Zagazig J. Agric. Res., Vol. 44 No. (4) 2017 1389-1401

Food and Dairy Research

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

EVALUATION OF LYCOPENE EXTRACTED FROM TOMATO PROCESSING WASTE AS A NATURAL ANTIOXIDANT IN SOME BAKERY PRODUCTS

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Received: 18/04/2017 ; Accepted: 21/05/2017

ABSTRACT: The present work aimed to study the chemical composition of tomato waste, optimizing the conditions for lycopene extraction, evaluating the antioxidant activity of obtained lycopene extract and utilizing it in some bakery products (cake and cookies). The study concluded that tomato waste obtained from tomato processing plant contained (on dry weight basis) 16.51% carbohydrates, 1.10% fats, 19.07% crude protein, 58.2% crude fiber 5.12% ash, 2500 ppm phosphorus, 12.52 ppm copper, 1379 ppm calcium, 94.71 ppm iron, 17693.75 ppm potassium and 3537 ppm sodium. On the other hand, the total carotenoid and lycopene in tomato processing waste were 654.76 mg/100g and 300.85 mg/100g on dry weight basis, respectively. Data obtained from using acetone: n-hexane (25:75) mixture as extraction solvent and different temperature and times for extraction showed that the optimum temperature was 40 ºC while the optimum extraction time was 45 min. Lycopene extracts prepared from dried tomato waste had higher lycopene recovery than those prepared from wet wastes. The data of antioxidant activity reflect the high antioxidant activity of lycopene extract which approximately equal that for ascorbic acid. Generally, the addition of 3-5% lycopene extract to cake and cookies enhanced their antioxidant activity, colour and sensory properties.

Key words: Tomato waste, solvent extraction, natural antioxidant, cake and cookie.

INTRODUCTION

Wastes derived from food processing are attractive source for their valuable bioactive components and colour pigments. These wastes are useful; they could be used as functional foods, food ingredients and additives, cosmetic products and nutraceutical applications. Food wastes usually represent an environmental problem for the industry, and many studies have been carried out on the potential utilization of several vegetable origin wastes for their inclusion in the human diet, which could reduce the industrial costs and justify new investments in equipment, providing a correct solution for the pollution problem connected with food processing (Lario *et al.*, 2004).

Tomato is the second world's major vegetable next to potatoes with a worldwide and Egypt production of 170.8 and 8.3 million tons, respectively (FAOSTAT, 2014). Around a quarter of the world's production of tomatoes is grown for the processing industry. The wastes resulted from the processing of tomatoes consists of skin, seeds and vascular tissue (Al-Wandawi *et al.*, 1985). It has been reported that tomato pomace makes up to 40% of the total processed tomatoes (Botinestean *et al*., 2014). The increase of waste quantities from tomato processing industry is an important ecological and financial problem. It is an excellent source of many nutrients and secondary metabolites that are important for human health; minerals, vitamins C, E, β-carotene, lycopene, flavonoids, organic acids, phenolics and chlorophyll (Giovanelli and Paradise, 2002). Tomato processing pomace is considered a promising source of bioactive compounds and potential natural source of antioxidants (Khalaf *et al.*,

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2014). It is a rich source of lycopene (Poojary and Passamonti, 2015). Tomatoes contain about 30–400 mg/kg of lycopene in pulp and about 20–30 mg/kg in peels (Sharma and Le Maguer, 1996; Naviglio *et al.*, 2008).

Lycopene, a member of carotenoids is a bioactive red coloured pigment naturally found in tomatoes and other red fruits such as watermelon, guava and pink grapefruit (Shi *et al.*, 2002). The interest in lycopene is increasing because its preventive properties toward numerous diseases. *In vitro*, *in vivo* and *ex vivo* studies have demonstrated that lycopene-rich foods are inversely associated to diseases such as cancers, cardiovascular diseases, diabetes, and others (Omoni and Aluko, 2005; Rao and Rao, 2007; Kong *et al.*, 2010; Papaioannou and Karabelas, 2012).

Lycopene from tomatoes is usually extracted using organic solvents such as hexane, acetone, ethanol, chloroform, petroleum ether, tetrahydrofuran (Naviglio *et al.*, 2008). A solvent mixture of hexane/acetone or hexane/ acetone/ ethanol solvent mixture is often used because the recovery and stability of lycopene extracted using these mixtures are superior compared to other solvents (Poojary and Passamonti, 2015). In addition, some recent studies have shown that lycopene could also be extracted using various advanced methods such as ultrasound assisted extraction, ultrasound/ microwave assisted extraction, supercritical fluid extraction, enzyme assisted extraction, selective inclusion in deoxycholic acid (Eh and Teoh, 2012).

