Evaluation of Natural Pigments Extracted from Tomato Wastes and the Possibility of their Encapsulation

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Original Research Article

ABSTRACT

This study aimed to evaluate the best methods from extracting natural pigments from tomato fruit wastes by four techniques used to extract lycopene and β-carotene each of them consisting of three solvents: ethanol, acetone and hexane in the following ratios (1:1:1), (2:1:1), (1:2:1) and (1:1:2) ml respectively. We studied too the possibility of encapsulation by freeze drying with a mixture of gelatin and gum Arabic as a carrier in nine microcapsules differing with respect to the total encapsulant (E) (2.5, 5.0, and 7.5%) and core (C) concentrations, the latter varying in relation to the total weight of encapsulant (25, 50, and 75%). The nine microcapsules were coded as follows: (1) E2.5/C25; (2) E2.5/C50; (3) E2.5/C75; (4) E5.0/C25; (5) E5.0/C50; (6) E5.0/C75; (7) E7.5/C25; (8) E7.5/C50; and (9) E7.5/C75. We found that the best solvent mixture for the extraction process was 1:1:2, and the most efficient microcapsules were E5.0/C75, E5.0/C50 and E2.5/C25. By studying the stability of the best three microcapsules when exposed to different values of heat, light, oxygen and pH, it was found that the most stable of them was E5.0/C75, followed by E5.0/C50 and then E2.5/C25. It was therefore recommended that further future studies are needed to evaluate the potential of this microcapsule as a natural additive in food, pharmaceuticals and cosmetics.

Keywords: Natural pigments; extracted; evaluation; tomato wastes; encapsulation.

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1. INTRODUCTION

The most extensively grown vegetable crop is the tomato (Lycopersicon esculentum). Every year, millions of tonnes of tomatoes are processed to make goods like ketchup and sauce. As a result, a sizable portion of the processed tomatoes—between 10% and 40%—are left behind as byproducts including peel, pulp, and seeds. The skin and pulp, which are lycopene-rich waste products from the production of tomato paste, make up around 70% of wet pomace [1]. The amount of waste processed annually is above 130 million tonnes, and the amount of waste generated, according to the estimation of the [2]. In actuality, a large fraction of tomatoes produced are unfit for fresh consumption due to undesirable colour, ripeness, or form, resulting in a financial loss for growers and a detrimental effect on the environment [3]. Although fresh tomatoes are frequently consumed, processed tomato products including tomato juice, paste, puree, ketchup, and sauce account for more than 80% of all tomato consumption [4]. Many different types of waste are produced during the commercial processing of tomatoes. The tomato pomace from the pulper makes up the majority of the tomato waste [1]. The dried pomace includes 44% seed and 56% pulp and skin, whereas the wet pomace contains 33% seed, 27% skin, and 40% pulp[5]. Tomato pomace typically makes about 3-5% (w/w) of the raw materials used for processing [6]. Additionally, the tomato processing industry produces a lot of residual tomato peel. As a result, good alternative to recycle tomato waste is currently one of the most important environmental issues. The huge quantities of tomato peels and seeds that are currently used as animal feed and fertiliser or disposed of make up the tomato pomace, the solid residue left over after the industrial processing of tomatoes [7,8]. However, it is still abundant in vitamins, phenolic compounds, and carotenoids, among which lycopene, which makes up 80–90% of the tomato's total pigments, is the most significant antioxidant. Lycopene is also one of the plant's most powerful antioxidants [9,10]. However, it is still rich in vitamins, phenolic compounds, and carotenoids, among which lycopene, which makes up 80–90% of the tomato's total pigments, is the most significant antioxidant. Lycopene is also one of the plant's most powerful antioxidants [11,12]. Additionally, phenolics are acknowledged for their antibacterial and antioxidant activity as well as their role in preventing a number of disorders linked to oxidative stress [13,14]. Numerous methods, such as the recovery and isolation of carotenoid compounds to be used for the micro-capsulation of functional foods, as well as for pharmaceutical and cosmetic products, instead of chemically synthesised molecules, have been suggested for this line of work given their antioxidant or nutritional properties [15,16].

There has been a significant degree of interest in common plant colours worldwide. These pigments have distinct colours and display a variety of hues, including orange (-carotene), yellowish-green (lutein), green (chlorophyll), and blue-purple (anthocyanin) [17]. The pigment lycopene gives reddish fruits and vegetables including tomatoes, papayas, pink grapefruits, pink guavas, and watermelons their colour. A carotenoid hydrocarbon is lycopene (additionally called carotene). These compounds' enhanced conjugated double bond configuration is a vital part of the carotenoids that gives them their beautiful colours and frames the light-retaining chromospheres [18]. These compounds include conjugated double bonds, which are responsible for any apparent hues. The wavelength value for maximum assimilation is larger the more notable the number of conjugated double bonds [19]. One of the most common colours used in the food business as a nutritious component because of its potential health benefits is lycopene [20]. The molecule has gained increased relevance as a result of its extensive use in cosmetics, drugs, and food. Meanwhile, the prices of raw resources are rising and they are becoming less accessible [21].

