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Carotenoid accumulation pattern and nutritional indices of Cherry-*Nasmata* and *Var-10* tomato varieties

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Abstract

Tomato is one of the main sources of dietary lycopene intake in humans and its intake in high proportions could therefore be a cheap and easy way of preventing degenerative diseases in developing countries. The present work studies the accumulation pattern of lycopene and beta-carotene as well as the variation of the biochemical and physiological characteristics in Cherry-*Nasmata* and *Var-10* tomato cultivars. Total solid contents range from 5.82 to 7.37% for Cherry-*Nasmata* cultivar and 6.00 to 10.84% for *Var-10* tomatoes. The higher solid contents in *Var-10* tomatoes are desirable for longer shelf life of the fruits. The pH values of the two tomato varieties vary between 3.67 and 4.21 except in the postharvest ripened Cherry-*Nasmata* tomatoes with values above 4.5, rendering the latter unsuitable for tomato processing. Titratable acidity is higher (0.16 - 0.43%) in Cherry-*Nasmata* ripened on the field than those subjected to postharvest ripening while a lower range (0.23 - 0.26%) was obtained for *Var-10* tomatoes. Reducing sugar contents in Cherry-*Nasmata* (1.44 - 3.73 per 100 g) is lower compared to that in *Var-10* (2.40 - 4.65 per 100 g). The sourness and sweetness indices (pH, titratable acidity and reducing sugar content) differ significantly ($p<0.05$) when the tomatoes were ripened under field and postharvest conditions. The maximum concentrations of lycopene (antioxidant index) of 9.42 and 6.68 µg/g were obtained at the Light-red and fully red stages of Cherry-*Nasmata* and *Var-10* tomato cultivars respectively under field ripening condition. The pro-vitamin A index (beta-carotene) contents range between 0.86 and 4.09 µg/g in Cherry-*Nasmata* while a lower range (0.63 to 2.07 µg/g) was obtained for *Var-10* tomatoes. The quantity of tomatoes to be consumed locally in order to meet the daily recommendation of 25.2 mg of lycopene in the diet is prescribed.

Introduction

The increased incidence in degenerative diseases such as cancer, cardiovascular disease and diabetes in developing countries, including Nigeria, has been of great concern. These health problems could however be prevented by the consumption of fruits and vegetables (Ganry, 2013) that are high in carotenoids, such as lycopene and beta-carotene. Tomato is a crop that constitutes an important part of human daily diet and is one of the most widely grown and economically important vegetable crops all over the world including South-western and Northern parts of Nigeria. Tomato *(Lycopersicon esculentum)* is a good source of antioxidants (Wang *et al*., 1996) with some of its phytonutrients identified to prevent illnesses by detoxification (Wang *et al*., 1996; Nguyen and Schwartz, 1999), promoting growth and for proper immune functioning (Shi and LeMaguer, 2000). Tomatoes have recently been identified to prevent adverse effects of lead of blood constituents (Salawu, 2010) and this may prove useful in combating the incidences of lead poisoning in Zamfara State of Nigeria. The beneficial effect of tomatoes is believed to be due to the action of antioxidant compounds such as carotenoids, ascorbic acid, tocopherols, and polyphenols, which reduce oxidative damage in the body (Giovannucci, 1999; Prior and Cao, 2000; Wargovich, 2000; Grassmann *et al*., 2002).

The consumption of tomato is believed to benefit the heart among other organs as they contain lycopene, which is one of the most powerful natural antioxidants. Lycopene has been associated with the prevention of prostate, head and neck cancers and might be strongly protective against neurodegenerative diseases (Rao and Balanchandran, 2002; Freedman *et al*., 2008; Zhang *et al*., 2009). Regular tomato consumption has been reported to be associated with decrease in the incidence of chronic degenerative diseases such as certain types of cancer and cardiovascular diseases (Giovannucci, 1999). These beneficial effects of tomato consumption

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are generally attributed to carotenoids, which are able to reduce the risk of certain types of cancer, arteriosclerosis and cataract formation (Frusciante *et al*., 2007). The two main carotenoids present in tomato are lycopene, major carotenoid (80 - 90%) that impacts the red colour to the fruit, and beta-carotene (Nguyen and Schwartz, 1999).

Since tomato is highly consumed today, it is certain that the demand will sky rocket later in future. However, tomato varieties are differentiated based on their antioxidant contents (Langlois *et al*., 1996). Factors that influence the overall antioxidant benefit of tomatoes; genetic variety, growing conditions, ripening techniques as well as harvest stages, have been studied extensively (Davies and Hobson, 1981; Leonardi *et al*., 2000; Tigist *et al*., 2013). However, there have been little or no information on the accumulation pattern of lycopene and beta-carotene in different tomato cultivars commonly grown in Nigeria as well as their nutritional indices.

