidant Contents Variations in Tomatoes under Air-Drying Process", in Journal of Food Science, **vol. 72**, no. 9, Dec. 2007, pp. 532-540

[3]. *O. A. Gumusay, A. A. Borazan, N. Ercal and O. Demirkol*,"Drying effects on the antioxidant properties of tomatoes and ginger", in Food Chemistry, **vol. 173**, Oct. 2015, pp. 156-162

[4]. *N. Konar, I. Haspolat, E. S. Poyrazoglu, K. Demir and N. Artik*,"A Review on Supercritical Fluid Extraction (SFE) of Lycopene from Tomato and Tomato Products", in Karaelmas Science and Engineering Journal, **vol. 2**, no. 1, Jun. 2012, pp. 69-75

[5]. *K. K. Pokharkar, D. V. Delvadia, J. B. Parag and P. B. Bhor*,"Effect of pre-treatments and drying methods on moisture percentage of dried Tomato Slices", in Archive of Food and Nutritional Science, **vol. 1**, Aug. 2017, pp. 24-26

[6]. *L. Azeez, S. A. Adebisi, A. O. Oyedeji, R. O. Adetoro and K. O. Tijani*,"Bioactive compounds contents, drying kinetics and mathematical modelling of tomato slices influenced by drying temperatures and time", in Journal of the Saudi Society of Agricultural Sciences, **vol. 18**, no. 2, Apr. 2019, pp. 120-126

[7]. *M. Butnariu*,"Methods of Analysis (Extraction, Separation, Identification and Quantification) of Carotenoids from Natural Products", Journal of Ecosystem & Ecography, **vol. 6**, no. 2, Jun. 2016, pp. 1-19

[8]. *V. Nour, T. D. Panaite, M. Ropota, R. Turcu, I. Trandafir and A. R. Corbu*," Nutritional and bioactive compounds in dried tomato processing waste", in CyTA-Journal of Food, **vol. 16**, Jan. 2018, pp. 222-229

[9]. *D. Pandya, S. Akbari, H. Bhatt and D. C. Joshi*,"Standardization of solvent extraction process for lycopene extraction from tomato pomace", in Journal of Applied Biotechnology & Bioengineering, **vol. 2**, no. 1, Jan. 2017, pp. 1-5

[10]. *A. Mendelova, M. Fikselova and L. Mendel*,"Carotenoids and lycopene content in fresh and dried tomato fruits and tomato juice", in Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, **vol. 147**, no. 5, Feb. 2013, pp. 1329-1337

[11]. *E. E. Abano, H. Ma and W. Qu*,"Influence of Air Temperature on the Drying Kinetics and Quality of Tomato Slices", in Journal of Food Processing & Technology, **vol. 2**, no. 5, Nov. 2011, pp. 1-9

[12]. *C. Yi, J. Shi, S. J. Xue, Y. Jiang and D. Li*,"Effects of supercritical fluid extraction parameters on lycopene yield and antioxidant activity", in Food Chemistry, **vol. 113**, no. 4, Apr. 2009, pp. 1088-1094

[13]. *J. A. Egydio, A. M. Moraes and P. T. V. Rosa*,"Supercritical fluid extraction of lycopene from tomato juice and characterization of its antioxidation activity", in Journal of Supercritical Fluids, **vol. 54**, no. 2, Apr. 2010, 159-164.
[14]. *B. P. Nobre, A. F. Palavra, F. L. P. Pessoa and R. L. Mendes*,"Supercritical CO_2 extraction of trans-lycopene from Portuguese tomato industrial waste", in Food Chemistry, **vol. 116**, no. 3, Mar. 2009, pp. 680-685
[15]. *W. C. Abreu, M. F. P. Barcelos, E. P. Silva and E. V. B. V. Boas*,"Physical and chemical characteristics and lycopene retention of dried tomatoes subjected to different pre-treatments", in Revista do Instituto Adolfo Lutz, **vol. 70**, no. 2, May 2011, pp. 168-174
[16]. *D. Kaur, A. A. Wani, D. P. S. Oberoi and D. S. Sogi*,"Effect of extraction conditions on lycopene extractions from tomato processing waste skin using response surface methodology", in Food Chemistry, **vol. 108**, Nov. 2008, pp. 711-718
[17]. *M. Shahnawaz, S. A. Sheikh, A. H. Soomro, A. A. Panhwar and S. G. Khaskheli*,"Quality characteristics of tomatoes (lycopersicon esculentum) stored in various wrapping materials", in Journal of Food Science and Technology, **vol. 3**, no. 5, Jul. 2012, pp. 123-128
[18]. *K. Sacilik*,"The Thin-Layer Modelling of Tomato Drying Process", in Agriculturae Conspectus Scientificus, **vol. 72**, no. 4, Jan. 2007, pp. 343-349
[19]. *J. M. Zdravkovic, N. V. Pavlovic, N. M. B. Vragolovic, D. Z. Moravcevic and M. M. Sevic*,"Preservation of vitamin c, lycopene and carbohydrate content in tomato dried in a tunnel type dryer", in Food and Feed Research, **vol. 44**, no. 2, Feb. 2017, pp. 133-142
[20]. *I. Navarro-Gonzalez, V. Garcia-Valverde, J. Garcia-Alonso and M. J. Periago*,"Chemical profile, functional and antioxidant properties of tomato peel fiber", in Food Research International, **vol. 44**, no. 5, Apr. 2011, pp. 1528-1535
[21]. *N. Bashir, M. A. Bhat, B. N. Dar and M. A. Shah*, "Effect of different drying methods on the quality of tomatoes", in Advances in Food Sciences, **vol. 36**, no. 2, Jun. 2014, pp. 65-69
[22]. *N. H. M. R. Mozumber, M. A. Rahman, M. S. Kamal, A. K. M. Mustafa and M. S. Rahman*,"Effects of Pre-drying Chemical Treatments on Quality of Cabinet Dried Tomato Powder", in Journal of Environmental Science & Natural Resources, **vol. 5**, no. 1, Aug. 2012, pp. 253-265
[23]. *M. Yusufe, A. Mohammed and S. Neela*,"Effect of drying temperature and duration on nutritional quality of cochoro variety tomato (lycopersicon esculentum l.)", in Annals: Food Science and Technology, **vol. 18**, no. 2, Feb.2017, pp. 145-152
[24]. *R. Sadin, G. R. Chegini and H. Sadin*,"The effect of temperature and slice thickness on drying kinetics tomato in the infrared dryer", in Heat Mass Transfer, **vol. 50**, Nov. 2014, pp. 501–507
[25]. *D. G. Mercer*,"An introduction to the dehydration and drying of fruits and vegetables", Department of Food Science, University of Guelph, Ontario, Canada, Nov. 2014
[26]. *B. P. Nobre, L. Gouveia, P. G. D. Matos, A. F. Cristino, A. F. Palavra and R. L. Mendes*,"Supercritical Extraction of Lycopene from Tomato Industrial Wastes with Ethane", Molecules, **vol. 17**, Jul. 2012, pp. 8397-8407
[27]. *H. Sahin, F. T. Aktas, H. Orak and P. Ulger*,"Influence of Pretreatments and different drying methods on color Parameters and lycopene content of dried tomato", Bulgarian Journal of Agricultural Science, **vol. 17**, no. 6, Mar. 2011, pp. 867-881