The extraction of carotenoids from vegetable sources is usually carried out by using organic solvents (e.g., hexane, acetone, chloroform, ethanol, etc.) because they are soluble in fat. A mixture of hexane with acetone and ethanol is often employed [22,23]. Furthermore, lycopene may be extracted from supercritical fluids using non-organic solvents since it is easily broken down by light, oxygen, and high temperatures. However, the solubility of these molecules is still rather low when compared to their solubility in organic solvents. It is more expensive because high pressures must be used to accomplish reasonable extraction from dried vegetable material [24]. As a result, from an industrial standpoint, solvent extraction is the best choice due to its ease of use and low cost. According to the mass of the finished products, the process takes a very long time and uses a lot of solvents.

Microencapsulation method has been used extensively in the food processing industry to shield food ingredients from deterioration, volatile losses, or early interaction with other ingredients. Therein, a membrane (wall system) is formed as a protective device to confine droplets or particles of the encapsulated material (core). Spray-drying is the microencapsulation method that is most frequently used in the food industry due to its continuous production and ease of industrialization. Other types of microencapsulation methods include solvent dispersion/evaporation, phase separation (coacervation), co-crystallization, and interfacial polymerization [25-28]. To my knowledge, no reports of lycopene microencapsulation using spray-drying exist.

Gelatin is an excellent wall material choice for microencapsulation by spray-drying because to its favourable emulsification, film-formation, water-solubility, edibility, and biodegradation qualities [29]. In addition, hydrocarbon compounds are also used as one significant component of wall materials [30], which, among other things, can serve as a plasticizer, encourages the development of spherical microcapsules with smooth surfaces and strengthens the bond between the materials used for the walls and the core, [29]. Gelatin and sucrose were successfully combined to microencapsulate beta-carotene, according to reports [31].

The purpose of this study is to assess the potential for encapsulating natural pigments extracted from tomato wastes.

2. MATERIALS AND METHODS

2.1 Materials

Plant material and dried tomato waste were prepared from fresh tomato waste material obtained after pressing the pulp as by-product from the fruit and vegetable processing industry (Al Habib Food Industries, Gamasa Industrial Zone, Dakahlia, Egypt). Tomato waste was dried in freeze dryer at -40°C for 48 h. Dried tomato waste material was ground, packed in vacuumed plastic bags and stored at -20°C until further analysis.

Chemicals were analytical grade and purchased from Algomhourya Company, Tanta city, Egypt.

2.2 Methods

2.2.1 Extraction of pigments

Four techniques were prepared for extraction of lycopene and β-carotene from tomato wastes, each was consisting of three solvents: ethanol, acetone and hexane in the following ratios (1:1:1), (2:1:1), (1:2:1) and (1:1:2) ml respectively.1g of liquidized pulp was added to the solvent's mixture. The mixture was placed in a tube covered with silver foil and a lid, and stored in a refrigerator at 3°C, where it remained until full depigmentation. Then another 10 ml of ethanol, 10 ml of acetone and 20 ml of hexane were added; this was later filtered in Whatman filter paper number 8, whereby 50 ml of distilled water was added for phase separation, and then the whole mixture was poured into a 150 mL test tube, discarding the previous fraction. The reading was carried out in the supernatant at 503 nm for the lycopene and 450 nm for the β-carotene. In both techniques, the equations to measure the level of β-carotene and lycopene were developed by [32], and the result was given in μg g-1 (Equations 1 and 2, respectively). The analysis of the pigments was determined in triplicate.

$$C_{\beta\text{-arotene}} = 4.624 \, XA_{450} - 3.091 \, XA_{503} \qquad (1)$$

$$C_{Lycopene} = 3.956 \, XA_{450} - 0.806 \, XA_{503} \qquad (2)$$

In which:

$C_{\beta\text{-caroteno}}$ $C_{Lycopene}$ = Lycopene and β-carotene concentration in μg g^{-1}.
A_{450} and A_{503} = absorbance in the respective wavelengths.

