Physical and chemical characteristics and lycopene retention of dried tomatoes subjected to different pre-treatments

Características físicas, químicas e retenção de licopeno em tomates secos submetidos a diferentes pré-tratamentos

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ABSTRACT
This study evaluated the physical and chemical characteristics (moisture, pH, acidity titratable, soluble solids and color) and lycopene retention in dried tomatoes submitted to different pretreatments. The tomatoes were cut longitudinally and submitted to the osmotic dehydration for 120 minutes. Six osmotic solutions were used with the following concentrations: NaCl 5%, NaCl 10%, NaCl 5% + sucrose 10%, NaCl 10% + sucrose 5%, sucrose 5%, sucrose 10% (w/v), and the osmotic dehydration was conducted with direct application of the solutes (NaCl or mixture of NaCl + sucrose). Soon afterwards the tomatoes were submitted to drying at 65°C for 12 hours. The osmo-convective drying promoted an increase in the level of soluble solids, titratable acidity and reduction of the pH, except for the sucrose solutions, that did not alter the pH of the tomatoes. The ternary solution (NaCl + sucrose), binary (NaCl 10%) and the direct application of the solutes promoted significant moisture reduction in relation to the control. The osmotic solutions only containing sucrose or NaCl 5% presented lycopene retention significantly superior to the other treatments. The use of the osmotic dehydration as pretreatment for drying of the tomato can contribute to accelerate the drying process and to preserve the tomato lycopene level.
Keywords. dried tomato, osmotic dehydration, lycopene.

RESUMO
Este estudo avaliou as características físicas e químicas (umidade, pH, acidez titulável, sólidos solúveis e cor) e a retenção de licopeno em tomates secos submetidos a diferentes pré-tratamentos. Os tomates foram cortados longitudinalmente e submetidos à desidratação osmótica por 120 minutos. Foram utilizadas seis soluções osmóticas com as seguintes concentrações: NaCl 5%, NaCl 10%, NaCl 5% + sacarose 10%, NaCl 10% + sacarose 5%, sacarose 5%, sacarose 10% (p/v). Foi também realizada desidratação osmótica com aplicação direta dos solutos (NaCl ou mistura de NaCl + sacarose). Em seguida, os tomates foram submetidos à secagem, a 65°C, durante 12 horas. A secagem osmoconvectiva promoveu aumento do teor de sólidos solúveis, acidez titulável e redução do pH, exceto para soluções de sacarose que não alteraram o pH dos tomates. As soluções ternárias (NaCl + sacarose), binária (NaCl 10%) e a aplicação direta dos solutos promoveram redução significativa da umidade em relação ao controle. As soluções osmóticas contendo apenas sacarose ou com NaCl 5% determinaram retenção de licopeno significativamente superior aos demais tratamentos. A utilização da desidratação osmótica como pré-tratamento para secagem do tomate pode contribuir para acelerar o processo de secagem e preservar o teor de licopeno de tomates.
Palavras-chave. tomate seco, desidratação osmótica, licopeno.

INTRODUCTION

The tomato is the second most produced horticultural product in the world, only being surpassed by the potato. Due to its low cost and availability throughout the year, its consumption is observed in all of the socioeconomic classes, reaching a considerable portion of the Brazilian population. The tomato is being widely cultivated in Brazil, being the main vegetable in production volume, with prominence for the states of Goiás, São Paulo, Minas Gerais, Pernambuco and Bahia, with about 77% of the annual national production[1].

The tomato and its products have been considered foods with functional properties, due to the positive effect of its consumption on the prevention of chronic diseases such as certain cancers and coronary heart disease (CHD). Those effects are associated to the presence of antioxidant phytochemicals, among which lycopene stands out. The tomato and its products constitute the main source of lycopene of the human diet[2,3].

The dehydration of the tomato to obtain the dried tomato has been seen as an important alternative to prolong the consumption period of the fruit, avoid production surplus waste and a commercialization alternative when the fresh tomato supply is higher than the demand[4].

The production of the dried tomato has been increasing in recent years, due to its growing appreciation in Brazilian cookery. Some research has been conducted with the objective of developing techniques to minimize alterations in the color, flavor and texture and loss of nutrients and lycopene due to the drying conditions applied to tomato[5,6]. Osmotic dehydration has been used as a pre-treatment for tomato drying, because it reduces the drying time, generating savings and improving the sensorial characteristics of the final product[6,7].

