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Lycopene Content in Tomatoes (*Lycopersicon esculentum* Mill): Effect of Thermal Heat and its Health Benefits

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ABSTRACT

Lycopene is a phytonutrient and an antioxidant and this pigment is responsible for the characteristic deep red colour of ripe tomatoes and their products. It plays an important role in human health and epidemiological studies have shown it to reduce the risk of chronic diseases. The lycopene content and stability in tomato purée during cooking was studied. Eight different tomato cultivars ('NH158', 'Three lobed', 'Ronita', 'Small local', 'Leader', 'Lindo', 'Big local' and 'Cherry') were planted for evaluation. The tomato slurries were subjected to thermal heat for 1, 2 and 3 h and analyzed for lycopene content by spectrophotometry. The absorbance was read at 502 nm. The lycopene content ranged from 70.25 to 147.29 µg/g, 'Leader' having the highest and 'Lindo' the lowest. The percentage loss of lycopene content after 1 h boiling ranged from 13.58-42.99% among the cultivars. Values obtained for 2 and 3 h heating were similar, ranging from 24.66-85.30%. However, 'Three-lobed' and 'Cherry' retained more of their lycopene content than the other six cultivars. A further loss in the lycopene content was observed when subjected to 3 h cooking suggesting that lycopene is not stable when exposed to longer heating. The levels of lycopene in tomato and the potential influence of thermal heat on its availability in tomatoes and tomato-based foods would be of interest to the food industry, tomato improvement and public health intervention programmes. This paper also summarizes the current state of knowledge of the properties of lycopene, and its possible health benefits.

Keywords: antioxidant, carotenoid, cooking, cultivars, phytonutrient

INTRODUCTION

Tomatoes constitute an important agricultural crop and are an integral part of the human diet. They are the second-most consumed vegetable after potato (FAOSTAT 2007). Although tomatoes are commonly consumed fresh, over 80% of tomato consumption comes from processed products such as tomato juice, paste, puree, ketchup and sauce (Shi and Le Maguer 2000). Rao and Agarwal (1998) indicated the potential health benefits of a diet rich in tomatoes and tomato products. Lycopene, a major carotenoid without provitamin activity, present in red tomatoes, is considered responsible for their beneficial effects (Stahl and Sies 1996; Gerster 1997; Rao and Agarwal 1999). The ability of lycopene to act as a potent antioxidant is thought to be responsible for protecting cells against oxidative damage and thereby decreasing the risk of chronic diseases (Rao and Agarwal 1999).

Tomatoes have been traditionally credited as rich sources of carotenoids and vitamins, particularly β-carotene, provitamin A and ascorbic acid (Hanson *et al.* 2004). Lycopene is a phytonutrient and a potent antioxidant; it is also a naturally occurring carotenoid responsible for the red colour in tomatoes, watermelons and pink grapefruits (Rao and Agarwal 1999; 2000). With a molecular formula of $C_{40}H_{56}$, lycopene has 11 conjugated double bonds and 2 non-conjugated double bonds, making it a highly unsaturated compound (Φ, Φ, and carotene). Although used as a food colorant for many years, it is only recently that it has been the subject of intense study with respect to its antioxidant activity and potential in alleviating chronic disease such as certain cancer and coronary heart disease (George *et al.* 2004). In turn, this has led to the idea of increasing levels of lycopene in crops, particularly tomato, by genetic crosses or genetic manipulation in order to increase the amount of lycopene in a typical diet (Bramley 2000).

In fresh tomatoes, the content of lycopene was reported to range from 25 to 2000 µg/g in raw tomato (Takeoka *et al.* 2001). The level of lycopene is directly related to ripeness and increasing pH (Thompson *et al.* 2000). The variation in the redness of different cultivars is mainly due to a difference in the levels of lycopene accumulated in their skins, and the only carotenoid constituent in the skin is lycopene (Adewuyi and Ademoyegun 2008). Thus, those factors may explain the wide variability of reported lycopene content in raw tomato. Also changes of lycopene content in tomato during storage, semi-drying and juice processing have been reported (Toor and Savage 2006). Although a decrease in lycopene content has been observed during these processes in some studies, this may be due to the temperature (below 80°C) used in those tomato processing methods, which increased free lycopene by disrupting cell walls or hydrolyzing lycopene derivatives rather than degrading lycopene (Thompson *et al.* 2000). Heat processing increases the bioavailability of lycopene by breaking cell walls and allowing extraction of lycopene from the chromoplasts, where it is found in raw tomatoes (Stahl and Sies 1996).