The high degree of conjugation of double bonds in the molecule makes lycopene one of the most potent antioxidants, with a singlet-oxygen-quenching ability twice as high as that of β-carotene and 10 times higher than that of α-tocopherol (Lavecchia and Zuorro, 2008; Papaioannou and Karabelas, 2012). Kaur *et al.* (2012) demonstrated that lycopene extract have a good antioxidant effects against several oxidants. The sunflower oil containing 50 to 200 ppm carotenoids from tomato peel showed a higher induction period compared to the sunflower oil containing 200 ppm (BHT) as a synthetic antioxidants (Rizk *et al.*, 2014).

Lycopene is in high demand by the pharmaceuticals industry as well as by the food, and cosmetics industries (Borguini and Torres, 2009). There is a growing interest in using lycopene as a value-added or functional ingredient in food products. Lycopene extract from tomatoes can be used as a nutritional supplement in several food categories such as baked goods, breakfast cereals, dairy products including frozen dairy desserts, dairy product analogues, spreads, bottled water, carbonated beverages, fruit and vegetable juices, soybean beverages, candy, soups, salad dressings, and other foods and beverages. Lycopene is a natural food colouring, thus eliminating the adverse effects of artificial food colourants. It provides colour shades ranging from yellow to red (Choksi and Joshi, 2007). In the food industry, lycopene is used as a food additive to enhance storage, stability and nutritional benefits. Due to its strong colour, non-toxicity and fat solubility, it is also used as a natural food colourant (Naviglio *et al.*, 2008). There are initiatives by food scientists to recycle lycopene-rich wastes as food ingredients. Fortifying dry fermented sausage with lycopene can be achieved by adding dried tomato peel to the meat mixture during sausage production. The presence of lycopene in these products was found in part better colour in the food products, enhanced nutritional quality, reduced lipid oxidation and increased stability during the shelf-life period (Doménech-Asensi *et al.*, 2013). Supplementing spaghetti with carotenoid from tomato peel increased the radical scavenging activity in the spaghetti by increasing the percentage of added carotenoid from tomato peel. Sensory evaluation of spaghetti prepared from carotenoid pigments from tomato peel revealed the highest score of colour, taste, texture and overall acceptability compared with control and other tested samples (Rizk *et al.* (2014).

This work aimed to study the ability of using lycopene pigment extracted from tomato wastes as a natural source of antioxidant in some bakery products (cake and petit four).

MATERIALS AND METHODS

Materials

Tomato wastes resulted from hot break process was obtained from one of the major tomato processing plant located in 6th October City, Egypt.

Wheat flour (72%), butter 80% fat, sunflower oil, cow milk 3.5% fat, eggs, sugar, vanillin, baking powder and coconut were purchased from local market, Zagazig city, Egypt. Chemicals were analytical grade and purchased from Algomhourya Company, Zagazig city, Egypt.

Methods

Preparation of tomato waste for extraction

In this work, tomato waste mostly tomato skin was used as a raw material to extract lycopene. Two types of tomato wastes were used in this study for extraction experiments. The first was obtained from industrial tomato processing (moisture content 79.66%) and the second was obtained in the laboratory (moisture content 81.54%). The process to produce the second type involves a juice extraction step and segregates seeds and other fibrous portion of the tomato fruits. After extracting the juice, the fibrous pulp portion is considered as waste. Both types of waste were dehydrated to moisture content of 3.51 and 3.43%, respectively. Extraction of lycopene was carried out using dehydrated tomato waste and wet tomato waste from industrial and laboratory tomato wastes.

The seeds were separated from tomato processing waste (skin) using 15% salt solution (NaCl). The moisture content of the wet tomato skin was about 79.66% (served as wet samples). The tomato waste (skin) was dried with hot air oven at 30°C for 12 hr., until moisture content 3.51% (served as dried samples).