2.2.2 Encapsulation process

The methodology for obtaining microcapsules by complex coacervation was adapted from procedures described in [33]. Gelatin and gum Arabic solutions were prepared by dissolution in water at 50°C. The gelatin solution (2.5, 5, and 7.5%) and oil dispersed lycopene (20% lycopene) were mixed in an Ultra Turrax shaker (IKA T18 Basic, Rio de Janeiro, Brazil) at 10.000 rpm for 3 minutes in order to obtain an emulsion. The emulsion was then mixed with the gum Arabic solution (2.5, 5, and 7.5%) by mechanical stirring. The pH was then adjusted to 4.0 ± 0.01 by adding hydrochloric acid (0.5 M) with a dropper. Up to this point in the process, the temperature was monitored and maintained at 50 ± 3°C. The

system was then cooled to 10°C in an ice bath and finally placed in a refrigerator at 3°C for 24 hours to complete particle precipitation.

After obtaining the coacervated microcapsules, they were concentrated by using a sieve (Mesh of 25 μm). The samples were concentrated in plexiglass plates covered with aluminum foil containing small holes and submitted to slow freezing in a freezer at −20°C for 24 hours. The frozen samples were then freeze-dried (Edwards Pirani 501 Freeze Dryer, West Sussex, UK) for about three consecutive days under the following operational conditions: condenser temperature of −60°C, 10^{-1} mbar pressure, and a final temperature of 25°C.

Nine microcapsules were studied, differing with respect to the total encapsulant (E) (2.5, 5.0, and 7.5%) and core investigated (C) concentrations, the latter varying in relation to the total weight of encapsulant (25, 50, and 75%). The nine microcapsules were coded as follows: (1) E2.5/C25; (2) E2.5/C50; (3) E2.5/C75; (4) E5.0/C25; (5) E5.0/C50; (6) E5.0/C75 ;(7) E7.5/C25; (8) E7.5/C50; and (9) E7.5/C75. The encapsulant rational maintained at 1:1 for all microcapsules, since this was the best ratio according to [34] who studied the microencapsulation of vetiver oil by complex coacervation using gelatin and gum Arabic as the encapsulating agents.

2.2.3 Determination of lycopene

The extracted solution of lycopene samples was analyzed in an HPLC system consisting of a Shimadzu HPLC pump LC-20AD×2 units, Shimadzu 996 photodiode array detector (PDA-UV/VIS detector) and Rheodyne 7725i manual sample injector with a 20-µL sample loop [35]. The system was controlled with Chromatography software (Shimad zu HPLC shimadzu 996 photodiode array detector (PDA-UVVIS) Rheodyne 7725i.

2.2.4 Determination of carotenoids

The carotenoids (lyco-red) separated from tomato peel were determined by Knauer HPLC pump 64 as indicated by the technique reported by [35] utilizing octadecyl silane C 18, 3.9 x 150 mm. For both HPLC columns, two solvents were used for elution: (1) methanol (2) ethyl acetic acid derivation. The flow rate was 1.8ml/min and absorbance were measured at 475 nm. A mixture of methanol and ethyl acetic acid (54:46)

as mobile phase, (sample amount: 20 µL, flow, 1.8 mL/ min) and identified at 475 nm.

2.2.5 Encapsulation efficiency

The method described in [36] to calculate encapsulation efficiency was adapted: about 10 mg of the sample were dissolved in 0.5 mL of water in order to break the microcapsules. Ten mL of acetone were then added. After mixing, the tubes remained at rest in the dark for about 2 h for decantation of the encapsulation material. Absorption was read in a spectrophotometer (Beckman DU70–CA, United States) in the visible wavelength 470 nm and using a previously elaborated standard curve it was possible to calculate the concentration of lycopene present in the microcapsules. Encapsulation efficiency was calculated as the quantity of lycopene present in the capsules compared to the lycopene initially used to produce them.

2.2.6 Stability of the lycopene

The lycopene stability in the microcapsules was studded as affected by heat, light, pH and oxygen was observed according to [37] with some modifications; in our study, the samples were tested directly in order to measure the changes in the concentration of lycopene, 1 gram of sample was weighed. The heat effect was evaluated with exposure of the samples between 25-90°C for 10 min in a controlled thermostatic water bath (Julabo, Germany). The measurement of the experiment time started immediately when the sample temperature reached the temperature set in the equipment. After each treatment, the samples were cooled to 10°C to stop the effect of the temperature. In evaluating the stability in light, the samples were placed in Petri dishes and stored in a refrigerator at 4°C with a relative humidity of 85%. The refrigerator was fitted with a 25 W lamp 20 cm above the samples. The effect of the pH change on the retention of carotenoids was evaluated at pH 3, 4, 5, 6, 7, 8, 9, 10 and 11, preparing a 1N NaOH solution for the alkaline pH and a solution of 1N H_2SO_4 for the acid pH regulated with a buffer solution. Each solution was used on the samples for 1 hour at room temperature and protected from light. For the oxygen stability tests, the samples were exposed in an oxygen atmosphere for 0, 2, 4, 6, 8 and 10 h. So, a hermetically sealed capsule was used, coupled to a vacuum pump and saturated with an injection of oxygen gas with a purity of 95%.

