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STUDY OF ENCAPSULATION PARAMETERS TO IMPROVE CONTENT OF LYCOPENE IN TOMATO (*SOLANUM LYCOPERSICUM* L.) POWDERS

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The aim was to examine conditions of convective drying and spray-drying to improve preservation of lycopene content in tomatoes. The weight, size, colour, pH and °Brix values were evaluated in fresh fruit (FF) and colour (L, a, b), hue, and chrome indices were analysed from dried tomatoes, too. Tomato paste was dried (40, 50, 60, and 80 °C with times of 540, 390, 270, and 240 min) under convection conditions and pulverized. In the encapsulation treatments core material with tomato powders of 50, 60, and 70%, shell solution of maltodextrin/gum arabic 1:1, flow rate of 4, 6, 9, and 12 ml min^{-1}, and inlet air T of 160, 170, and 180 °C were used. The physicochemical properties of FF corresponded to a degree of ripeness for consumption. The a, a/b, and hue values of dried tomatoes at 50 °C significantly correlated to red colouring and higher lycopene content (47.98±1.49 mg/100 g). The encapsulation with 50% and 60% of tomato powders, 170 °C and 9 ml min^{-1} treatments increased lycopene contents to 10.41 mg/100 g, 10.20 mg/100 g, and 11.51 mg/100 g, respectively. The results demonstrated that the physicochemical and functional properties were influenced by drying conditions, providing useful information for increasing the stability of lycopene in dried tomatoes.

Keywords: lycopene, tomato drying, antioxidant, encapsulation

Tomato belonging to the family Solanaceae is considered an important vegetable, since it adds to the gastronomic variety and is included in our daily diet. Mexico is the leading exporter of tomatoes, its production is mainly directed to the United States. For this reason, it is recognized to be a crop of great socioeconomic importance (SAGARPA, 2015). Tomato is one of the main sources of minerals, vitamins, and antioxidants due to its lycopene content (LUNA-GUEVARA et al., 2014). Lycopene is a carotenoid found in certain fruit and vegetables, it is a liposoluble pigment responsible for the red-orange colour and it has outstanding antioxidant properties. Main sources of lycopene are tomato and its derivatives and other fruit, such as watermelon, cherry, pink grapefruit, pink guava, red pepper, and papaya (CANTRELL et al., 2003).

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Tomato is commonly marketed as a fresh vegetable; however, it is a highly perishable product due to its high water content, which limits its distribution. For this reason, several reports have been carried out oriented to its preservation, including dehydration in slices, cubes, and powder (Mariem & Mabrouki, 2014). Convective drying is one of the most important preserving technologies used for fruit and vegetables, however changes and degradation of bioactive compounds depend on drying conditions (Mireles-Arriaga et al., 2016).

An alternative for preservation of the nutritional and bioactive properties is the use of microencapsulation, which is a technique that is applied to protect numerous solid, liquid, and gaseous ingredients from the environmental conditions, particularly the oxidation reactions caused by light or oxygen (Perez-Masia et al., 2015, Martinez-Hernandez et al., 2016). The goal of this study was to evaluate convective drying and spray-drying as alternatives to preserve lycopene content in tomatoes.

1. Materials and methods

1.1. Raw material

Fresh type tomatoes were selected by the following criteria: uniformity in size, insect-free, fresh appearance and firmness, the edible maturity was 6 (red) according to the colour chart of USDA (1997). Also, to guarantee ripeness of the fruit, the physicochemical properties, such as colour parameters a (green-red), b (blue-yellow), L (luminosity), indices a/b, hue, chroma, pH and °Brix were evaluated, since vegetable matter in the ripened stage has the greatest lycopene content (Luna-Guevara et al., 2014).

1.2. Obtaining of encapsulated tomato powders

Since tomato has high water content (90–95%), it was necessary to achieve higher solids concentration for spray-drying treatments.

1.2.1. Convective drying. Tomatoes were homogenized into paste form, which was uniformly spread and the start weight was recorded. Then, the samples were subjected to the drying treatments with temperatures 40, 50, 60, and 80 °C using an oven (Binder, model FD53, Germany); these were weighed every 15 min during the first 2 h and every 30 min until reaching the constant weight. When equilibrium was assumed, the moisture content was determined at 105 °C. The moisture content of the product was expressed as free moisture fraction Ψ (the removable water portion remaining in the product) (Eq. 1).

$$\Psi = \frac{X - X_e}{X_o - X_e} \tag{1}$$

where Ψ: free fraction moisture; X: initial moisture; X_0: moisture at different temperatures and X_e: equilibrium moisture.