Extraction of lycopene

Lycopene extraction was carried out according to Poojary and Passamonti (2015). The effects of three independent variables including extraction temperature (20, 30 and 40°C), extraction time (15, 30, 45 and 60 min) and moisture content of row material on the recovery of lycopene were investigated. Where, 50 ml of solvent (25:75 acetone: n-hexane) was added to 3 g (wet weight) of wet or dried tomato waste in conical flasks and mixed using a glass rod. The flasks were placed in a shaking water bath for 15, 30, 45 and 60 min at 20, 30 and 40°C and the extracts were filtered. Solvents were completely removed by rotary evaporator at 50°C.

Analytical methods

Moisture, crude protein, carbohydrates, fats, fibers and ash contents were determined according to AOAC (2005). Copper, calcium, iron, potassium and sodium were determined using atomic absorption device (Unicom, England) according to Walsh (1955) while phosphorus was determined by element appreciation chromatography device as described by Marker (1992). The direct determination of lycopene, by measuring the colour of tomato products, was carried out with a reflectance colorimeter HunterLab colour analyzer (Hunter Lab Colour Flex EZ, USA), which measures reflected rather than transmitted light, as described by Anthon and Barrett (2006). Total carotenoids were determined by the method of Sharma and Maguer (1996). Lycopene yield (Y%) was determined according to Poojary and Passamonti (2015) using the following equation:

$$Y(\%) = \frac{\text{Amount of extracted lycopene}}{\text{Amount of lycopene in tomato pulp waste}} \times 100$$

Determination of free radical scavenging activity (DPPH Assay)

The extraction process was carried out according to Poojary and Passamonti (2015) using the optimum conditions determined in this work as mentioned above. 10 g powdered cake or cookies samples was extracted with 100 ml of the solvent (25:75 acetone: n-hexane) at 40°C for 45 min using water bath with contentious shaking then the extracts were filtered.

2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity was measured following the method of Nanjo *et al* (1996). 1 ml of lycopene extract or cake/cookies extract was taken in different test tubes. 4 ml of 0.004% DPPH dissolved in acetone: n-hexane solvent (1:3) according to the solvent used for lycopene

extraction was added to each test tube and the contents were incubated at room temperature for 30, 60, 90 and 120 min. The absorbance of the solution was read at 517 nm. The absorbance without sample was treated as control. Percentage of antioxidant activity of free radical DPPH was calculated as follows:

$$\text{Inhibition (\%)} = \frac{A_{control} - A_{sample}}{A_{control}} \times 100$$

The DPPH activity of the extract was compared with ascorbic acid (0.1 g dissolved in 100 ml distilled water.

Recipes and preparation of cake

The formula used to prepare the cake was as follow: 500 g wheat flour (72%), 60 ml sunflower oil, 320 ml cow milk 3.5% fat, two eggs, 300 g sugar, 2 g vanillin, 16 g baking powder and 4 g coconut powder. This formula served as a control and named $CK_{control}$. The oil was substituted with 1, 3 and 5% of lycopene extract and the resulted cake samples were named $CK_{1\%}$, $CK_{3\%}$ and $CK_{5\%}$. The ingredients were well mixed and backed in electric oven at 180°C for 45 min and cooled at room temperature for 2 hrs. The cakes were divided into 5 × 5 cm pieces and packaged in polyethylene bags.

Recipes and preparation of cookies

The formula used to prepare the cookies was as follow: 500 g wheat flour (72%), 750 g butter (80% fat), 2 eggs, 150 g powdered sugar, 1 g vanillin and 8 g baking powder. This formula served as a control ($COK_{control}$). The butter was substituted with 1, 3 and 5% of lycopene extract were named $COK_{1\%}$, $COK_{3\%}$ and $COK_{5\%}$. The ingredients were well manually mixed, formed and backed at 180 °C for 15 min and cooled at room temperature for 2 hrs. The resulted cookies were packaged in polyethylene bags and directly subjected to evaluation and analyses.

Specific volume determination

Samples were weighted (g) after 2 hours of cooling at room temperature. The volume (cm^3) was measured by rapeseed replacement method. Specific volume was obtained by dividing the volume of sample by their weight according to the method described in the AACC (1983).

Colour determination

Colour values expressed as lightness (L), redness (a) and yellowness (b) were measured using a HunterLab colour analyzer (Flex EZ, USA).

All tests were performed in triplicate.