Osmotic dehydration of foods consists of the partial removal of water by the pressure caused when the product is put in contact with a hypertonic solution of solutes (sugar, salt or both), thus decreasing the food water activity. When the food is put in the hypertonic solution, the water passes through the cell walls of the fruit to the solution[7]. Its application in the dehydration of the tomato can contribute to preserve the lycopene levels. However, the use of solutes and different concentrations can alter the physical characteristics and chemistries of the final product.

The preservation of the lycopene content of tomato during drying is essential to maintain their functional properties. This work was conducted with the objective of evaluating the effects of the application of osmotic dehydration, as pre-treatments for the drying of tomatoes, on their physical and chemical characteristics and on lycopene retention.

MATERIAL AND METHODS

This work was conducted in the Food Science Department of the Federal University of Lavras (UFLA), in Lavras, Minas Gerais. In this study, tomatoes of the Bonus cultivar were used, produced in an organic system in the horticulture sector of the Federal University of Lavras. After harvest, the tomatoes were selected, washed in running water to eliminate dirt and stored under room temperature until completely ripe, reaching an intense red coloration in every fruit.

The tomatoes were divided in 2 kg lots, sanitized in chlorinated water (200 ppm), for 15 minutes. Soon afterwards, under room temperature, they were cut with stainless steel knife perpendicular to the longitudinal direction, forming pieces corresponding to a fourth of the tomato. The seeds were removed with a stainless steel spoon.

The obtaining of the dried tomato was carried out using two different techniques: osmo-convective (OCD) and hot air convective drying (CD). In the osmo-convective drying, the hot air convective drying is preceded by osmotic dehydration. The tomatoes were submitted to the osmotic dehydration, for 120 minutes, as pre-treatment for drying convective. To perform the osmotic dehydration (OD), the cut tomatoes, without seeds, were immersed in different solutions, at a proportion of 1:3 tomato/solution (g/mL), as follows: OD_1 (NaCl 5%), OD_2 (NaCl 10%), OD_3 (NaCl 5% + sucrose 10%), OD_4 (NaCl 10% + sucrose 5%), OD_5 (sucrose 5%), OD_6 (sucrose 10%) (w/v). Osmotic dehydration without immersion in solution was also conducted, with the direct application of solutes (OD_7 NaCl and OD_8 NaCl + sucrose, proportion 1:1, w/w), in which the tomatoes were covered by a fine layer of NaCl, isolated or combined with sucrose.

After the osmotic dehydration, the tomatoes were distributed in stainless steel trays and placed in an oven, with air circulation at 65°C. The trays remained in the oven for 12 hours and then the samples removed and submitted to the physical and chemical analyses. For the control treatment, 2 kg of tomatoes was submitted to direct drying (convective drying-CD) in the oven without being submitted to the osmotic dehydration.

All of the physical and chemical analyses were determined in the dried tomatoes from the osmo-convective and convective drying and in the fresh tomato.

The coloration was measured using the Minolta CR-400 colorimeter, with the determination in the system CIE L*, a*, b*, with a standard white ceramic plate. The readings were taken directly at the central points of the internal (endocarp) and external (epicarp) surfaces of the dried tomato slices. Five readings of each sample were taken.

The moisture was determined by the gravimetric method employing heat, according to the procedure of the Association of Official Analytical Chemists – AOAC[8]. The soluble solids level (SS) was determined using the Atago, I model N-1 refractometer, according to AOAC[8].

The hydrogenic potential was measured using a portable Ingold, pH206 pHmeter. The titratable acidity was determined by titration with a solution of NaOH 0.1M and phenolphthalein as indicator, according to the Adolfo Lutz Institute[9]. The results were expressed in mg citric acid.100g^{-1} of the fruit.

The lycopene level was determined according to the method proposed by Nagata e Yamashita[10]. The lycopene was extracted using a mixture of acetone and hexane (4:6). The extracts were submitted to spectrophotometer readings at different wavelengths (453, 505, 645 and 663 nm) and the lycopene concentration was calculated according to the equation:

$$\text{Lycopene (mg/100 mL)} = 0.0458.A_{663} + 0.204.A_{645} + 0.372.A_{505} - 0.0806.A_{453}.$$

The results were transformed to be expressed in µg.g^{-1}.

