Thermal Processing and Lycopene Content of Tomatoes- A Public Health Perspective

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ABSTRACT

In this era of rising prevalence of chronic health conditions, functional properties of fruits and vegetables are of utmost emphasis. Lycopene, belonging to class of carotenoids, is one of the chief phytochemical known for being a natural colorant as well as for providing health benefits. Tomatoes are a major source of lycopene in the diet. However, tomatoes are not only used in raw but also in processed and cooked format in cuisines round the world. This necessitates the optimization of functional properties of cooked tomato products. The current study aims at describing potential health benefits of processed tomato puree through studying its lycopene content at various temperatures. A before and after 3 X 3 factorial experimental study design was used for this study. A comparison of lycopene content of tomatoes under following variants of processing was carried out: temperature (raw vs.75°C vs. 88°C) and time (5 vs.15 vs.30 minutes). Findings indicate that cooking improved the available lycopene content in tomato puree. Maximum values of lycopene were noted after treatment at 88 °C for 30 minutes (4.7 mg/100g compared to 0.20 mg/100g in raw). Optimization of lycopene content of cooked tomato puree by conscious monitoring of processing time and temperature would aid in achieving this goal.

Keywords: *Lycopene, Phytochemicals, Thermal processing, Retention, Tomatoes*

1. INTRODUCTION

Lycopene is a bioactive carotenoid present mainly in red fruits and vegetables such as tomatoes, water melon, pink grape fruits, apricots and pink guavas (Perveen et al., 2015). Among dietary carotenoids, lycopene has been regarded as one of the strongest antioxidants. Epidemiological evidence has shown several health benefits of lycopene consumption like decreasing the risk of cardiovascular diseases and cancers. It has been studied to reduce the atherogenicity of lipoproteins because of its antioxidant properties (Martínez-Hernández et al., 2016). Human beings are unable to synthesize lycopene, therefore it has to be ingested through dietary sources. Tomatoes are one of the richest sources of lycopene. As much as 85% of dietary lycopene is contributed by tomatoes (Perveen et al., 2015). Lycopene content of processed products such as tomato puree affects its grade and appearance and is an important factor to be considered by food manufacturers (Marsic, Gasperlin, Abram, Budic, & Vidrih, 2011).

It is a common belief that raw fruits and vegetables are healthier option for consumption. Current dietary guidelines also recommend the use of raw fruits and vegetables as necessary part of a healthy dietary pattern. Although processing or handling may lead to loss of nutritional components in fruits and vegetables through processes including thermal degradation, leaching, oxidation, certain functional properties may be enhanced through processing. Cooking of tomato products can either increase or reduce active lycopene content. Thermal isomerization of lycopene can enhance its extraction from tomato puree (Honda et al., 2017). Heat processing of lycopene containing plant foods can induce "cis" isomerization of lycopene, thereby enhancing the favorable effect on its absorption. It is established that cis-isomers have more health promoting properties than all-trans isomers. Thermal processing of fruits and vegetables that are rich in lycopene can, therefore, result in improved bioavailability than raw products (Martínez-Hernández et al., 2016). However, it has been revealed that cooking for longer time and at higher temperatures can reduce the stability of lycopene in end product (Ishiwu Charles, Iwouno, Obiegbuna James, & Ezike Tochukwu, 2014). Processing time of beyond 90 minutes can result in oxidation and thermal degradation of lycopene (Raponi, Moscetti, Monarca, Colantoni, & Massantini, 2017) especially at frying temperatures.

There is interest in developing new processing methods in order to achieve food safety, shelf life and preservation of nutritional quality of processed foods. The present study aimed to find out optimal time and temperature for maximum retention of lycopene in tomatoes. This finding shall be of interest to health

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professionals to help promoting the healthful dietary practices for therapeutic as well as for preventive purposes.

2. METHODS

2.1. Study design

Comparison of lycopene content of tomatoes under various temperature and time conditions was carried out using a before and after 3 X 3 experimental factorial design.