Sensory evaluation

Sensory evaluation was conducted according to the method described by Mansour and Khalil (2000). The samples were served to 10 panelists (Staff member of Food Science Department, Faculty of Agriculture, Zagazig University, Egypt) without care of age or sex. The panelists were subjected to sensory evaluation using a 9-point hedonic scale for colour, taste, odour, texture and overall acceptability. A numerical basis as a sort of evaluation from 1 to 9 was used where (1 =dislike extremely, 2= dislike very much, 3= dislike moderately, 4= dislike slightly, 5=neither like nor dislike, 6= like slightly, 7= like moderately, 8, like very much, 9= like extremely).

Statistical Analysis

The data of the present study were subjected to analysis of variance (ANOVA) using SAS software (SAS Institute, 1990). Differences between means were determined by the least significant difference test, and significance was defined at $P<0.05$. All measurements were carried out in triplicates.

RESULTS AND DISCUSSION

Chemical Composition of Tomato Waste

Table 1 shows the chemical composition of tomato processing waste. The results showed that tomato waste contained (on dry weight basis) 16.51% carbohydrates, 1.10% fats, 19.07% crude protein, 58.2% crude fiber 5.12% ash, 2500 ppm phosphorus, 12.52 ppm copper, 1379 ppm calcium, 94.71 ppm iron, 17693.75 ppm potassium and 3537 ppm sodium. On the other hand, the total carotenoid and lycopene content of tomato waste were 654.76 mg/100g and 300.85 mg/100g (on dry weight basis), respectively. These results are in agreement with Rodriguez and Kimura (2004) and Rizk *et al*. (2014) who stated that the amount of carotenoid

Table 1. Chemical composition of tomato processing waste (on dry weight basis)

Component	Quantity
Moisture	79.66%
Carbohydrates	16.51%
Fats	1.10%
Crude proteins	19.07%
Crude fibers	58.2%
Ash	5.12%
Minerals	
Phosphorus	2500 ppm
Copper	12.52 ppm
Calcium	1379 ppm
Iron	94.71 ppm
Potassium	17693.75 ppm
Sodium	3537 ppm
Lycopene	300.85 mg/100g
Total carotenoid	654.76 mg/g

from tomato waste ranged from 520 to 950 mg/ 100g. Aghel *et al.* (2011) found that lycopene is the major sources of carotenoid in tomato peel and this pigment represents more than 85% of all carotenoid. Its concentration can vary from 30 to 200mg in the fresh products or from 430 to 2000 mg/100g dry weight. Tomato pomace contains 49-59% fibers, 7-14% carbohydrates, 10-27% proteins, 11-17% fat and 3-5% ash (Knoblich *et al.,* 2005; Del Valle *et al.,* 2006; Silva *et al.,* 2016). Knoblich *et al.* (2005) stated that tomato peels contained 2.7 g/kg phosphorus, 7.6 g/kg copper, 1.8 g/kg calcium, 75.5 g/kg iron, 28.3 g/kg potassium and 83.8 g/kg sodium.

Recovery of Lycopene Extracted from Tomato Waste (Skin) at the Optimum Conditions

The operating parameters of lycopene extraction were temperature, time and the initial moisture content of raw materials. The initial concentrations of lycopene (total lycopene content) in tomato wastes were determined and it was found to be 30.85 and 160.44 mg/kg for the industry waste and laboratory waste, respectively.

Generally, the extraction yield of lycopene obtained with different experimental conditions in this study varied between 8.49 and 93.59%. This indicates that the extraction yield of lycopene greatly depends upon the extraction conditions employed (solvent composition, solvent/meal ratio, temperature and cycles of extractions) as well as nature of the starting material used (tomato variety, composition of the waste and portion of the fruit *etc.*).

Table 2 shows the recovery of lycopene extracted from tomato wastes at the optimum conditions. The optimum conditions of the extraction process for all samples were 40ºC and 45 min. Lycopene extracts prepared from dried wastes had higher lycopene recovery than those prepared from wet samples. For dried samples, lycopene extract prepared from the laboratory tomato waste had the maximum lycopene recovery 93.59% followed by that obtained from industrial waste 92.93%. Although the recovery of lycopene from the dried samples was similar,

Table 2. Recovery of lycopene extracted from industrial and laboratory tomato wastes

Tomato waste characteristics			Lycopene content in the extract (mg/kg)	Lycopene recovery (%)
Source	**Moisture content (%)**	**Lycopene content (mg/kg)**		
Industrial waste	3.51%*	30.85	28.67	92.93
	79.66%**		25.22	81.75
Laboratory waste	3.43*	160.44	150.16	93.59
	81.54**		143.13	89.21

* Dried tomato waste. ** Wet tomato waste.

the concentration of lycopene in the industrial tomato waste was found to be extremely low 30.85 mg/kg) compared to laboratory tomato waste (160.44 mg/kg). This indicates that the operation used in industrial scale such as high temperature used in hot-break (79°C) and the finishing steps, resulted in extraction of high concentration of lycopene into the juices. For wet samples, lycopene extract resulted from laboratory tomato waste and that obtained from industrial waste had 89.21 and 81.75% lycopene recovery, respectively.