The lycopene retention percentage was calculated according to the equation

$$\%R = \frac{\textit{lycopene in dried tomato } (\mu g \times 100g^{-1}\ DM) \times 100}{\textit{lycopene in fresh tomato } (\mu g \times 100g^{-1}\ DM)}$$

where: DM = dry matter

The study was conducted using a completely randomized design (CRD) with three repetitions, totaling 10 treatments and 30 portions. For the data analysis, the SISVAR program was used[11]. The data were submitted to the variance analysis, complemented with the Scott-Knott test to 5% of probability.

RESULTS AND DISCUSSION

The averages of moisture, pH, soluble solids (SS), titratable acidity (TA) and SS/TA of fresh tomatoes and those submitted to osmo-convective (OCD) and convective (CD) drying are presented in Table 1.

The osmo-convective and convective drying reduced the moisture of the tomatoes significantly, after 12 hours of drying. The osmo-convective drying was more effective than the convective drying (control), when solution of NaCl at 10%, (OCD_2), ternary solutions of NaCl + sucrose (OCD_3 and OCD_4) and solutes without immersion (OCD_7 and OCD_8) were used. Corrêa et al.[5] also observed that the osmotic dehydration favors the loss of moisture of the tomato during the drying process. The application of the osmotic dehydration as pre-treatment can reduce the tomato drying time, reducing the costs of this processing stage.

Considering only the osmo-convective drying, the pre-dehydration with solutes without immersion was more effective than the pre-dehydration with immersion in solutions, due to greater solute concentration of these treatments that increase the osmotic effect. It is important to observe that the osmotic solutions only containing sucrose (OCD_6 and OCD_5) presented performance equal or inferior to the control (CD). That can occur due to the

Table 1. Average values of physical and chemical characteristics of tomatoes subjected to osmo-convective and convective drying and the fresh tomato

Treatments	Moisture (%)	pH	SS (°Brix)	TA (% citric acid)	SS/TA
OCD_1	75.83^c	3.91^b	18.97^d	0.70^c	27.09^b
OCD_2	71.56^d	3.72^c	27.50^b	0.81^b	34.10^a
OCD_3	71.84^d	3.98^b	22.00^c	0.81^b	27.31^b
OCD_4	70.35^d	3.65^c	22.00^c	0.80^b	27.61^b
OCD_5	85.63^b	4.02^b	14.30^d	0.70^c	19.83^c
OCD_6	79.07^c	4.03^b	16.87^d	0.72^c	23.95^b
OCD_7	61.95^e	3.52^d	30.80^a	0.84^a	37.17^a
OCD_8	63.03^e	3.64^c	33.00^a	0.85^a	38.65^a
CD	79.21^c	4.21^a	17.60^d	0.77^b	22.85^b
Fresh Tomato	95.07^a	4.14^a	5.50^e	0.38^d	14.34^c
CV	3.47	1.88	10.74	4.05	12.26

SS = soluble solids, TA = titratable acidity, OCD_1 = NaCl 5%, OCD_2 = NaCl 10%, OCD_3 = NaCl 5% + sucrose 10%, OCD_4 = NaCl 10% + sucrose 5%, OCD5 = sucrose 5%, OCD_6 = sucrose 10%, OCD_7 = NaCl without immersion, OCD_8 = NaCl + sucrose without immersion, CD = convective drying. Averages followed by same letter in the column do not differ by Scott-Knott test at 5% probability fact that the sugar forms a barrier on the tomato surface, hindering the exit of water from the fruit during drying[12]. On the other hand, in spite of the sucrose presence in the ternary solutions (OCD_3 and OCD_4), these presented moisture reduction superior to the control. This was probably observed due to the presence of NaCl, that reduced the formation of the sugar layer on the food surface, promoting higher dehydration rates[6].

The osmo-convective drying reduced the pH of the tomato significantly compared to the control and fresh tomato. The pre-dehydration with NaCl without immersion (OCD_7) led to the highest pH reduction among all the treatments, due to higher concentration of organic acids, followed by NaCl + sucrose (OCD_8) and NaCl 10% in solution (OCD_2). Venske et al.[13] found pH average equal to 3.98 in tomatoes dehydrated to 81.6% moisture. The reduction of the pH reduces the microbial proliferation, favoring the conservation of the product[14].