Sample preparation

Fresh, mature and ripe tomatoes of ROMA variety (Solanum Lycopersicum) commonly grown in Lahore, Pakistan were purchased from a local farm house. The experimental work was performed in Plant Biotechnology and Organic Food Laboratory, Pakistan Council of Scientific and Industrial Research (PCSIR). Before lycopene content analysis, the tomatoes were blanched for five minutes after thorough washing. Peels of tomatoes were removed and they were grinded and deseeded. Raw tomato puree, thus obtained, was divided into seven equal parts. One part of tomato puree was kept as raw in a sterilized jar as baseline measure. Other six portions were subjected to heat treatment at various time and temperatures. Three portions were subjected to heat at 75 °C for 5, 15, and 30 minutes while the rest of the portions were heated at 85° C for 5, 15 and 30 minutes. After that, all seven samples were labeled and placed in sterilized jars until further analysis was performed.

2.2. Determination of Lycopene Content

A rapid method for the estimation of lycopene in tomato products is based on measurement of absorption of the petroleum ether extract of the total carotenoids. Carotene has a comparatively negligible absorbance while lycopene has a large absorbance. For lycopene estimation, 10 g tomato puree from each sample was weighed. The samples were repeatedly macerated with 20 ml acetone in a pestle and mortar until the residue was colorless. The acetone extract was then transferred to a separating funnel. Fifteen ml water and 20 ml petroleum ether were added to the funnel. The mixture was shaken until it formed two separate layers. This extraction of acetone with petroleum ether was repeated thrice until the mixture was colorless. Acetone layer was discarded. A small quantity of anhydrous Na_2SO_4 was added to the petroleum ether extract. It was transferred to a 50 ml volumetric flask and volume was made up with petroleum ether. Each sample mixture was wrapped in aluminum foil and left in dark place over night. Dilutes were made using 10 ml from each mixture and added to 50 ml petroleum ether. Color was measured in a 1cm cell at 503 nm in a spectrophotometer using petroleum ether as blank.

Lycopene content of the sample was then calculated using following formula

$$\text{mg of lycopene}/100\text{ g} = \frac{3.1206 \times \text{OD of sample} \times \text{Volume made up} \times \text{Dilution} \times 100}{1 \times \text{Wt of sample} \times 1000}$$

2.3. Statistical Analysis

Data was analyzed using Statistical Package for Social Sciences (SPSS, Version 21.0). Between group differences were statistically analyzed. One-way and two-way analyses of variance (ANOVA and MANOVA) were applied followed by post-hoc tests. All statistical testing was performed at 95% confidence interval with 0.05 as cutoff for significance.

3. RESULTS

Proximate analysis of raw tomato puree showed that it was mainly composed of water with 95% moisture content. Protein and fat contents were found to be in trace amounts while crude carbohydrates composed

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3g/100g of sample. Ash and fiber contents were 0.41 and 0.02% respectively (Figure 1).