Several other researchers have obtained different quantity of lycopene by using different types of starting material and different extraction conditions. Tan and Soderstrom (1989) recovered 25 mg/kg of lycopene from tomato paste with 95% ethanol and low boiling petroleum ether (40–60ºC). Kaur *et al*. (2008) extracted lycopene from tomato skin with hexane: acetone: ethanol in 2:1:1 ratio and reported a maximum lycopene yield of 19.8 mg/kg with a 30:1 *V/W* solvent/meal ratio, four extractions, 50ºC temperature and 8 min extraction time. Lavecchia and Zuorro (2008) extracted lycopene from tomato peels with hexane, ethyl acetate and hexane: acetone: ethanol (2:1:1, *V/V*). In their study, the lycopene yield ranged between 136 and 1044 mg/kg, on a dry weigh basis, however, they showed that the lycopene yield could be significantly enhanced by using samples treated by cell-wall degrading enzymes.

Antioxidant Activity of Lycopene Extracts

2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay is the most widely used method for screening antioxidant activity, since it can accommodate many samples in short period and detect active ingredients at low concentration. The decrease in absorbance of DPPH radical scavenging caused by antioxidant was due to the scavenging of the radical by hydrogen donation. It is visually noticeable as a colour change from purple to yellow (Spanos and Wrolstad, 1990).

DPPH inhibition (%) of lycopene extracts prepared from tomato wastes at the optimum conditions of extraction as well as ascorbic acid is presented in Table 3. The obtained results indicated that the DPPH inhibition ranged between 78.46 to 89.90% for all obtained lycopene extracts and between 86.50 to 91.94% for ascorbic acid at different incubation times. Moreover the DPPH inhibition (%) increased gradually with the increasing of incubation time from 0 to 120 min. Lycopene extract prepared from laboratory tomato wastes had the highest level of DPPH inhibition (89.90%) after 120 min compared to other lycopene extracts. While lycopene extract prepared from industrial tomato waste had 81.75% of DPPH inhibition after 120 min of incubation time. Generally, these results reflect the high antioxidant activity of lycopene extract which approximately equal that for ascorbic acid.

Use of Lycopene Extract in Cake Processing

Cakes were prepared after adding different levels of lycopene extract then baked and cooled. The oil added to prepare cake samples was substituted with 1, 3 and 5% of lycopene extract and the resulted cake samples were named $CK_{1\%}$, $CK_{3\%}$ and $CK_{5\%}$.

Table 3. DPPH inhibition (%) of lycopene extracts compared with ascorbic acid

Characteristics of lycopene extract		DPPH Inhibition (%), during incubation time (min)				
Source	**Lycopene content (mg/kg)**	**0**	**30**	**60**	**90**	**120**
Industry	28.67	78.56	79.02	79.65	81.19	81.75
	25.22	75.81	76.15	76.97	77.73	78.46
Laboratory	150.16	85.68	86.84	88.63	88.90	89.90
	143.13	83.05	84.43	87.09	87.75	86.54
Ascorbic acid		86.50	88.61	89.45	90.40	91.94

Specific Volume of Cakes

Specific volume is considered one of the most important quality attributes of food products as well as bakery products that influence consumer choice and contributes to quality assessment (Ktenioudaki and Gallagher, 2012). The specific volume of cake indicates the amount of air that can retained in the final product. A higher gas retention and higher expansion of the product (Gomez *et al.*, 2008) leads to a higher specific volume. Specific volume of cake containing different levels of lycopene extract is presented in Table 4. Specific volume of $CK_{control}$, $CK_{1\%}$, $CK_{3\%}$ and $CK_{5\%}$ were found to be 2.81, 2.61, 2.71 and 2.79 cm^3/g, respectively. It could be noticed that no clear variations were observed among all cake samples. All samples had a good specific volume comparing with data obtained by several researches who found that the specific volume of baked goods as well as cakes ranged between 1.79 to 2.49 cm^3/g (Rosell and Santos, 2010; Chaiya and Pongsawatmanit, 2011; Sanz-Penella *et al*., 2013; Collar *et al.*, 2014; Scheuer *et al.*, 2016).