The dehydration, in spite of the treatment used, produced increase in the concentration of the organic acids, causing significant elevation of the titratable acidity (TA) of the tomato (Table 2). The tomatoes submitted to the osmotic dehydration with sucrose solution (OCD_5 and OCD_6) and NaCl at 5% (OCD_1) presented significantly lower TA than the control. However, the tomatoes submitted to the pre-dehydration with solutes without immersion (OCD_7 and OCD_8) presented TA significantly higher than the control ($p < 0.05$). The TA of the tomatoes submitted to the other treatments did not differ from that observed in the control. The elevation of the TA promoted by the dehydration can be associated to the tendency of the fall of the pH of the dried tomatoes. However, the elevation of the TA was not proportional to the water loss observed with the drying. Other authors have observed an increase of the TA in tomatoes submitted to drying[13,15].

The convective and osmo-convective dehydration promoted significant increase ($p < 0.05$) of the tomato soluble solids (SS) levels. That increase is due to the loss of water during the dehydration of the tomato and the transfer of solutes during the pre-dehydration.

The treatments with osmo-convective drying without immersion (OCD_7 and OCD_8), which produced the highest water loss during drying, also determined higher SS levels. Unlike the other treatments, the osmotic pre-dehydration with solution of NaCl at 5% and with sucrose solutions at 5% and 10% determined SS levels statistically equal to those observed in the control. In general, the SS level of the fresh tomato varies between 4° and 6° Brix and it increases with maturation and dehydration of the fruit[16]. Silva et al.[15] found higher SS levels in tomatoes submitted to the osmo-convective drying with solution of NaCl 5% + sucrose 10% (28.33 °Brix) than with solution of NaCl at 10% (24.33 °Brix), different from that observed in this study. The presence of sodium chloride in the solution can favor the sucrose incorporation in the tomato, due to the increase of the cell membrane permeability, caused by physical alterations provoked by the sodium chloride[6]. The elevation of the SS levels was not totally proportional to the moisture reduction of the tomatoes, indicating that solute transfer occurred during the osmotic dehydration.

The SS/TA ratio, that has a decisive role in the flavor of the tomato, increased significantly compared to fresh tomato, except for the treatment with sucrose solution at 5%. However, only the treatments with osmo-convective drying without immersion (OCD_7 and OCD_8) and with immersion in solution of 10% sodium chloride (OCD_2) produced significant increase of the SS/TA ratio in relation to the control (CD). According to Lisiewska and Kmiecik[17], SS/TA ratio values higher than 10 indicate optimum combination between sugar and acidity, being correlated with mild flavor. All of the dried tomatoes of the present study presented an SS/TA ratio above 10. It is worth remembering that the dried tomato in preserves, available in the retail market, will have the flavor influenced by the mixture of oils and seasonings used to elaborate the preserve. In general, mixtures of olive oil and soy or sunflower oil are used, with addition of seasonings such as garlic, salt and oregano.

Analyzing the joint data of Table 1, the osmo-convective dehydration with NaCl without immersion (OCD_7) stands out, that determined lower moisture and pH values and higher SS/TA ratio, that potentially can be associated to longer shelf life and better flavor.

The average levels of lycopene and its retention percentage undergoing drying tomatoes and fresh tomatoes are presented in Table 2.

The water removal by the osmo-convective and convective drying processes led to a significant increase (between 3.1 and 5.8 times) of the lycopene level concentration in the dried tomatoes compared to the fresh tomatoes. Various studies have shown higher lycopene levels in the dehydrated tomato in relation to the fresh tomato[3,18,19]. Muratore et al.[18] verified a lycopene level increase from 2.8 to 3.5 times in dehydrated tomatoes. The increase of the lycopene level observed in products derived from the tomato, such as extracts and sauces, is due to the

Table 2. Average values of the lycopene content and retention percentage of tomatoes subjected to osmo-convective and convective drying and the fresh tomato