Dried tomatoes were pulverized in a coffee grinder (Krups, model: GX410011V, Mexico), all powders were sieved through a mesh of 420 microns, stored at room temperature in the dark. Lycopene contents were analysed (mg/100 g), and tomato powders with the highest concentrations of the antioxidant compound were selected for encapsulation treatments.

1.3. Lycopene analyses

The extraction and quantification of the lycopene content was carried out from 0.05 g of dried product or 0.7 g of encapsulated powder, according to Sadler and co-workers (1990). To each sample, 18 ml of solvent was added (hexane, acetone, and ethanol; in a 2:1:1 proportion), and they were vigorously shaken for approximately 15 min. Non-polar phases were collected for the assessment of absorbance at 503 nm.

1.4. Spray-drying treatments

1.4.1. Feed emulsions. Tomato powders (50–70%) were used as core, maltodextrin 10E (Maltodex, Mexico) and gum arabic (C 740, E300 Boruka, Mexico) were utilized as score materials in a ratio 1:1. All materials were homogenized to form an aqueous solution with 12% of total soluble solids.

1.4.2. Spray drying process. The aqueous solutions were spray dried using a Prendo (Mexico) spray dryer according to the conditions mentioned in Table 1 (T×1–T×10), the encapsulated products were stored under room temperature and absence of sunlight.

Table 1. Encapsulation treatments with different contents of tomato powder, conditions, and process variables

Treatments	Variables	Process conditions
1, 2, 3, 4	Flow rate 4, 6, 9, 12 (ml min^{-1})	Inlet T 170 °C Content of tomato powder 50%
5, 6, 7	Inlet T 160, 170, 180 (°C)	Flow rate 9 ml min^{-1} Content of powder 50%
8, 9, 10	Contents of powder 50, 60, 70 (%)	Inlet T 170 °C Flow rate 9 ml min^{-1}

1.5. Statistical analysis

The effects of the drying and microencapsulation treatments were evaluated on the lycopene content. The data of each treatment were analysed according to a completely randomized design and analysis of variance (ANOVA), with α=0.05. The significant differences among the mean values were determined through Tukey's mean comparison tests, using the Statistix software (Statistix 8.1).

2. Results and discussion

2.1. Characteristics of the fresh fruit

The variables weight, size, colour, pH, and soluble solids (°Brix) are considered quality parameters of the fresh tomato; these physical characteristics are related to the acceptance in the market and nutritional value (Luna-Guevara et al., 2014; Martinez-Hernandez et al., 2016). In Table 2, the mean values of the physical parameters of the fruit used in this research are shown. The fruit were classified as medium-size and category 7 according to the Codex Stan 293-2007 (2007). The pH value 4.25 is considered optimal and recommended for ripened fruit (Anthon et al., 2011). The relationship between acidity and sugar content is decisive in the flavour of the tomato (Turhan & Şeniz, 2009). Regarding soluble solids, Santiago and co-workers (1998) reported that a value greater than or equal to 4.0 °Brix is considered the optimum. In this research, a slightly lower value was obtained, providing less sweet taste to the fruit.

Table 2. Physicochemical properties and lycopene content of fresh fruit tomatoes

	Physicochemical characteristics					
	Weight (g)	Equatorial diameter (cm)	Axial diameter (cm)	pH	Soluble solids (°Brix)	
Average values	88.74±4.17	5.83±0.34	4.36±0.19	4.33±0.17	3.93±0.12	
	Parameters and indices of colour and lycopene					
	L	a	b	Chroma	Hue	Lycopene (mg/kg FW)
Average values	34.61±2.24	30.20±1.38	24.91±2.46	39.19±2.11	50.55±2.71	14.25±2.5

Data expressed as average n=3±standard deviation

The colour development of tomatoes is an indicator of the maturity stage and quality in the market; the red colour is due to degradation of chlorophyll and synthesis of carotenoids (Lopez & Gomez, 2004). The results for the colour and lycopene content obtained in this study are indicated in Table 2, the a value is a good indicator of red colour development and the degree of ripening in tomato, while parameter b shows yellow discoloration, both parameters are related to the lycopene and xanthophyll contents, respectively (Batu, 2004). According to the classification reported by Arias and co-workers (2000), the values L and a obtained in this research correspond to very ripe tomatoes, although the Hue parameter is for colour between orange and red.

