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Lemon Juice Enhances Antioxidant Nutritional Quality of Tomato (*Solanum lycopersicon*)

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Abstract

The tomato plant is economically important and nutritionally beneficial to man. It is perishable in nature and preserved traditionally using lemon juice. The effects of this practice on antioxidant nutrients of this global vegetable food crop were investigated in this study. Tomatoes were preserved in four jars labelled 1 to 4. Jar 1 contained peeled, ground tomatoes (PG) and peeled non-ground tomatoes (PNG) without lemon juice. Jar 2 contained peeled, ground tomatoes and peeled non-ground with lemon juice (PG+LJ and PNG+LJ). Jar 3 contained unpeeled, ground tomatoes (UPG) and unpeeled non-ground (UPNG) samples while jar 4 contained unpeeled, ground and unpeeled non-ground samples with lemon juice (UPG+LJ and UPNG +LJ). The samples were analyzed for their antioxidant contents. Results revealed that concentration of ascorbic acid in tomato samples preserved with lemon juice varied from 14.70 – 20.30mg/100g FW. The values were significantly different ($p<0.05$) from the controls (PG, UPG, UPNG and PNG). The total phenolics content of lemon juice preserved tomatoes were also significantly different ($p<0.05$) from the control samples with UPNG+LJ having the highest phenolics content of 12.90mg/100g. The value of flavonoids ranged from 1.51 (PNG) to 2.95mg/100g (UPG+LJ) while β-Carotene was from 1.78mg/100g (PNG+LJ) to 4.68mg/100g (PG+LJ). The unpeeled samples generally had higher antioxidant nutrients in comparison with the peeled samples. This study is relevant to the tomato canning industry and suggests that the use of lemon juice as tomato preservative agent should be encouraged.

Keywords: Preservation; lemon juice; antioxidant nutrients, peeling; tomato

1. Introduction

Tomato (*Solanum lycopersicon*) is one of the most popular and extensively consumed vegetable crops worldwide. It is a major source of antioxidants contributing to the daily intake of a significant amount of these molecules (Emmanuelle *et al*., 2005: Kotkov et al., 2011). These compounds (Table 1) play important roles in inhibiting reactive oxygen species responsible for many chronic degenerative diseases such as certain types of cancer and cardiovascular diseases, through free-radical scavenging, metal chelation, inhibition of cellular proliferation, and modulation of enzymatic activity and signal transduction pathways (Luigi *et al*., 2007). The beneficial effects of tomato consumption are generally attributed to carotenoids, which are able to reduce the risk of certain types of cancer, arteriosclerosis and cataract formation (Miguel *et al*., 2006; Canene-Adams et al., 2007).

Tomatoes are highly perishable; it has been found that 20-30% tomatoes end up spoiled due to improper handling and storage conditions (Takeoka *et al*., 2001). The fruit may or may not be peeled, but stems and calices should be removed. With the increase in tomato production, more emphasis should be made on their extensive use as well as processing and preservation thereby ensuring better storage during the season of availability for better utilization during the off season. Because of the unique flavour and richness in nutrition value, tomatoes have great potential for being processed into products like juice, chutney, ketchup and soup (Wilhelm *et al*., 2001). Tomatoes can be preserved by canning, drying, freezing, or pickling. Raw tomatoes or raw tomato products can be kept refrigerated, but will spoil over time due to bacteria, yeasts, and molds. Traditionally, tomato is mostly preserved by drying and addition of lemon juice (William and Dennis, 2004; Amarowicz et al., 2009). Drying is done locally by spreading of tomato fruits under the sun to remove the water content. This method is popular in northern Nigeria where there is higher temperature; this is because tomato needs higher temperature to remove the water content (Etim, 1984).

Addition of lemon juice to tomato before preservation is common in Africa (William and Dennis, 2004). Tomatoes are often considered to be acidic, but their pH can vary significantly depending on their degree of ripeness and genotype. In general, the more ripe the tomato, the higher is the pH. Lemon juice increases the acidity of tomato thereby preventing the growth of micro-organisms. The aim of this study was to examine the effects of this practice on antioxidant nutritional quality of the tomato food crop.