Treatments	Lycopene (μg.g^{-1} FM*)	Lycopene (μg.g^{-1} DM#)	Lycopene Retention (%)
OCD_1	105.34^b	435.83^a	97.53^b
OCD_2	96.03^c	353.76^c	80.50^d
OCD_3	107.87^b	383.05^b	85.72^c
OCD_4	80.54^e	271.64^d	60.78^e
OCD_5	67.83^f	472.02^a	105.57^a
OCD_6	92.30^c	441.00^a	98.65^b
OCD_7	93.56^c	245.69^d	54.98^f
OCD_8	126.87^a	343.16^c	76.79^d
CD	67.28^f	328.92^c	73.60^d
Fresh Tomato	22.03^g	446.85^a	100.00
CV	4.70	5.42	3.83

**FM = fresh matter, DM = dry matter, OCD_1 = NaCl 5%, OCD_2 = NaCl 10%, OCD_3 = NaCl 5%+ sucrose 10%, OCD_4 = NaCl 10% + sucrose 5%, OCD_5 = sucrose 5%, OCD_6 = sucrose 10%, OCD_7 = NaCl without immersion, OCD_8 = NaCl + sucrose without immersion, CD = convective drying. Averages followed by same letter in the column do not differ by Scott-Knott test at 5% probability*

Table 3. Average values and standard deviations of the color parameters L* a* b*, in tomatoes subjected to osmo-convective and convective drying and the fresh tomato

Treatments	Internal wall			External wall		
	L*	a*	b*	L*	a*	b*
OCD_1	36.85^b	23.60^b	11.33^b	37.40^a	25.77^b	15.41^b
OCD_2	37.43^b	29.26^a	15.34^a	39.15^a	26.19^b	17.04^b
OCD_3	32.81^c	27.61^a	14.15^a	36.60^b	25.39^b	17.71^b
OCD_4	38.12^b	27.11^a	14.87^a	36.05^b	28.79^b	22.20^a
OCD_5	38.50^a	23.26^b	14.46^a	35.88^b	27.10^b	20.74^a
OCD_6	36.83^b	28.76^a	15.20^a	35.47^b	25.88^b	18.32^b
OCD_7	39.68^a	30.52^a	17.88^a	37.98^a	30.72^a	20.95^a
OCD_8	39.40^a	29.41^a	16.33^a	37.77^a	34.76^a	23.17^a
CD	39.78^a	21.19^b	9.61^b	39.43^a	23.53^b	14.15^b
Fresh Tomato	33.95^c	20.23^b	9.68^b	37.38^a	26.78^b	26.06^a
CV	4.82	5.39	3.97	4.82	12.70	13.97

OCD_1= NaCl 5%, OCD_2 = NaCl 10%, OCD_3 = NaCl 5%+ sucrose 10%, OCD_4 = NaCl 10%+ sucrose 5%, OCD_5 = sucrose 5%, OCD_6 = sucrose 10%, OCD_7 = NaCl without immersion, OCD_8 = NaCl + sucrose without immersion, CD = convective drying. Averages followed by same letter in the column do not differ by Scott-Knott test at 5% probability

action of the temperature that favors the rupture of the cell walls, increasing the availability of the free lycopene[20]. Furthermore, during the tomato processing, moisture reduction occurs, increasing the lycopene concentration[21].

The tomatoes submitted to the osmo-convective drying with immersion in solutions with sucrose (OCD_5 and OCD_6) or NaCl 5% (OCD_1) had a significantly higher average lycopene retention than the other treatments. Also was observed that the increase of the sodium chloride level in the osmotic solutions reduced the lycopene retention, while the increase of the sucrose level in the ternary solutions elevated the retention of this carotenoid. Tonon et al.[22] also found higher lycopene retention in tomatoes submitted to the osmotic dehydration with solutions containing sucrose. According to Shi et al.[23] the sugar penetrates into the cell matrix and increases the bonding force of the lycopene with the cell matrix, reducing the lycopene oxidation.

The treatment with 5% sucrose presented a lycopene retention percentage above 100%. This probably occurred because the lycopene was not fully extracted in fresh tomatoes due to be bonded to cell matrix components, which hinders its extraction from the fruit. According to Rodrigues-Amaya[24] heat treatment breaks down the structures of the tomato cell matrix improving the extraction of lycopene.