Antioxidant Activity (DPPH inhibition) of Cakes

DPPH inhibition (%) of cake samples containing different levels of lycopene extract as well as ascorbic acid is viewed in Table 5. The addition of lycopene extract to cake clearly improved the antioxidant capacity of the resulted cakes. In addition to that, over the time of incubation the DPPH inhibition was progressively increased for all studied samples. At the beginning of incubation time, $CK_{1\%}$, $CK_{3\%}$ and $CK_{5\%}$ had 62.64, 68.23 and 71.01%, respectively. While at the end of incubation time (120 min) the respective values were increased to 64.72, 72.43 and 75.75%, respectively. On the other hand, ascorbic acid solution which used for comparison had 75.50% at 0 time and 80.94% at 120 min.

Colour Values of Cakes

In the food industry, colour has become more and more important in terms of how food is displayed and sold, and thus it is an indicative parameter used in quality control. It is also added to foods to stimulate the appetite (Araújo *et al.*, 2012).

Colour values (L, a, and b) of cake samples containing different levels of lycopene extract and control are presented in Table 6. The level of lightness values of cake containing different levels of lycopene was found to be slightly higher than the control sample. Similarly, colour values a and b did not vary between the control and the lycopene added cakes.

Sensory Evaluation of Cakes

The sensory evaluation was performed by rating the liking of the sensory characteristics of all cake samples for crust colour, crumb colour, taste, odour, texture, and overall acceptability using a 9-point hedonic scale. Sensory attributes of cake samples containing different levels of lycopene extract and control are shown in Table 7. For taste, odour and overall acceptability, there were no significant differences between the cake samples and control sample. For crust colour $CK_{control}$ had higher score than other samples, while no significant differences could

Table 4. Specific volume of cake containing different levels of lycopene extract

Sample	$CK_{control}$	$CK_{1\%}$	$CK_{3\%}$	$CK_{5\%}$
Weight (g)	25.62	25.05	24.84	25.60
Volume (cm^3)	71.99	65.38	67.31	71.42
Specific volume (cm^3/g)	2.81	2.61	2.71	2.79

Table 5. DPPH inhibition (%) of cake samples containing different levels of lycopene extract compared with ascorbic acid

Sample	DPPH Inhibition (%)				
	0 min	30 min	60 min	90 min	120 min
$CK_{control}$	42.98	42.38	43.45	43.56	44.19
$CK_{1\%}$	62.64	61.47	63.04	64.65	64.72
$CK_{3\%}$	68.23	69.33	70.36	70.32	72.43
$CK_{5\%}$	71.01	73.32	73.72	74.12	75.75
Ascorbic acid	75.50	78.61	79.45	80.40	80.94

Table 6. Colour attributes of cake samples containing different levels of lycopene extract

Sample	Colour attributes (Hunter lab. values)					
	Lightness (L)		Redness (a)		Yellowness (b)	
	Crust	Crumb	Crust	Crumb	Crust	Crumb
$CK_{control}$	32.07	42.63	9.92	3.13	18.03	21.11
$CK_{1\%}$	32.58	43.25	11.89	4.14	17.66	18.61
$CK_{3\%}$	33.82	43.53	11.48	3.90	18.62	20.57
$CK_{5\%}$	34.22	43.98	9.79	3.64	17.41	21.54

Table 7. Sensory evaluation of cake samples containing different levels of lycopene extract

Sample	Colour		Taste (9)	Odour (9)	Texture (9)	Overall acceptability (9)
	Crust (9)	Crumb (9)				
$CK_{control}$	8.00 ± 0.81^{a}	7.92 ± 0.95^{a}	7.84±0.80	8.00±0.81	8.15 ± 0.68^{ab}	8.07±0.75
$CK_{1\%}$	7.38 ± 0.76^{b}	7.23 ± 0.83^{b}	7.92±0.64	8.00±0.58	7.88 ± 0.50^{b}	8.00±0.70
$CK_{3\%}$	7.61 ± 0.96^{ab}	7.69 ± 0.75^{ab}	7.77±1.09	7.84±1.06	8.03 ± 0.32^{b}	8.07±0.67
$CK_{5\%}$	7.84 ± 0.98^{ab}	7.84 ± 0.80^{a}	8.00±0.71	8.00±0.81	8.42 ± 0.53^{a}	8.11±0.76
F-test	*	*	N.S.	N.S.	*	NS
LSD	0.53	0.54	-	-	0.35	-

NS, * and **: not significant, significant at 0.05 and 0.01 levels, respectively.