While most tomatoes produced worldwide are used in the production of tomato paste, a significant number of tomatoes are consumed fresh. In spite of the interest in the role of lycopene in the prevention of chronic diseases, information regarding the lycopene content of commonly grown and consumed tomatoes and their food products in West Africa is lacking, hence, it is necessary to estimate the effect of thermal heat on lycopene content. In this study, eight locally grown tomato cultivars were subjected to boiling for 1, 2 and 3 h to evaluate changes in lycopene content among the cultivars. This would provide valuable informa-

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Table 1 Lycopene content (µg/g) in eight varieties of tomato (*Lycopersicon esculentum*) after different cooking times.

Varieties	*Raw	After 1 h	After 2 h	After 3 h
NH 158	91.67 ± 0.56 c	72.62 ± 1.12 a	51.59 ± 1.45 b	51.29 ± 1.17 b
3 Lobed	75.01 ± 1.24 f	50.16 ± 1.02 a	49.81 ± 1.60 a	49.21 ± 1.19 b
Ronita	83.69 ± 1.30 d	48.41 ± 1.10 a	15.30 ± 1.10 b	12.30 ± 0.89 c
Small local	79.77 ± 0.98 e	51.99 ± 1.77 a	20.54 ± 1.28 b	19.49 ± 1.37 b
Leader	147.29 ± 0.94 a	78.97 ± 1.78 a	76.97 ± 1.81 a	74.21 ± 1.07 b
Lindo	70.25 ± 0.96 g	60.71 ± 1.20 a	34.53 ± 1.39 bc	33.73 ± 1.13 c
Big local	100.41 ± 0.72 b	71.05 ± 0.56 a	36.51 ± 0.90 b	30.57 ± 1.29 c
Cherry	90.09 ± 1.10 c	70.25 ± 1.13 a	67.87 ± 0.90 b	51.46 ± 0.82 c
Mean	92.27	62.96	44.14	40.28
Range	70.25-147.29	48.41-78.97	15.30-76.97	12.30-74.21

Results are means of triplicate analyses from each of the three replications ± Standard deviations.
Values with the same letter in the same row are not significantly different for processed samples at 95% confidence level.
*Values for the raw with same letter in the same column are not significantly different at 95% confidence level.

tion on lycopene loss in tomatoes subject to heat. Since these are generally used in daily tomato food preparation and for the food industry, it would be possible to suggest the tomato cultivars that have the potential to retain more lycopene content during processing. Also, the health benefits of lycopene in tomato, a major source of food in Nigerian household diets, are discussed.

MATERIALS AND METHODS

Eight tomato cultivars ('NH158', 'Three lobed', 'Ronita', 'Small local', 'Leader', 'Lindo', 'Big local' and 'Cherry') were planted on the experimental plot of the National Horticultural Research Institute, Idi-Ishin, Ibadan. The cultivars were planted in three replicates using a Randomized Complete Block Design. The fruits were analyzed at maturity for lycopene content.

Tomato cooking procedure

To eliminate inconsistencies in lycopene content among the different cultivars, the tomato fruits were crushed in a Waring blender and the slurry was used for analysis. The slurry was separated into portions weighing 2 g each in a test tube, covered with aluminum foil to exclude light and placed in a water bath at boiling point. Each treatment (raw, 1 h, 2 h and 3 h) was conducted in triplicate. The heated samples were left to cool at room temperature and used to determine lycopene content. The loss in lycopene content was calculated based on the percentage loss of lycopene compared with the control.