The osmotic dehydration can be used as a first step in the drying of tomatoes, because it contributes to the removal of water and the preservation of the lycopene level and color, which is the most important quality attribute of that fruit[25]. Sanjinez-Argandon et al.[26] verified that the use of the osmotic dehydration as a pre-treatment in the guava drying process improved the final quality of the product, increasing the vitamin C and carotenoid retention. Those results were attributed to the reduction of the product of oxidation due to the formation of a sugar layer on the guava surface, reducing the contact with oxygen. The results observed in the present study show that the lycopene retention was only favored with the osmotic solutions with NaCl 5% and NaCl 5% + 10% sucrose (OCD_1 and OCD_3), and 5% or 10% sucrose (OCD_5 and OCD_6). The pre-dehydration with NaCl without immersion promoted lycopene retention inferior to that of the control.

The average values of the color parameters L*, a*, and b* of the dried and fresh tomatoes measured on the internal and external surfaces of the slices are presented in Table 3.

For tomatoes, the coloration is the main purchase decision factor used by the consumer[27]. The parameters L* and a* presented significant variation, mainly in the internal wall of the tomatoes. While the parameter L* (clarity) presented tendency of increase in the internal wall, except for the treatment with solution of NaCl 5% + 10% sucrose (OCD_3), in the external wall, that parameter remained stable for most of the treatments. In the external wall, the pre-dehydration with solutions containing sucrose led to significant reduction of the L* parameter in relation to the fresh tomato. The darkening observed in those treatments can be associated to the higher formation and accumulation of hydroxymethylfurfural (HMF). Cámara et al.[28] (2003) found a higher HMF level in ketchup, a product that receives sucrose addition during processing, compared to the industrialized tomato juice.

The convective drying did not significantly modify the a* value of the internal and external walls of the tomatoes, suggesting little, or no, interference in the red coloration of the dehydrated fruits, in comparison with the fresh tomato. The same was observed for the osmo-convective drying using NaCl 5% (OCD_1) and sucrose 5% (OCD_5). While the other treatments led to a higher a* value in the internal wall of the tomato, only the treatments OCD_7 and OCD_8 led to it in the external wall. Because the red coloration is desirable in tomato and its products, the treatments OCD_7 and OCD_8 stand out, which resulted in the highest a* values in the dried tomatoes.

In general, the coloration remained more stable in the external wall of the tomatoes, probably due to protection exercised by the presence of the cuticle that minimizes the solute exchanges and contact with oxidizing agents.

A significant increase of the parameter b* was observed for all the treatments in the internal wall, except for the pre-dehydration with NaCl 5%. That fact can be related to the possible increase of the cis lycopene isomers, that give a more orange tone to the tomato. On the other hand, in the external wall, the b* values presented significant reduction for most of the treatments (OCD_1, OCD_2, OCD_3, OCD_6 and CD). According to Heredia et al.[29] (2010), the emergence of orange tones in dehydrated tomatoes is related to the presence of cis lycopene isomers. Shi et al.[23] found L* values equal to 36.7 and 38.4, for tomatoes dried in a vacuum system at 55°C with osmotic pre-dehydration and fresh tomatoes, respectively. Silva et al.[15] observed increase of the L*, a* and b* values in tomatoes submitted to the osmo-convective drying with osmotic solutions of NaCl 10% and NaCl 5% + sucrose 10%, the solution containing sucrose having preserved the color parameters better.

Emphasize the importance of verifying, in future works through sensorial analyses, if the color alterations detected using the color parameters L*, a* and b*, are sufficient to modify consumer preference in relation to the dried tomato.

CONCLUSIONS

Different types and concentrations of solutes influence the effectiveness of the osmotic dehydration differently, as a pre-treatment in the osmo-convective dehydration process.

The osmo-convective dehydration, using pure NaCl, presents as the most effective, from the preservation and sensorial potential point of view, for jointly leading to lower moisture and pH values and higher SS/TA ratio and a* value in the dried tomatoes, although it led to a 45% decrease in the lycopene retention;

The increase of the sodium chloride concentration in the binary solutions harms the lycopene retention. To the contrary, the sucrose addition to the ternary solutions of sodium chloride and sucrose favors the lycopene retention.

The osmo-convective dehydration with 5% sucrose solution, followed by the 10% sucrose and 5% NaCl solutions, led to higher lycopene retention in the dried tomato.

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