2. Materials and Methods

Plant Material: Healthy orange – red ripe tomato fruits and fresh lemon (*Citrus limon*) fruits were purchased at Sasa market, Ibadan, Nigeria.

Preservation Procedure: Tomatoes of the same size and shape were selected and washed with distilled water. The lemon fruit were also washed with distilled water and cut into two pieces each, squeezed to remove the

juice, which was sieved to obtain clean juice. The washed tomatoes were divided into four groups as follows:-
Group1: Peeled Ground (PG); Peeled Not Ground (PNG)
Group 2: Unpeel Ground (UPG); Unpeel Not Ground (UPNG)
Group 3: Peeled Not Ground + Lemon Juice (PNG + LJ); Peeled Ground + Lemon Juice (PG+ LJ)
Group 4: Unpeel Ground + Lemon Juice (UPG + LJ); Unpeel Not Ground + Lemon Juice (UPNG + LJ).

Treatment of peeled tomatoes: The washed tomatoes were dipped into hot water at 60-70^{o}c for 30 seconds, then they were taken out as quickly as possible. They were then plunged immediately into cold water for 10minutes, to loosen the skin. The tomatoes were completely peeled. The peeled tomatoes were filled into two clean 1 litre jars which are free of cracks and chips. Some of the peeled tomatoes were homogenized, then added to fill up the two jars leaving about 1cm of air underneath the lid. 10mls of lemon juice was added to one of the jars. The jars were closed tightly and sterilized at 60^{o}c for 45minutes. The treatment was replicated thrice and jars with contents were kept at ambient temperature for twenty eight days.

Treatment of Unpeeled Tomatoes: The washed tomatoes were filled into two clean 1litre jars. 10ml of lemon juice was added to one of the jar. Some of the peeled tomatoes were homogenized and added to fill up the two jars leaving about 1cm of air underneath the lid. This was replicated thrice and the jars were then closed tightly and sterilized as described above.

Determination of Ascorbic Acid: Ascorbic acid content of preserved tomato extracts were determined by the method of Klein and Perry (1982). About 1g of preserved tomato samples was homogenized. The homogenate were added to 15ml of 0.1ml/L potassium phosphate buffer (pH 7.4) and stirred gently at 4^{o}c for 1hr. The extract was centrifuged at 3000 x 9 at 4^{o}c for 15minutes.1ml of supernatant was added to 9ml of 0.05mol/L DPIP and allowed to mix for 15s. The absorbance at 515nm was measured on Spectrumlab 23A spectrophotometer using 20ml/L M-phosphoric acid as a blank.

Determination of Lycopene: Lycopene content of tomato extract was determined by a modified colorimetric method proposed by Rao *et al,* (1998). 6ml aliquot of the extract was added to test tubes, after which 8mls of hexane/methanol/acetone (2:1:1:v/v) was added for 1hour. Then syringe and needle was used to remove the extract. The absorbance of the extract was measured at 502nm against a blank (extraction solvent) using a spectrum lab 23A spectrophotometer.

Determination of β-carotene: β-carotene was determined according to the method of Bayfield (1971). 1g of samples were homogenized and then hydrolyzed with 15ml of 5% alcoholic KOH in boiling tubes for 20 minutes at 60^{o}c in a water bath. The tubes were cooled and the content of each tube was extracted with 40ml of petroleum ether by shaking vigorously. The upper petroleum ether layer was carefully collected into a small beaker by syringe and needle. The final oily residue was then added to 5ml chloroform. The absorbance of the sample extracts were measured spectrophotometrically at wavelength 440nm with chloroform as blank.

Determination of Total Phenolics: The method of Zhishen *et al*; 1999 was used. Aliquots (1ml) of the extracts was diluted fivefold (v/v) with distilled water, after which 2.5ml of freshly diluted 0.2ml/L Folin-Ciocalteu reagent was added. This was followed by addition of 2ml, 75g/L sodium carbonate, and then samples were vortexed for 20s. Samples were then allow to cool after which absorbance was read at 765nm using spectrum lab 23A spectrophotometer.