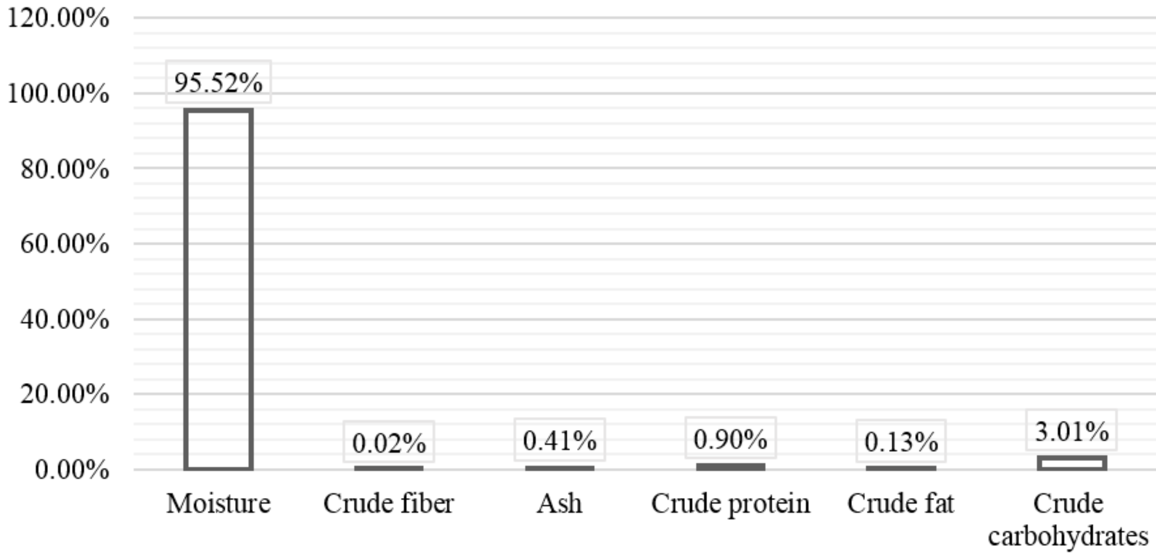

Figure 1. Proximate analysis of raw tomato puree (RAMA variety) obtained from indigenously grown tomatoes of Lahore, Pakistan.

Between-group analysis was performed in order to observe the differences in lycopene contents of tomato puree at varying cooking temperature and time conditions. Table 1 shows the individual difference in lycopene contents at different temperature and time conditions. Findings of One-way ANOVA indicate that mean lycopene content was significantly increased upon heating. Lycopene content of tomatoes showed a gradual increase with increasing time and temperature from 0.20±0.10 mg/100g in raw samples to 3.36±1.48 mg/100g and 2.03±2.02 mg/100g in samples heated for 30 minutes and at 88°C respectively (Table 1). Post Hoc tests (Table 2) show that each of the temperature-time variate was significantly different from one another. Therefore, largest lycopene content differences were observed between uncooked vs. sample heated at 88°C and of uncooked vs. sample heated for 30 minutes (Table 2). One way MANOVA revealed a significant multivariate main effect for cooking time as well as temperature. Also there was a significant interaction between time and temperature, about 99% of variation in lycopene contents was explained by combined effect of longer heating and heating at higher temperature (Table 3). In simple words, heating at higher temperature for a longer time rendered greatest increase in lycopene content. Highest lycopene content was observed after heating at 88°C for 30 minutes (Tables 2 & 3). A larger raise in lycopene content was observed by heating at 88°C for 30 minutes compared to heating at 75°C for same time period (Figure 2).

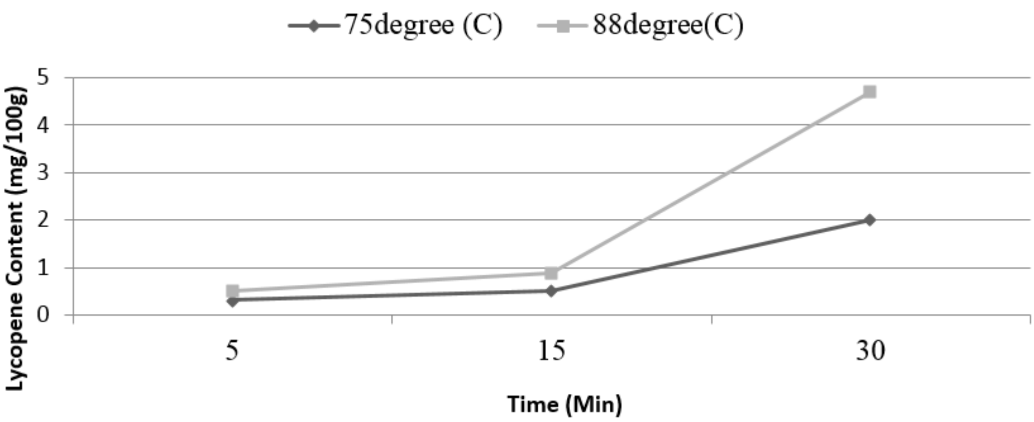

Figure 2. Main effects of time and temperature on lycopene content of tomato puree.

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Table 1. Effect of heat processing time and temperature on lycopene content of tomatoes.

Processing conditions (n=7)		Lycopene content (mg/100g) M±SD	ANOVA	p-value
Time (Minutes)	Zero	0.20±0.10	F(2,14)= 4709	<0.001
	5	0.41±0.11		
	15	0.68±0.21		
	30	3.36±1.48		
Temperature (°C)	Laboratory temperature (unheated)	0.20±0.10	F(1,14)= 1574	<0.001
	75	0.94±0.81		
	88	2.03±2.02		

Table 2. Pairwise comparison of time and temperature ranges on lycopene content.