Lycopene extraction and estimation

The lycopene content was determined according to the method of Sadler *et al.* (1990). The samples of raw and heated tomato slurries were mixed with 40 ml of a mixture of *n*-hexane: acetone: ethanol (2: 1: 1) containing 2.5% (w/v) ascorbic acid. The mixture was agitated continuously for 30 min with a shaker; 10 ml of water was added followed by another 5 min of agitation. The solution was separated into a distinct polar and non-polar layer in a separation flask and the polar phase was carefully drawn out. The organic layer was separated and filtered through dehydrated sodium sulphate. The hexane phase was collected into a 25-ml standard flask and made up to the mark with n-hexane. The optical density of the *n*-hexane extract was measured spectrophotometrically (Jenway 6400 model) at 502 nm against an *n*-hexane blank. Concentration of lycopene was calculated using an extinction coefficient ($E^{\%}$) of 3150.

All analyses were carried out in triplicate from each of the three replications. Data was subjected to analysis of variance (ANOVA) using the generalized linear model (GLM) procedure of statistical analysis software (SAS 2003). Duncan's multiple range test was used to separate the means and differences at $p<0.05$ were considered to be significant.

RESULTS AND DISCUSSION

The lycopene content of the raw tomatoes were analyzed in all eight cultivars. The lycopene content ranged from 70.25 to 147.29 µg/g on a fresh weight basis (**Table 1**). This is comparable to values reported for fresh tomatoes (20.4 to 141 µg/g FW) by George *et al*. (2004) and (25 to 2000 µg/g FW) by Takeoka *et al.* (2001); but lower than values (3110 to 6700 µg/g FW) reported by Dewanto *et al*. (2002), and (3310 µg/g FW) reported by Mayeaux *et al*. (2006). 'Leader' had the highest lycopene content (147.29 µg/g) and 'Lindo' had the lowest (70.25 µg/g). Significant differences ($p<0.05$) in the lycopene content in the raw samples were observed among the eight cultivars studied. The variation in the lycopene content of tomatoes obtained from different parts of the world is probably due to the differences in their growing conditions, the cultivar and the ripening stage of tomatoes. These factors could account for the variation in the lycopene levels reported in different studies (Thompson *et al*. 2000; Takeoka *et al*. 2001). Average Canadian daily dietary intake of lycopene is about 25.2 mg. 50% of this lycopene is from fresh tomatoes and the remaining 50% is from various processed tomato products (Rao *et al.* 1998). From this study, the 8 cultivars can be said to have high amounts of lycopene. **Table 2** shows the percentage loss of lycopene content. The percentage loss of lycopene content at 1 h thermal treatment ranged from 13.58 to 42.99%. 'Leader' lost 42.99% of its lycopene content while 'Lindo' lost 13.58%. Values obtained for 2 and 3 h heating were similar, ranging from 24.66 to 85.30%. A significant difference ($p<0.05$) was observed in the lycopene content during 2 and 3 h thermal treatment for most of the cultivars studied except for 'NH158', 'Small local' and 'Lindo'. Longer heating, as was the case of 3 h thermal treatment, further reduced the level of lycopene in most cultivars, except for '3-lobed' and 'Leader' which showed some level of stability since the percentage loss was not very significant. This study shows that heat facilitates reduction of lycopene content and the main cause of lycopene degradation is the oxidation of lycopene by light and heat. This is in agreement with the report of Shi *et al.* (2003) on the effects of light exposure and heat on the stability of lycopene. Heat processing increases the bioavailability of lycopene by breaking cell walls and allowing extraction of the lycopene from the chromoplasts, where it is found in raw tomatoes (Stahl and Sies 1996). Ingestion of 23 mg of lycopene from tomato paste increased serum lycopene levels by 2.5-fold (Gartner *et al.* 1997) but the same amount of lycopene,

Table 2 Percentage (%) loss of lycopene content in cooked tomato varieties as compared with raw samples.