Determination of Total Flavonoids: This was determined by a modified colorimetric method described by Zhishen *et al,* (1999). 1ml aliquot of the extract was added to a 25ml volumetric flask. The volume was made up to 5ml with distilled water, 0.3ml of 50g/L sodium nitrite was added and the flask was allowed to stand for 5minutes. Then 0.6ml of 100g/L aluminum chloride was added. After 6 minutes of mixing, 2ml of 1mol/L sodium hydroxide was added, followed by 2.1ml of distilled water. The absorbance at 510nm was read against a blank (water).

Statistical Analysis

Data were statistically analyzed by analysis of variance (ANOVA) using Statistica package, version 7.1, Statsoft Inc. The results were presented as mean $\pm$ SE; significant difference ($p<0.05$) between means were determined by Duncan's multiple range test.

3. Results and Discussion

The results of analysis of preserved tomato in this study revealed that the tomato samples are excellent sources of antioxidants. In comparison with reported values in the literature (Table 1), β-carotene and phenolics contents were relatively higher while lycopene, flavonoids and vitamin c (ascorbic acid) contents were within similar range.

The concentration of ascorbic acid, total phenolics and total flavonoids in the preserved tomatoes are shown in Table 2. Ascorbic acid (vitamin C) was the most abundant antioxidant in all the samples with a concentration range of 14.70 to 20.30mg/100g FW^{b}. The values of those preserved with lemon juice were significantly different ($p<0.05$) from the control (PG, UPG, UPNG and PNG). Vitamin C chelates heavy metal ions, reacts

with singlet oxygen and other free radicals, and suppresses peroxidation, reducing the risk of arteriosclerosis, cardiovascular diseases and some forms of cancer (Howard et al., 2000). Preservation of ascorbic acid content during storage is usually difficult because it undergoes oxidation (Campbell et al., 2004). The observed higher value of ascorbic acid in the peeled ground samples: PG (18.10mg/100gFW^{b}); PG + LJ (19.80mg/100gFW^{b}) when compared to the peeled non-ground samples: PNG (14.70 mg/100gFW^{b}); PNG + LJ (17.20 mg/100gFW^{b}) respectively, may be due to the fact that the L-dehydroascorbate which is oxidized form of ascorbic acid present in the latter might have been reduced to the active L-ascorbate in the former.

There was a significant difference ($p<0.05$) in the concentration of total phenolics of the preserved tomatoes, relative to control. Generally, the unpeeled samples had higher phenolics content in comparison with the peeled samples. UPNG + LJ gave the highest total phenolics concentration (12.90mg/100g) while the least value was obtained in PG (4.62mg/100g). Processing (peeling and grinding) might have resulted in the observed difference and this is an indication that phenolics are present in large concentration in the skin of tomato. Phenolic compounds have been associated with the inhibition of atherosclerosis and cancer due to their ability to chelate metals, inhibit lipid peroxidation and scavenge free radicals (Borguini and Torres, 2009).

The total flavonoids concentration varied from 1.51mg/100g (PNG) to 2.95mg/100g (UPG+LJ). There was a significant difference ($p<0.05$) between unpeeled samples (UPNG, UPG, UPNG + LJ and UPG + LJ) and peeled samples (PNG, PG, PG + LJ and PNG + LJ). This is in agreement with the observation of Dewanto et al., 2002 that there was no significant difference ($p>0.05$) in the total flavonoid content of processed tomatoes.

The results for β-Carotene and lycopene showed no significant difference ($p>0.05$) in all samples of tomato analyzed (Table 3). PG+LJ gave the highest β-Carotene concentration of 4.68mg/100g while UPG gave the highest lycopene content of 11.03mg/100g. However, PNG+LJ gave the least β-Carotene and lycopene concentration of 1.78mg/100g and 8.42mg/100g respectively. Lycopene is a carotenoid compound wildly present in tomato and it is the pigment principally responsible for the characteristic deep-red colour of ripe tomato fruits and tomato products (Shi and Le Maguer, 2000). The β – carotene values obtained in this study were higher than the literature values. In previous studies on organic tomatoes, no strong positive correlation was observed in β-carotene and lycopene contents, as different results including higher levels (Caris-Veyrat *et al*., 2004) and lower levels (Rossi *et al*., 2008) have been reported.

