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

Ademoyegun Olufemi Temitope¹ • Akin-Idowu Pamela Eloho²•² • Ibitoye Dorcas Olubunmi³

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 phytoneutrant and a potent antioxidiant; 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 C₄₀H₅₆, 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 lead 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. 2000). 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 bio-availability 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-
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, Ibi-Ishin, Ibadan. The cultivars were planted in three replicates using a Randomized Complete Block Design. The fruits were analyzed at maturity for lycopene content. The lycopene content was determined according to the method of Sadler et al. (1990). The samples of raw and heated tomato were prepared in triplicate from each of the three replications. Data was subjected to analysis of variance (ANOVA) using the generalized linear model (GLM) procedure of 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 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 (Stuhl 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, was added followed by another 5 min of agitation. The solution 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 distinct polar and non-polar layer in a separatory funnel and the polar phase was carefully drawn out. The organic layer was separated into a distinct polar and non-polar layer in a separatory funnel and the polar phase was carefully drawn out. The organic layer was separated into a distinct polar and non-polar layer in a separatory funnel and the polar phase was carefully drawn out.

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Raw</th>
<th>After 1 h</th>
<th>After 2 h</th>
<th>After 3 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH 158</td>
<td>91.67 ± 0.56 c</td>
<td>72.62 ± 1.12 a</td>
<td>51.59 ± 1.45 b</td>
<td>51.29 ± 1.17 b</td>
</tr>
<tr>
<td>3 Lobed</td>
<td>75.01 ± 1.24 f</td>
<td>50.16 ± 1.02 a</td>
<td>49.81 ± 1.60 a</td>
<td>49.21 ± 1.19 b</td>
</tr>
<tr>
<td>Ronita</td>
<td>83.69 ± 1.30 d</td>
<td>48.41 ± 1.10 a</td>
<td>15.30 ± 1.10 b</td>
<td>12.30 ± 0.89 c</td>
</tr>
<tr>
<td>Small local</td>
<td>79.77 ± 0.98 e</td>
<td>51.99 ± 1.77 a</td>
<td>20.54 ± 1.28 b</td>
<td>19.49 ± 1.37 b</td>
</tr>
<tr>
<td>Leader</td>
<td>147.29 ± 0.94 a</td>
<td>78.97 ± 1.78 a</td>
<td>76.97 ± 1.81 a</td>
<td>74.21 ± 1.07 b</td>
</tr>
<tr>
<td>Lindo</td>
<td>70.25 ± 0.96 g</td>
<td>60.71 ± 1.20 a</td>
<td>34.53 ± 1.39 bc</td>
<td>33.73 ± 1.13 c</td>
</tr>
<tr>
<td>Big local</td>
<td>100.41 ± 0.72 b</td>
<td>71.05 ± 0.56 a</td>
<td>36.51 ± 0.90 b</td>
<td>30.57 ± 1.29 c</td>
</tr>
<tr>
<td>Cherry</td>
<td>90.09 ± 1.10 c</td>
<td>70.25 ± 1.13 a</td>
<td>67.87 ± 0.90 b</td>
<td>51.46 ± 0.82 c</td>
</tr>
<tr>
<td>Mean</td>
<td>92.27</td>
<td>62.96</td>
<td>44.14</td>
<td>40.28</td>
</tr>
<tr>
<td>Range</td>
<td>70.25-147.29</td>
<td>48.11-78.97</td>
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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.

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

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<td>Ronita</td>
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<td>42.16</td>
<td>81.72</td>
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**Antioxidant activities**

- Singlet oxygen quenching $K_q (M^{-1} s^{-1})$: $17 \times 10^5$ (Bohm et al. 2006) Basu and Imrhan 2007
- Radical scavenging (Troxol equivalents): 2.9 (Bohm et al. 2002)
- Reaction of carotenoid radical anions with $O_2$: $2 \times 10^8$ (Canene-Adams et al. 2005)

**Biological activities**

- Induction of gap junctional communication: $++++$ (Vine and Bertram 2006)
- Suppression of cell proliferation (MCF-7): $++++$ (Karas et al. 2000)
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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 well known carotenoid provitamin A (β-carotene). Lycopene interferes with cell cycle progression and insulin-like growth factor I signaling in mammary cancer cells. Nutrition and Cancer 36, 101-111


Mayeaux M, Xu Z, King JM, Prinyawiwatkul W (2003a) Rapid extraction of lycopene and β-carotene from reconstituted tomato paste and pink grapefruit homogenate. Journal of Agricultural and Food Chemistry 51, 45-51


Sadler G, Davis J, Dezman D (1990) Rapid extraction of lycopene and β-carotene from reconstituted tomato paste and pink grapefruit homogenate. Journal of Food Science 55, 1460-1461


Shi J, Le Maguer M (2000) Lycopene in tomatoes: chemical and physical pro-
properties affected by food processing. Critical Reviews in Food Science and Nutrition 40, 1-42
Stahl W, Sies H (1992) Uptake of lycopene and its geometric isomers is greater from heat-processed than from unprocessed tomato juice in humans. Journal of Nutrition 122, 2161-2166
Vine AL, Bertram JS (2005) Upregulation of connexin 43 by retinoids but not by non-provitamin A carotenoids requires RARs. Nutrition and Cancer 52, 105-113