2.3 Statistical Analysis

All experiments were run in triplicate and results were represented as means ± standard deviation. Statistical analyses were carried out using Origin 7.0 software package and Microsoft Office Excel 2010.

3. RESULTS AND DISCUSSION

3.1 Pigment Extraction Methods

The effect of solvent mixtures on the yield of β-carotene and lycopene produced from tomato wastes as in Table (1), where significant differences were observed between the effect of the solvent mixtures on the yield of β-carotene, which ranged between 24.5-27.2 µg/g and the best of these mixtures was (1:1:2) and the least effective is (1:1:1). Also, the results showed the same effect of the solvent mixture on the yield of lycopene, which ranged between 24.5-27.2 µg/g of tomato wastes, where the highest yield was obtained from the solvent mixture (1:1:2), and the lowest yield was the mixture (10:10:10). These results are due to the polar strength of the hexane solvent by increasing its concentration in the mixture.

According to [38], when combining the solvents for the extraction of carotenoids pigments, the efficiency was superior in comparison to the usage of solvents individually. Since, the polar solvents, such as ethanol and acetone, are able to enter phospholipidic substances which compose the cell lipoprotein membranes, whilst a polar solvent, such as hexane, are more efficient in solubilizing carotenoids. Lycopene and β-carotene are considered to be a polar substance.

Table 1. Effect of extraction techniques on the yield contents of β-carotene and lycopene pigments

Solvent mixture*	β-carotene (µg/g)	Lycopene (µg/g)
(1:1:1)	24.5[d]	44.3[d]
(2:1:1)	26.8[b]	46.7[b]
(1:2:1)	25.6[c]	45.2[c]
(1:1:2)	27.2[a]	47.7[a]

*= (ethanol: acetone: hexane)

Therefore, the effect of polar and a polar solvent mixture in extracting pigments is higher than the effect of one single polar or a polar solvent, which leads to obtaining a better performance in extracting pigments, which also was observed in this study.

3.2 Encapsulation Efficiency

Encapsulation efficiency of lycopene was evaluated for nine microcapsules as shown in Table 2 where, it was found that the highest efficiency was with microcapsules 6: E5.0/C75, 1: E2.5/C25 and 5: E5.0/C50, which were 99.77%, 99.56% and 97.28%, respectively. The lowest efficiency in microcapsules 2: E2.5/C25; 3: E2.5/C75 and 8: E7.5/C50 which were 90.86%, 92.73% and 92.73%, respectively. "High values are normally found in the literature for the encapsulation efficiency of coacervated capsules [39] when gelatin and gum Arabic are used as the encapsulating agents". However, "when pectin and soy protein isolate were used as the encapsulating agents to encapsulate propolis and casein hydrolysate, the encapsulation efficiencies were in the range from 66–72% [40] to 78–91%" [41]. "These results confirmed that gelatin and gum Arabic were more efficient encapsulating agents than pectin and soy protein isolate. When lycopene was encapsulated by spray drying, the encapsulation efficiencies were in the range from 21.01 to 29.73% using modified starch" [42], from 12.1 to 82.2% using gelatin and sucrose [43] and from 25.6 to87.5% [27] using gum Arabic, gellan gum, and maltodextrin as the encapsulation material.

Table 2. Efficiency of the lycopene microcapsules

Microcapsuletion	Encapsulation efficiency (%)
1	99.56[a]
2	90.86[c]
3	92.05[c]
4	96.34[b]
5	97.28[ab]
6	99.77[a]
7	95. 87[b]
8	92.73[bc]
9	95.07[bc]

Different letters in the same column indicate that there was significant difference between samples ($P < 0.05$). Microcapsules 1: E2.5/C25; 2: E2.5/C25; 3: E2.5/C75; 4: E5.0/C25; 5: E5.0/C50; 6: E5.0/C75; 7: E7.5/C25; 8: E7.5/C50; and 9: E7.5/C75

In view of these results, it is possible to affirm that complex coacervation is a more efficient method to encapsulate lycopene than spray drying. This can be explained by the milder temperatures used in complex coacervation, an important factor for the encapsulation of a highly sensitive compound such as lycopene.