	Group (I)	Group (J)	Mean diff. in lycopene contents	SE	p
Heating time	Zero minute	5 minutes	-.210*	0.041	<0.001
	Zero minute	15 minutes	-.483*	0.041	<0.001
	Zero minute	30 minutes	-3.158*	0.041	<0.001
	5 minutes	15 minutes	-.273*	0.034	<0.001
	5 minutes	30 minutes	-2.948*	0.034	<0.001
	15 minutes	30 minutes	-2.675*	0.034	<0.001
Heating temperature	Unheated	75°C	-.740*	0.039	<0.001
	Unheated	88°C	-1.828*	0.039	<0.001
	75°C	88°C	-1.088*	0.027	<0.001

Note: *Mean difference is significant at 0.05 level.

Table 3. Combined effect of time and temperature on lycopene content of tomatoes.

	SS	df	MS	F	p	Partial η2
Intercept	25.966	1	25.966	7679	<0.001	0.998
Time	31.846	2	15.923	4709	<0.001	0.999
Temperature	5.325	1	5.325	1574	<0.001	0.991
Time x Temp.	5.845	2	2.923	864	<0.001	0.992

4. DISCUSSION

The present study was carried out to provide empirical evidence on relation of thermal processing of tomato puree with lycopene contents. In this study, optimal time and temperature combination for maximum retention of lycopene contents of tomato puree was determined. Research on the effects of thermal processing on food composition has been a subject of contradiction. In the present research, lycopene content of tomato puree was found to be significantly improved when subjected to thermal processing. Highest lycopene content was observed after heating at 88°C for 30 minutes.

Cooking and processing is generally regarded as a mechanism to decrease the bioavailability of nutrients. Processed foods are considered to have lower contribution towards health benefits than raw food items. In alignment with this theory, Darsan, Reshma, and Anu (2013) have observed a decrease in lycopene content of tomatoes during heat treatment as compared to the raw product which was in contrast to our study findings. Similarly Bellili, Khenouce, Benmeziane, and Madani (2019) have reported that commonly used domestic cooking methods (griddling, baking and frying) result in decreased lycopene contents. However, several researchers have reported an increase in available lycopene content in tomato puree compared with its raw form as discussed below. Jorge et al. (2018) found that heated air flow leads to increased lycopene contents in tomatoes. Similar findings were observed in our research as well. This increase in lycopene content has been suggested to be because of lower degradation rates of lycopene upon dehydration (Gümüşay, Borazan, Ercal, & Demirkol, 2015). Another mechanism as suggested by Mayeaux et al. (2006) is that the presence of moisture or water may help in slowing down the heat transfer to the tomato product, and thus, may lessen the heat damage, resulting in increase in lycopene content of the product. In the present study, proximate analysis of raw tomatoes indicated that moisture content constitutes the major portion of its weight (Figure 1). Therefore, it is plausible to theorize that with progressing dehydration, lycopene contents may increase. However, it is important to note that lycopene contents cannot increase indefinitely upon heating because it would degrade beyond certain thermal conditions. An optimal temperature and heating time after which further heat treatment may adversely affect the lycopene contents is of concern to food industrialists as well as health professionals. Heating at 88°C for 30 minutes was found to maximize the lycopene contents of tomato puree in current research.

The findings of current study can be valuable for food manufacturers in developing efficient procedures aimed at maximum retention of lycopene in their products. Processed foods, like tomato puree, not only offering convenience but also functional properties would be of more interest to the consumers. The findings of this research can also be of help in planning educational sessions for general public to maximize the retention of functional benefits of cooked tomatoes.

5. CONCLUSION

From this study, it is concluded that heating tomato puree at 80° C for 30 minutes can result in maximum rise of lycopene content. This potential influence of thermal processing on lycopene content availability in tomatoes and tomato-based products would be of interest to food industrialists as well as to the consumers. Promotion of tomato products heated to this optimum time-temperature combination can have potential functional benefits on health. A finished product with enhanced functional properties, providing culinary convenience as well as with enhanced eye appeal would be of interest to consumers, food industrialists as well as to health professionals.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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