4. Conclusion

Antioxidants play a major role in determining tomato fruit nutritional quality. This study show that the use of lemon juice to increase the shelf life of tomato enhanced the antioxidant nutritional quality and that unpeeled samples have higher antioxidant nutrients than the peeled samples.

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Table 1: Literature concentration range and optional concentration of different antioxidant components in tomato

Antioxidant	Literature Concentration Range	Optimal Concentration mg/100g FW[b]
Lycopene	1.86 – 14.62	10.63
β-carotene	0.11 – 1.07	0.57
Phenolic acids	2.75 – 4.68	5.36
Flavonoids	1.15 – 8.16	5.02
Vitamin C	2.20 - 21	13.7

b =fresh weight
Source: Luigi *et al.*, 2007

Table 2: Ascorbic acid, total phenolics and total flavonoids content of preserved tomatoes.

Tomato samples	Ascorbic Acid mg/100gFW[b]	Total Phenolics mg/100gFW[b]	Total flavonoids mg/100gFW[b]
PNG	14.70 ± 0.77	6.96 ± 0.31	1.51 ± 0.29
PNG +LJ	17.20 ± 0.37	7.82 ± 0.23	1.99 ± 0.004
PG	18.10 ± 0.43	4.62 ± 0.21	1.67 ± 0. 21
PG + LJ	19.80 ± 0.41	8.68 ± 0.41	1.95 ± 0.002
UPG	17.90 ± 0.29	9.60 ± 0.24	2.76 ± 0.15
UPG +LJ	19.60 ± 0.66	11.60 ±0.86	2.95 ± 0.005*
UPNG	18.60 ± 0.43	10.16 ± 1.29	2.72 ± 0.33
UPNG + LJ	20.30 ± 0.41*	12.90 ±1.26*	2.91 ± 0.007

a = values are mean ± SE, b =fresh weight, * = Significantly different from other values in the column ($p<0.05$), PNG = Peeled tomato Not Ground, PNG + LJ = Peeled tomato Not Ground + Lemon Juice, PG = Peeled tomato Ground, PG +LJ = Peeled tomato Ground + Lemon Juice, UPG = Unpeel tomato Ground, UPG + LJ = Unpeel tomato Ground + Lemon Juice, UPNG = Unpeel tomato Not Ground, UPNG + LJ = Unpeel tomato Not Ground + Lemon Juice

Table 3: β-carotene and lycopene content of preserved tomatoes

Tomato samples	β-carotene mg/100gFW[b]	Lycopene mg/100gFW[b]
PNG	2.88 ±1.08	9.23 ± 2.49
PNG +LJ	1.78 ± 0.05	8.42 ± 2.62
PG	2.82 ± 1.30	9.50 ± 3.10
PG + LJ	4.68 ± 0.34*	8.74 ± 3.14
UPG	2.26 ± 108	11.03 ± 4.11*
UPG + LJ	3.48 ± 0.17	9.80 ± 4.37
UPNG	2.80 ± 1.31	10.79 ± 4.13
UPNG + LJ	3.98 ± 0.21	10.86 ± 4.11

a = values are mean ± SE, b =fresh weight, * = Significantly different from other values in the column ($p<0.05$), PNG = Peeled tomato Not Ground, PNG + LJ = Peeled tomato Not Ground + Lemon Juice, PG = Peeled tomato Ground, PG +LJ = Peeled tomato Ground + Lemon Juice, UPG = Unpeel tomato Ground, UPG + LJ = Unpeel tomato Ground + Lemon Juice, UPNG = Unpeel tomato Not Ground, UPNG + LJ = Unpeel tomato Not Ground + Lemon Juice