2.2. Drying characteristics

Initial moisture of fresh tomatoes was 92.35±0.30%. The kinetics of the moisture content loss of tomato samples was determined at temperatures of 40, 50, 60, and 80 °C. The variation of the free fraction moisture (Ψ) over time at different temperatures is given in Figure 2. The drying process is characterized by a progressive decreasing of moisture content with time obtaining 540, 390, 270, and 240 min for 40, 50, 60, and 80 °C, respectively, reaching a percentage of final moisture less than 15%.

In Table 3, the results of the parameters of colour and lycopene content of the dried tomatoes are presented. Luminosity varied significantly depending on the drying temperature, the treatment at 80 °C a decreased the value of L, producing powders that are more opaque. Regarding parameter a, tomatoes treated at 50 °C had more reddish tones. Parameter b varied inversely with the drying temperature (Table 3). Hue significantly correlated with a/b (r=0.998); both indices are related to the reddish colouring of tomato (Arias et al., 2000). The intensity or saturation (Chroma) of colour increased at 50 °C, providing tomato powder with more purity. Likewise, chroma together with parameters a and b significantly correlated with lycopene content (r=0.96, 0.89, and 0.83, respectively).

Table 3. Colour parameters and contents of lycopene in dehydrated fruit at different temperatures

	Drying temperatures (°C)			
	40	50	60	80
L	41.87±0.19 c	45.84±0.21 b	54.51±0.11 a	39.77±0.32 d
a	33.40±0.63 bc	36.69±0.39 a	34.10±0.33 b	32.58±0.76 c
b	20.18±0.21 a	19.82±0.09 a	18.35±1.51 ab	16.35±0.20 b
Hue	58.86±0.72 b	61.62±0.17 a	61.74±1.88 a	63.35±0.79 a
Chroma	39.02±0.44 b	41.70±0.38 a	38.74±0.88 b	36.46±0.61 c
a/b	1.66±0.05 b	1.85±0.01 ab	1.87±0.15 ab	1.99±0.07 a
Lycopene (mg/100 g)	44.25±0.48 ab	47.93±2.6 a	41.94±1.49 bc	39.99±0.90 c

Data expressed as average n=3±standard deviation. Values in a column followed by the same lowercase letter indicate no significant difference between dried samples according to the Tukey's test (P<0.05).

According to KULJARACHANAN and co-workers (2009), drying time and temperature significantly affect bioactive compounds. This effect was also observed in this study, higher lycopene contents were obtained at drying temperatures of 50 °C and 40 °C; however, with the latter, drying time was 540 min (Fig. 1). The results obtained for lycopene content were similar to those obtained by KERKHOFS and co-workers (2005), who found values of 45.6 to 59.2 mg/100 g using convective drying at 45 °C. Tomato powders obtained with dehydration treatment at 50 °C, with the maximum lycopene contents, were selected to be used in encapsulation experiments.

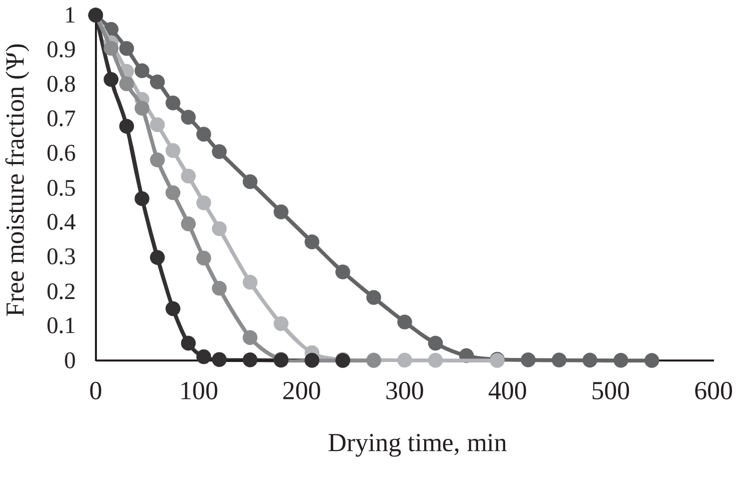

Fig. 1. Variation of the free moisture fraction (ψ) with respect to time during the drying of tomato fruit at different temperatures