LSD: Least Significant Difference

be observed between $CK_{3\%}$ and $CK_{5\%}$. $CK_{control}$ and $CK_{5\%}$ had similar crumb colour. $CK_{5\%}$ had the highest score of taste and texture compared to other samples being 8.00±0.71 and 8.42±0.53 (like very much), respectively. Chaiya and Pongsawatmanit (2011) studied quality of batter and sponge cake prepared from wheat-tapioca flour blends and reported that colour, odour and overall acceptability liking ranged between 6.6 – 6.7, 6.5 – 6.7 and 6.3 – 7, respectively.

Use of Lycopene Extract in Cookies Processing

The butter used to prepare cookies samples was substituted with 1, 3 and 5% of lycopene extract and the resulted petit four samples were named $COK_{1\%}$, $COK_{3\%}$ and $COK_{5\%}$, respectively.

Specific Volume of Cookies

Specific volumes of petit four enhanced with lycopene extract samples as well as control are presented in Table 8. Specific volumes of all tested samples ranged between 2.15 - 2.18 cm^3/g. These results revealed that no negative impact on specific volumes was observed after lycopene addition to cookies.

Antioxidant Activity (DPPH inhibition) of Cookies

Table 9 shows the DPPH inhibition (%) of cookies samples containing different levels of lycopene extract as well as ascorbic acid. The addition of lycopene to cookies improved the antioxidant activity of the resultant products. Where, the DPPH inhibition during 120 min ranged between 56.98 - 59.83 for $COK_{control}$, 61.74 - 65.34 for $COK_{1\%}$, 75.64 - 78.04 for $COK_{3\%}$ and 79.91 - 83.86% for $COK_{5\%}$. These results show that the (%) inhibition of DPPH was increased when the added concentration of lycopene in the cookies butter was increased. Moreover the increase in (%) inhibition of DPPH was directly related to the reaction time. $COK_{5\%}$ sample had the highest per cent of DPPH inhibition. On the other hand, ascorbic acid had 80.94% DPPH inhibition at 120 min. $COK_{5\%}$ had higher DPPH inhibition than ascorbic acid at 0, 30, 60, 90 and 120 min of incubation time.

Colour Values of Cookies

Colour attributes (L, a and b values) of cookies samples containing different levels of lycopene extract and control are illustrated in Table 10. It was noticed that lightness (L) and redness (a) were gradually increased due to the increase in lycopene addition. $COK_{5\%}$ had the highest L value (44.25) followed by $COK_{3\%}$ (42.85), $COK_{1\%}$ (42.22) and $COK_{control}$ (41.57). The same trend was observed for redness (a) and yellowness (b) of cookies samples.

Sensory Evaluation of Cookies

Table 11 presents the sensory evaluation of cookies samples containing different levels of lycopene extract as well as control. Generally no significant variations were recorded between cookies containing lycopene extract and control sample regarding odour and texture values. $COK_{3\%}$ was judged as the best sample for colour, taste, odour, texture and overall acceptability recording 8.38±0.65, 8.31±0.63, 8.23 ±0.60, 8.15±0.80 and 8.23±0.70, respectively.

Conclusion

From the results obtained in the present study, it can be concluded that tomato waste had a high amount of lycopene with high antioxidant activity. Solvent (25:75 acetone/n-hexane) extraction is an effective method for lycopene extraction from tomato wastes when used at 40ºC for 45 min. This study therefore, supports the use of lycopene extracted from tomato waste for enhancing antioxidant capacity, colour and sensory properties of some bakery products.