3.3 Lycopene Microcapsules Stability when it was Exposed to Heat

Table 3 shows the effect of different temperatures from 20 to 90°C on the stability of lycopene microcapsule for the three best microcapsules its E5.0/C75, E2.5/C25 and E5.0/C50. It was noted that there were no significant differences between the three microcapsules when they were exposed to temperatures up to 40°C, but significant differences appeared between them with increasing temperature, and the most stable microcapsule was E5.0/C75, followed by E5.0/C50, and the least stable was E2.5/ C25. It was also observed that the stability of lycopene microencapsulation decreased with increasing temperature in all mixtures.

These results may be due to the increase in the proportion of gel and gum Arabic coated with lycopene particles', which makes it less susceptible to the effect of heat. These results are in agreement with those of 00000000000 [37] they found r that retention rate is higher in gelatin, sugar and lecithin with increasing temperature;

At 90°C, the retention level of gelatin, sugar and lecithin reached 90.11%, mixture of maltodextrin: gum Arabic reached 83.18% and β-carotene extracted from sunflower oil reached 75.23% reported values greater than 95% in lutein microencapsulated with gelatin and starch as wall material when evaluated at temperatures of 90°C.

3.4 Lycopene Microcapsules Stability when Exposed to Light

Table 4 shows the effect of illumination time on light stability of lycopene microcapsule for the three best microcapsules its E5.0/C75, E2.5/C25 and E5.0/C50. The data shown in the table indicate that there are significant differences between the microcapsules for their ability to be stable by increasing the time of exposure to light. The microcapsule E5.0/C75 was the most stable, which decrease to 53%, after 30 days, followed by E5.0/C50 by 51%, and the least stable of them was E2.5/C25 by 47%. The results also showed that increasing the exposure time of microcapsules to light had a significant effect on the extent of lycopene stability in them.

Table 3. Microcapsule stability at different temperature

Temperature (°C)	Retention rate of lycopene (%)		
	E5.0/C75	E2.5/C25	E5.0/C50
20	100[Aa]	100[Aa]	100[Aa]
30	98[Aa]	97[Aa]	98[Aa]
40	97[Aab]	95[Ab]	96[Ab]
50	95[Ab]	88[Cc]	91[Bc]
60	90[Ac]	80[Cd]	85[Bd]
70	85[Ad]	72[Ce]	77[Be]
80	81[Ae]	66[Cf]	72[Bf]
90	75[Af]	60[Cg]	66[Bg]

Different small letters in the same column indicate that there was significant difference between temperatures and different capital letter in the same row between samples ($P < 0.05$)

Table 4. Effect of Illumination time on light stability of lycopene microcapsule

Illumination time (day)	Retention rate of lycopene (%)		
	E5.0/C75	E2.5/C25	E5.0/C50
0	100[Aa]	100[Aa]	100[Aa]
5	94[Ab]	87[Bb]	92[Ab]
10	85[Ac]	78[Bc]	83[Ac]
15	74[Ad]	65[Cd]	70[Bd]
20	65[Ae]	57[Ce]	61[Be]
25	60[Af]	50[Cf]	53[Bf]
30	53[Ag]	47[Bf]	51[Af]

Different small letters in the same column indicate that there was significant difference between temperatures and different capital letter in the same row between samples ($P < 0.05$)

[44] have studied that "light could trigger oxidation and isomerization processes in carotenoids, reducing the concentration; the wall materials in gelatin, sugar and lecithin encapsulation, because they are good emulsifying agents, reduced the action of light in the core of the microparticles, thereby decreasing the processes of oxidation and isomerization in the carotenoids". [37] "microencapsulated lutein with porous starch and gelatin as wall materials, and reported retention levels of 90% in microencapsulated lutein exposed to light for 30 days".

3.5 Lycopene Microcapsules Stability to pH Changes

The effect of pH variation on the stability of lycopene microcapsule in E5.0/C75, E2.5/C25 and E5.0/C50 can be seen in Table 5. There were insignificant differences between the three microcapsules up to 8 pH and then significant differences after that up to 10 pH, and it was noted that the microcapsules E5.0/C75 was more tolerant of high pH, followed by E5.0/C50 and then E2.5/C25. It was also found that there were no significant differences between the pH numbers for all microcapsules up to pH 8, then significant differences after that by increasing the pH number in all mixtures. There were insignificant differences between the three microcapsules up to 8 pH and then significant differences after that up to 10 pH, and it was noted that the mixture E5.0/C75 was more tolerant of high pH, followed by E5.0/C50 and then E2.5/C25. There was also a significant increase in the percentage of lycopene by microencapsulation in all microcapsules up to pH 8 and then a significant decrease in the increase of pH after that in all microcapsules, and the most decrease was in the microcapsule

E2.5/C25, followed by E5.0/C50 and then E5.0/C75 where it was 71, 85 and 89%, respectively.