Varieties	Raw	After 1 h	After 2 h	After 3 h
NH 158	91.67 ± 0.56	20.78	43.72	44.05
3 Lobed	75.01 ± 1.24	32.05	33.60	34.40
Ronita	83.69 ± 1.30	42.16	81.72	85.30
Small local	79.77 ± 0.98	34.83	74.25	75.57
Leader	147.29 ± 0.94	42.99	47.74	49.62
Lindo	70.25 ± 0.96	13.58	50.85	51.99
Big local	100.41 ± 0.72	29.24	63.64	69.56
Cherry	90.09 ± 1.10	22.02	24.66	42.88

Table 3 Chemical and biochemical properties of lycopene and β-carotene.

	Lycopene	β-Carotene	Reference
Number of fully conjugated double bonds	11	9	Mayeaux *et al*. 2006
Antioxidant activities			
Singlet oxygen quenching *Kq* (M^{-1} s^{-1})	17×10^9	13×10^9	Basu and Imrhan 2007
Radical scavenging (Trolox equivalents)	2.9	1.9	Bohm *et al*. 2002
Reaction of carotenoid radical anions with O_2 ; *k* (M^{-1} s^{-1})	2×10^8	25×10^8	Canene-Adams *et al*. 2005
Biological activities			
Induction of gap junctional communication	++	++++	Vine and Bertram 2006
Growth inhibition of chemically transformed cells	+	++++	Liu *et al*. 2006
Suppression of cell proliferation (MCF-7)	++++	++	Karas *et al*. 2000
Provitamin A activity	-	+++	Tapiero *et al*. 2004

- = absence of activity; + = presence of activity; ++ = activity is twice as high; +++ = activity is three times as high; ++++ = activity is four times as high

when provided in the form of fresh tomatoes, failed to increase the serum lycopene suggesting that lycopene from fresh tomatoes is not readily bioavailable. Because of the high number of double bonds, carotenoids can undergo *trans*- to *cis*-isomerization if exposed to light within their absorption range. Thermal energy or chemical reactions can also induce inter-conversion (Gerster 1997). Moreover, lycopene in raw tomatoes is present mainly in *trans*-isomeric form. Heat processing of tomato juice was shown to enhance its isomerization to *cis*-isomers and thereby making it more bioavailable (Stahl and Sies 1992). In this study, the reduction in the lycopene content at 1, 2 and 3 h thermal processing ranged from 48.41-78.97, 15.30-76.97 and 12.30-74.21 μg/g, respectively. Though the effect of thermal heat reduced the lycopene content, since the availability of lycopene is increased during heat processing, levels obtained from this study can still meet the recommended daily intake for lycopene.

Health benefits of lycopene

Several epidemiological studies have indicated a beneficial effect of tomato consumption in the prevention of some major chronic diseases, such as some types of cancer and cardiovascular disease (Sesso *et al*. 2003; Benner *et al*. 2007). One of the major phytochemicals in tomato products contributing to the prevention of cancer is lycopene (Frohlich *et al*. 2006). Lycopene is beneficial for human health, and processing of tomatoes enhances the bioavailability of lycopene (Shi and Le Maguer 2000).

Table 3 shows the relationship between lycopene and a well known carotenoid provitamin A (β-carotene). Lycopene has been reported to quench singlet oxygen twice as good as beta-carotene and it is one of the most potent antioxidants of the carotenoids (Basu and Imrhan 2007). In addition to its antioxidant properties (Bohm *et al*. 2002; Porrini *et al*. 2005), reports from epidemiological studies, studies in animals and cell-culture experiments have suggested that lycopene has anticarcinogenic properties (Tang *et al*. 2005). lycopene has been shown to induce cell–cell gap junctional communication (Vine and Bertram 2005), inhibit tumor cell proliferation (Mossine *et al*. 2008) and repress insulin- like growth factor receptor activation (Karas *et al*. 2000).

Lycopene has shown distinct antioxidant and anticarcinogenic effects at cellular levels, and definitely contributes to the health benefits of consumption of tomato products. Consumption of naturally occurring carotenoid-rich fruits and vegetables, particularly processed tomato products containing lycopene, should be encouraged, with positive implications in health and disease.

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