: 40°C; : 50°C; : 60°C; : 80°C

2.3. Encapsulation conditions

There are several factors that influence core material stability, such as the flow rate, inlet air temperature, and shell materials. The variation in the flow rate of encapsulation treatments had a significant effect on lycopene content (Fig. 2), may be due to the fact that this parameter influences the internal temperature of the capsulate, and proper temperature values generate favourable conditions for the encapsulation of sensitive compounds such as lycopene (Beristain et al., 2001). In encapsulated tomato lycopene content increased with a value of 11.51±0.15 (mg/100 g) at a flow rate of 9 ml min^{-1}, while treatments T×2 and T×4 with flow rates of 6 ml min^{-1} and 12 ml min^{-1}, respectively, caused no significant differences in the lycopene contents. These results are associated with droplet size and thickness of the capsules during spray-drying process, incorrectly chosen values enable lesser quantity tomato powder to be pulled into the encapsulate, resulting a reduction in the lycopene content. Wang and Chen (2006) used flow rates of 3 and 30 ml min^{-1} and Nunes and Mercadante (2007) encapsulated tomato with lycopene contents of 2.8 mg/100 g and 10 mg/100 g, which were lower and higher than those reported in this study. For spray-drying treatments it was observed that at inlet temperature T×6 (170 °C) the lycopene content was higher in comparison to T×7 (180 °C) with values of 10.41±0.06 and 8.24±0.12 mg/100 g, respectively. Shu and co-workers (2006) reported that an increase in the inlet T impedes the balance between the water evaporation rate and the formation of stable films, exposing the encapsulated material to high temperatures, and that is the reason why T×7 provided lower lycopene content. Likewise, Aguilar-Rocha and co-workers (2012) observed a significant increase in the oxidation of lycopene when exposed to 180 °C during spray-drying process.

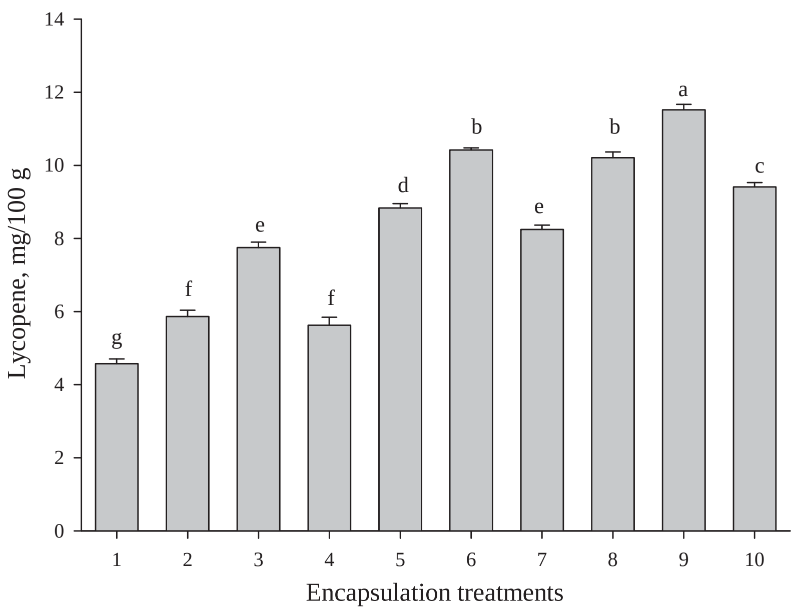

Fig. 2. Variation of lycopene contents of tomato powders with different encapsulation treatments. Data expressed as average n=3±standard deviation. Values with the same lowercase letter indicate no significant difference between treatments according to the Tukey's test (P<0.05)

Finally, the quantity of tomato powder incorporated in the encapsulated solution also influences lycopene content, T×8 (50%) and T×9 (60%) reached the highest values of 10.20±0.16 mg/100 g and 11.51±0.15 mg/100 g, respectively. While for T×10 (70%) the lycopene content decreased, which is in agreement with findings of SHU and co-workers (2006) and AGUILAR-ROCHA and co-workers (2012), who reported that higher core amount (encapsulated material) reduces retention and encapsulation efficiencies, resulting in elevated degradation of bioactive compounds. Such results suggest that the principal factor for the preservation of lycopene is the conformation of more stable matrices and not the higher concentration of the tomato powder. Therefore, an increase in the quantity of tomato powder added to the emulsion decreases the proportion and the stability of encapsulating agents in the emulsion, determinant conditions for the formation of the microcapsules (DRUSCH & MANNINO, 2009).

3. Conclusions

The results of this study demonstrated that tomato powder obtained at 50 °C and 390 min with conventional drying presented the highest content of lycopene and optimal colour parameters. By encapsulation with correctly selected parameters (tomato powder content, inlet temperature, and flow rate), microcapsules of tomato retained higher lycopene content. This technique could be utilised in various products to effectively prevent losses of valuable compounds.

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