[37] described "a similar behavior in microencapsulated lutein with gelatin and starch as the wall material when exposed to a pH between 1.00 and 11. The retention level in the evaluated pH range presented significant differences ($p <0.05$) between the three tested samples: gelatin, sugar and lecithin, with 84.21%, had a statistically higher retention rate than maltodextrin: gum Arabic (79.23%) and β-carotene extracted from sunflower oil (65.23%)".

3.6 Lycopene Microcapsules Stability when Exposed to Oxygen

In Table 6 effect of oxygen on the retention level in E5.0/C75, E2.5/C25 and E5.0/C50 can be seen. With an increase in the hours of exposure of lycopene microcapsules to oxygen, significant differences were observed between the three microcapsules. It was also noted that the most stable of them was E5.0/C75, followed by E5.0/C50, then E2.5/C25. It was also found that the increase in the number of days of exposure of the microcapsules to oxygen led to a significant decrease in the content of the three microcapsules of lycopene, as it was 74, 60, and 51% for E5.0/C75, E5.0/C50 and E2.5/C25, respectively after 10 days. "Comparing β-carotene extracted from sunflower oil with gelatin, sugar and lecithin and maltodextrin: gum Arabic showed that the wall materials provided an oxygen barrier, reducing the degradation of the carotenoids present in the core of the microparticles because this environmental factor is responsible for degradation by the oxidation and isomerization of carotenoids", as previously reported by [44,45].

Table 5. Effect of pH variation on stability of lycopene microcapsule

pH	Retention rate of lycopene (%)		
	E5.0/C75	E2.5/C25	E5.0/C50
4	87[Ae]	70[Bd]	85[Ad]
5	88[Ade]	71[Bcd]	87[Ac]
6	90[Ac]	73[Bb]	89[Ab]
7	92[Ab]	74[Bab]	90[Aab]
8	94[Aa]	75[Ca]	91[Ba]
9	92[Ab]	73[Cb]	88[Bbc]
10	89[Ad]	71[Ccd]	85[d]

Different small letters in the same column indicate that there was significant difference between temperatures and different capital letter in the same row between samples ($P < 0.05$)

Table 6. Effect of oxygen on stability of lycopene microcapsules

Oxygen exposure time (h)	Retention rate of lycopene (%)		
	E5.0/C75	E2.5/C25	E5.0/C50
0	100[Aa]	100[Aa]	100[Aa]
2	96[Ab]	93[Bb]	95[Ab]
4	90[Ac]	80[Cc]	86[Bc]
6	83[Ad]	69[Cd]	79[Bd]
8	79[Ae]	60[Ce]	73[Ae]
10	74[Af]	51[Cf]	60[Bf]

Different small letters in the same column indicate that there was significant difference between temperatures and different capital letter in the same row between samples ($P < 0.05$)

4. CONCULOSION

In this paper, we evaluate some methods of extracting pigments from tomato fruit residues and encapsulation using a mixture of gelatin and gum Arabic as a carrier in nine microcapsules differing with respect to the total encapsulant (E) (2.5, 5.0, and 7.5%) and core (C). concentrations, the latter varying in relation to the total weight of encapsulant (25, 50, and 75%). The nine microcapsules were coded as follows: (1) E2.5/C25; (2) E2.5/C50; (3) E2.5/C75; (4) E5.0/C25; (5) E5.0/C50; (6) E5.0/C75; (7) E7.5/C25; (8) E7.5/C50; and (9) E7.5/C75. We evaluated them all and chose the best three of them were E5.0/C75, E5.0/C50 and E2.5/C25. We studied their stability to heat, light, oxygen and pH. We studied their stability to heat, light, oxygen and pH, and it was found that the most stable of them was E5.0/C75, followed by E5.0/C50. Future studies are needed to evaluate the potential of this microcapsule as a natural additive in food, pharmaceuticals and cosmetics. Finally, it could be clearly concluded through this study that it is possible to follow successful technique in extracting lycopene and β-carotene.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERANCES

1. Kaur D, Wani AA, Oberoi DP, Sogi DS. Effect of extraction conditions on lycopene extractions from tomato processing wastes skin using response surface methodology. Food Chem. 2008;108:711–8.
   DOI: 10.1016/j. food chem. 2007.11.002
2. World Processing Tomato Council (WPTC). The 2020 Processed Tomato Yearbook; 2021,2020.
   Available:http://www. tomatonews.com/pdf/yearbook/2020/index. html#48
   (Accessed on 30 June).
3. Lovdal T, Van Droogenbroeck B, Eroglu EC, Kaniszewski S, Agati G, Verheul M, Skipnes D. Valorization of Tomato Surplus and Waste Fractions: A Case Study Using Norway, Belgium, Poland, and Turkey as Examples. Foods. 2019;8:229.
4. Rao VS, Waseem Z, Aggarwal S. Lycopene content of tomatoes and tomato products and their contribution to dietary lycopene. Food Res. Int. 1998;31:737-741.
5. Sogi DS, Bawa AS. Studies on dehydration of tomato processing waste. Indian Food Packer. 1998;52(2):26-29.
6. Lu Z, Wang J, Gao R, Ye F, Zhao G. Sustainable valorisation of tomato pomace: A comprehensive review. Trends in Food Sci. Technol. 2019;86:172-187.
7. Strati IF, Oreopoulou V. Recovery of carotenoids from tomato processing by-products e a review. Food Res. Int. 2014; 65:311.
8. Rossini G, Toscano G, Duca D, Corinaldesi F, Foppa Pedretti E, Riva G. Analysis of the characteristics of the tomato manufacturing residues finalized to the energy recovery. Biomass Bioenergy. 2013;51:177–182.
9. Szabo K, Catoi AF, Vodnar DC. Bioactive Compounds Extracted from Tomato Processing By-Products as a Source of Valuable Nutrients. Plant. Foods Hum. Nutr. 2018;73:268–277.
10. Kalogeropoulos N, Chiou A, Pyriochou V, Peristeraki A, Karathanos VT. Bioactive phytochemicals in industrial tomatoes and their processing byproducts. LWT-Food Sci. Technol. 2012;49:213–216.
11. Kaur G, Uisan K, Ong KL, Ki Lin CS. Recent Trends in Green and Sustainable Chemistry & Waste Valorisation:

Rethinking Plastics in a Circular Economy. Curr. Opin. Green Sustain. 2018;9:30–39.

12. Naziri E, Nenadis N, Mantzouridou FT, Tsimidou MZ. Valorization of the major agrifood industrial by-products and waste from Central Macedonia (Greece) for the recovery of compounds for food applications. Food Res. Int. 2014;65:350–358.

13. Szabo K, Diaconeasa Z, Catoi AF, Vodnar DC. Screening of Ten Tomato Varieties ProcessingWaste for Bioactive Components and Their Related Antioxidant and Antimicrobial Activities. Antioxidants. 2019;8:292.

14. Szabo K, Dulfb FV, Diaconeasaa Z, Vodnara DC. Antimicrobial and antioxidant properties of tomato processing byproducts T and their correlation with the biochemical composition. Food Sci. Technol. 2019;116:108558.

15. Stoica RM, Tomulescu C, Ca arica A, Soare M. Tomato by-products as a source of natural antioxidants for pharmaceutical and food industries—A mini-review. Sci. Bull. Ser. F Biotechnol. 2018;22:200–204.

16. Zuorro A, Fidaleo M, Lavecchia R. Enzyme-assisted extraction of lycopene from tomato processing waste. Enzym. Microb. Technol. 2011;49:567–573.

17. Mortensen A. Carotenoids and other pigments as natural colorants. J. Pure Appl. Chem. 2006;7 :1477–1491.
Available: https://doi.org/10.1351/pac200678081477

18. Rodriguez A, Kimura M. Carotenoids in foods. In harvest plus handbook for carotenoid analysis, IFPRI and CIAT: Washington, DC, USA. 2004;2–7.

19. Rodriguez A. A guide to carotenoid analysis in foods, ILSI Press: Washington, D.C., USA. 2001;1–45.

20. Rao AV, Rao LG. Carotenoids and human health. Pharmacol. Res. 2007;55:207–216.
Available:https://doi.org/10.1016/j.phrs.2007.01.012

21. Amin I, Mukhrizah O. Antioxidant capacity of methanolic and water extracts prepared from food-processing by-products. J. Sci. Food Agric. 200686:778–784.
Available:https://doi.org/10.1002/jsfa.2414

22. Shi J, Le Maguer M. Lycopene in tomatoes: chemical and physical properties affected by food processing. Crit Rev Food Sci. Nutr. 2000;40:1–42.
DOI: 10.1080/10408690091189275

23. Vanden Berg H, Faulks R, Granado HF, Hirschberg J, Olmedilla B, Sandmann G. The potential for the improvement of carotenoid levels in foods and the likely systemic effects. J. Sci. Food Agric. 2000; 80:880–912.
DOI: 10.1002/(SICI)1097-0010(20000515)80:7880: AID-JSFA646>3.0.CO;21

24. Mattea F, Martin A, Jose Cocero M. Carotenoid processing with supercritical fluids. J Food Eng. 2009;93:255–65.
DOI: 10.1016/j.jfoodeng.2009.01.030

25. Jimenez M, Garcia HS, Beristain CI. Spray-drying microencapsulation and oxidative stability of conjugated linoleic acid. European Food Research and Technology. 2004;219:588–592.