The aim of this research work was to compare the accumulation pattern of lycopene and beta-carotene as well as the variation of the biochemical and physiological characteristics in Cherry-*Nasmata* and *Var-10* cultivars of tomato fruits locally bred in Nigeria under field and ambient temperature conditions of ripening.

Materials and Methods

Sample preparation

Seeds of two tomato cultivars (Cherry-*Nasmata* and *Var-10*) were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria and were planted on an open organic farmyard (without fertilizer application) in Ogbomoso, Nigeria between June and September rainy season, 2013. The fruits were identified at National Horticultural Institute (NIHORT), Ibadan, Nigeria. The tomatoes were independently and randomly selected, picked and packed into opaque polythene bags to prevent light irradiation and then taken into the laboratory where they were rinsed with some doubly distilled water and left to drain for some minutes. Tomatoes subjected to postharvest ripening were harvested at the breaker stages and ripened under ambient temperature. Individual tomatoes were cut into small pieces with knife and 500 g of the tomato pieces were homogenized.

Determination of titratable acidity, pH, total solid and reducing sugar contents of tomatoes

The titratable acidity, TA (expressed as % citric acid) was determined by the titration of the homogenized tomato sample with 0.01 N NaOH using phenolphthalein indicator (AOAC. 1990). The pH was determined in 30 g samples of tomato serum with a digital pH-meter. The total solid content (TS) was determined by drying 3 g of tomato in an oven at 105^0C for 3 hours (AOAC. 1990). The reducing sugar content was determined as previously described (Johnson *et al.*, 1966).

Extraction and quantification of lycopene and beta-carotene

Conventional solvent extraction method (Perkins-Veazie *et al*., 2001) was employed for carotenoid extraction. Lycopene and beta-carotene from the tomato fruits were extracted with hexane, methanol and acetone (2:1:1) containing 2.5% butylated hydroxytoluene (BHT). The extract was treated with doubly distilled water, methanol and 20% KOH/ methanol (1:1:1) to saponify any triglyceride present. The extract was then washed with doubly distilled water and re-dissolved in hexane. The absorbances of the hexane extracts were measured at 450 and 502 nm using Genesys 10S V1.200 spectrophotometer (Buck Scientific, USA). The lycopene and beta-carotene concentrations were determined from the values of the absorbances at 450 and 502 nm using previously reported protocol (Fish, 2012; Abdul-Hammed *et al*., 2013).

Data analysis

The values presented are means of 3 measurements ± Standard deviation (SD) on fresh weight basis. The significant differences between the mean values were analyzed using GraphPad QuickCalcs Software (from GraphPad Software Inc., USA) by employing the use of student's t-test.

Results and Discussion

Tomatoes, the nutritious fruits commonly used as vegetables, have grabbed the attention of millions of health seekers, due to its thrilled phytochemical nutrients. Tomatoes qualities and appearance change during post-harvest handling as a result of continuous respiration process in the fruit, even after harvest (Žnidarčič and Požrl, 2006). The tomatoes ripened at ambient temperature here were harvested at the breaker stages rather than at the more common mature green stages among some Nigerian farmers and as practised by staked fresh-market tomato farmers in eastern United States (Davis and Gardner, 1994).

The variation of the total solid contents in Cherry-*Nasmata* and *Var-10* tomato cultivars are as shown in Figure 1. For field ripening, the solid contents range

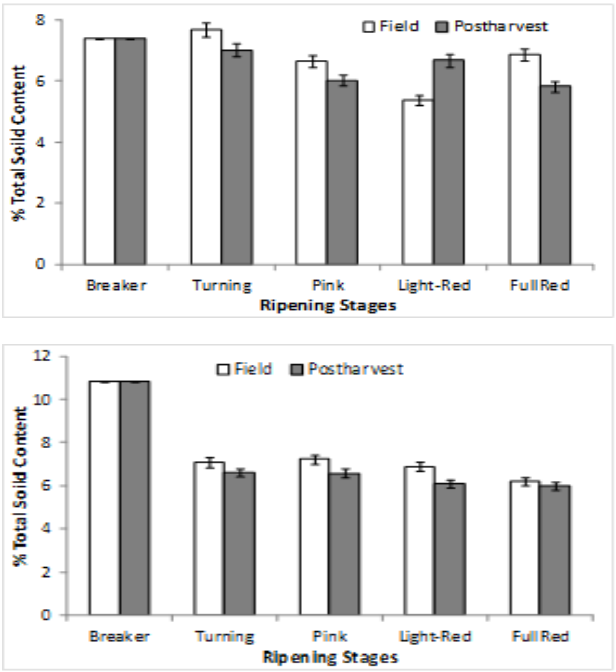

Figure 1. Total solid contents of (A) Cherry-*Nasmata* and (B) *Var-10* tomato cultivars at different ripening stages under the field and post-harvest ripening conditions. Significant differences between the mean values are indicated with NS (not significant), *(significant at $p<0.05$) and ** (significant at $p<0.01$).