Table 8. Specific volume of cookies containing different levels of lycopene extract

Sample	$COK_{control}$	$COK_{1\%}$	$COK_{3\%}$	$COK_{5\%}$
Weight (g)	6.34	5.97	6.12	5.82
Volume (cm^3)	13.63	12.89	13.34	12.63
Specific volume (cm^3/g)	2.15	2.16	2.18	2.17

Table 9. DPPH inhibition (%) of cookies samples containing different levels of lycopene extract compared with ascorbic acid

Sample	DPPH Inhibition (%)				
	0 min	30 min	60 min	90 min	120 min
$COK_{control}$	56.98	42.43	43.02	43.97	59.83
$COK_{1\%}$	61.74	61.30	63.69	64.76	65.34
$COK_{3\%}$	75.64	76.12	77.16	78.58	78.04
$COK_{5\%}$	79.91	80.08	82.73	83.03	83.86
Ascorbic acid	75.50	78.61	79.45	80.40	80.94

Table 10. Colour attributes of cookies samples containing different levels of lycopene extract

Sample	Colour attributes (Hunter lab. values)		
	Lightness (L)	Redness (a)	Yellowness (b)
$COK_{control}$	41.57	6.42	19.11
$COK_{1\%}$	42.22	7.72	19.53
$COK_{3\%}$	42.85	7.34	20.28
$COK_{5\%}$	44.25	7.84	21.96

Table 11. Sensory attributes of cookies samples containing different levels of lycopene extract

Sample	Colour (9)	Taste (9)	Odour (9)	Texture (9)	Overall acceptability (9)
$COK_{control}$	7.85 ± 0.90^{b}	7.54 ± 1.05^{b}	8.15±0.80	8.07±0.76	8.08 ± 0.64^{ab}
$COK_{1\%}$	7.69 ± 0.63^{b}	8.08 ± 0.75^{ab}	8.08±0.64	7.85±0.80	7.81 ± 0.56^{b}
$COK_{3\%}$	8.38 ± 0.65^{a}	8.31 ± 0.63^{a}	8.23±0.60	8.15±0.80	8.23 ± 0.70^{a}
$COK_{5\%}$	8.08 ± 0.64^{ab}	7.85 ± 0.80^{ab}	8.00±0.71	7.85±0.80	7.85 ± 0.69^{b}
F-test	*	*	NS	NS	*
L.S.D.	0.54	0.59	-	-	0.38

NS, * and **, not significant, significant at 0.05 and 0.01 levels, respectively.

LSD: Least Significant Difference.

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تقييم الليكوبين المستخلص من مخلف تصنيع الطماطم كمضاد أكسدة طبيعى فى بعض منتجات المخابز

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يهدف البحث إلى دراسة التركيب الكيماوى للمخلف الناتج من تصنيع الطماطم، والظروف المثلى لإستخلاص الليكوبين منه، وتقييم النشاط المضاد للأكسدة لمستخلص الليكوبين، واستخدامه فى تصنيع بعض منتجات المخابز (الكيك والكوكيز)، لخصت الدراسة أن مخلف الطماطم الناتج من مصنع لصناعة منتجات الطماطم يحتوى على (على أساس الوزن الجاف) ١٦.٥١% كربوهيدرات، ١.١٠% دهون، ١٩.٠٧% بروتين خام، ٥٨.٢٠% ألياف خام، ٥.١٢% أملاح معدنية، ٢٥٠٠ جزء فى المليون فوسفور، ١٢.٥٢ جزء فى المليون نحاس، ١٣٧٩ جزء فى المليون كالسيوم، ٩٤.٧١ جزء فى المليون حديد، ١٧٦٩٣ جزء فى المليون بوتاسيوم، ٣٥٣٧ جزء فى المليون صوديوم، وعلى الجانب الآخر فان الكاروتينات الكلية والليكوبين فى مخلف الطماطم تعادلا ٦٤٥.٧٦ ملجم/١٠٠جم و ٣٠٠.٨٥ ملجم/١٠٠جم (على أساس الوزن الجاف) على التوالى، وأظهرت نتائج استخدام الاسيتون: هكسان كمذيب لإستخلاص الليكوبين على درجات حرارة ومدد مختلفة أن درجة الحرارة المثلى للإستخلاص هى ٤٠ درجة مئوية، بينما مدة الإستخلاص المثلى هى ٤٥ دقيقة، هذا ويحتوى مستخلص الليكوبين المحضر من مخلف الطماطم المجفف على معدل إستخلاص ليكوبين أعلى من ذلك المحضر من مخلف طماطم رطب، وتعكس نتائج دراسة النشاط المضاد للأكسدة النشاط العالى المضاد للأكسدة لمستخلص الليكوبين والتى تعادل تقريبا حمض الأسكوربيك، وأن إضافة ٣-٥% مستخلص ليكوبين للكيك والكوكيز قد حسن من النشاط المضاد للأكسدة واللون والخواص الحسية.

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