26. Re MI. Microencapsulation by spray drying. Drying Technology. 1998;16:1195–1236.

27. Rodrıguez-Huezo ME, Pedroza-Islas R, Prado-Barragan LA, Beristain CI, Vernon-Carter EJ. Microencapsulation by spray drying of multiple emulsions containing carotenoids. Journal of Food Science. 2004;69(7):E351–E359.

28. Schierle J, Bretzel W, Buhler I, Faccin N, Hess D, Steiner K. Content and isomeric ratio of lycopene in food and human blood plasma. Food Chemistry. 1997;59:459–465.

29. Bruschi ML, Cardoso ML, Lucchesi MB, Gremiao MP. Gelatin microparticles containing propolis obtained by spray-drying technique: preparation and characterization. International Journal of Pharmaceutics. 2003;264:45–55.

30. Ozgur AB, Mustafa BART. Spray drying of sumac flavour using sodium chloride, sucrose, glucose and starch as carriers. Journal of Food Engineering. 2005;69: 253–260.

31. Zhu X, Xu SY, Wang Z. Gelatin as microencapsulating agents for B-carotene. Food and Fermentation Industries. 1998;24:11–15 (in Chinese).

32. Georgé S, Tourniaire F, Gautier H, Goupy P, Rock E, Caris-Veyrat C. Changes in the contents of carotenoids, phenolic compounds and vitamin C during technical processing and lyophilisation of red and yellow tomatoes. Food Chemistry. 2011;124(4):1603-1611.
Available:http://dx.doi.org/10.1016/j.foodchem.2010.08.024

33. Lamprecht A, Schafer UF, Lehr CM. Characterization of microcapsules by

confocal laser scanning microscopy: Structure, capsule wall composition and encapsulation rate. European Journal of Pharmaceutics and Biopharmaceutics. 2000;4(1):1–9.

34. Prata AS, Zanin MHA, Re MI, Grosso CRF. Release properties of chemical and enzymatic crosslinked gelatin-gum Arabic microparticles containing a fluorescent probe plus vetiver essential oil, Colloids and Surfaces B. 2008;67(2) :171–178.

35. Gaylek G, Chen TS, Philip T. Quantitative analysis of carotenoid and carotenoid ester in fruits by HPLC. J. Food Sci. 1987; 52:1071- 1075.

36. Risch SJ, Reineccius GA. Spray-dried orange oil–effect of emulsion size on flavor retention and shelf stability. In: Flavor Encapsulation, Cap 8. American Chemical Society, Washington, 1988;68–77.

37. Wang Y, Ye H, Zhou C, Lv F, Bie X, Lu Z. Study on the spray-drying encapsulation of lutein in the porous starch and gelatin mixture. Euro Food Res Technol. 2012; 234(1):157-163.
DOI: 10.1007/s00217-011-1630-6

38. Amr AS, Hussein DS. Tomato pomace pigment: Extraction and use as food colorant. Jordan Journal of Agricultural Sciences. 2013;9(1):72-85.
Available:http://dx.doi.org/10.12816/00010 93

39. Leclercq S, Harlander KR, Reineccius GA. Formation and characterization of microcapsules by complex coacervation with liquid or solid aroma cores. Flavour and Fragrance Journal. 2009;24(1):17–24.

40. Nori MP, Favaro-Trindade CS, Alencar SM, Thomazini M, Balieiro JCC, Castillo CJC. Microencapsulation of propolis extract by complex coacervation. LWT: Food Science and Technology. 2011;44(2): 429–435.

41. Mendanha DV, M Ortiz SE, Favaro-Trindade CS, Maur A, Monterrey-Quintero ES, Thomazini M. Microencapsulation of casein hydrolysate by complex coacervation with SPI/pectin. Food Research International. 2009;42(8):1099–1104.

42. Rocha GA, Favaro-Trindade CS, Grosso CRF. Microencapsulation of lycopene by spray drying: Characterization, stability and application of microcapsules, Food and Bioproducts Processing. 2012;90(1): 37.

43. Shu B, Yu W, Zhao Y, Liu X. Study on microencapsulation of lycopene by spray-drying. Journal of Food Engineering. 2006;76(4):664-669.

44. Boon CS, McClements DJ, Weiss J, Decker EA. Factors influencing the chemical stability of carotenoids in foods. Crit Rev Food Sci Nutr. 2010;50(6):515-532.
DOI: 10.1080/10408390802565889

45. Loksuwan J. Characteristics of microencapsulated β-carotene formed by spray drying with modified tapioca starch, native tapioca starch and maltodextrin, Food Hydrocoll. 2007;21(5):928-935.