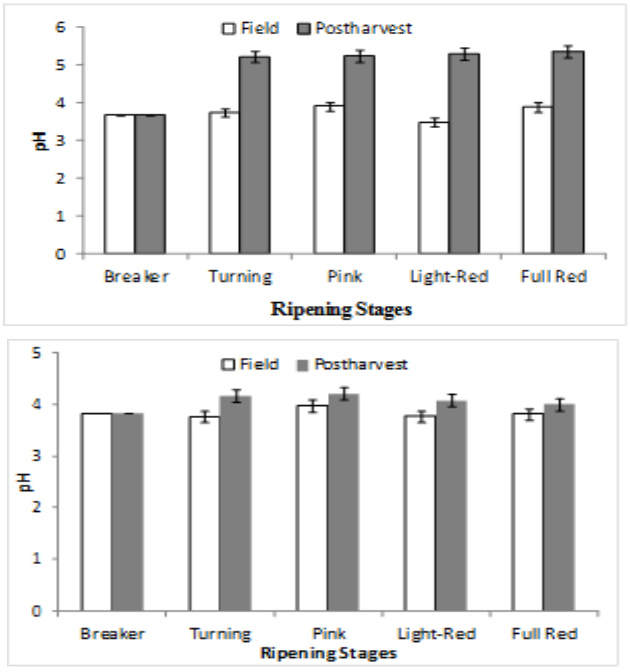

Figure 2. Variation of fruits pH of (A) Cherry-*Nasmata* and (B) *Var-10* tomato cultivars at different ripening stages under the field and post-harvest ripening conditions. Significant differences between the mean values are indicated as in Figure 1

from 5.39 to 7.67% and 6.20 and 10.84% for Cherry-*Nasmata* and *Var-10* tomato cultivars respectively, while the respective ranges of 5.82 to 7.37% and 6.00 to 10.84% were observed for the two cultivars at ambient temperature ripening. The solid contents are lower at light red and full red than at other ripening stages in both cultivars. Except at light red stage of Cherry-*Nasmata* tomatoes, the values of solid contents are higher at field ripening than at ambient temperature ripening. The mean difference between the solid contents in both cultivars obtained under the two ripening techniques are moderately significant ($p<0.05$) at turning and pink stages and extremely significant ($p<0.01$) at other stages except at fully red stage of *Var-10* cultivar. In tomato paste production, solid contents are indications of fruit quality and yield factor, as breeders seek tomato varieties with higher solid contents. The decreasing trends of solid contents from breaker stage to the full ripe stage between the field ripened and ambient temperature ripened tomatoes were in contradiction with the trend when tomatoes were harvested at mature green stages and ripened at ambient temperature (Abdul-Hammed *et al*., 2009; Tigist *et al*., 2013). This confirms previous findings with big-local and 3-lobes tomatoes harvested at breaker stages and subject to post-harvest ripening (Abdul-Hammed *et al*., 2012). Therefore, if it is desired to subject tomatoes to post-harvest handling, harvesting at mature green stages will be better than at breaker stages, in order to maintain the durability and longer shelf life of processed tomato products.

Titratable acidity and pH are two important qualities attributes of processing tomatoes. Figure 2 show how the pH of the tomatoes vary with ripening stages under the two ripening techniques. The pH values are in the range of 3.49 to 3.91 and 3.67 to 5.35 in Cherry-*Nasmata* cultivar for field and ambient temperature ripening respectively while the values range from 3.76 to 3.91 and from 3.83 to 4.21 in *Var-10* tomato cultivars for the two techniques respectively. The pH values are lowest at breaker stage and an increasing pH trends were observed in both cultivars. This is in agreement with previous report (Mohammed *et al*., 1999) but contrary to other reports (Abdul-Hammed *et al*., 2009; 2012). The mean pH differences between the two ripening techniques are extremely significant ($p<0.01$) for all ripening stages in Cherry-*Nasmata* cultivar, moderately significant ($p<0.05$) at turning and light red stages in *Var-10* cultivar but not significant at pink and fully red stages of *Var-10* cultivar. In general, tomato products are classified as acidic foods ($pH<4.6$) with the pH below 4.5 being important as a desirable trait. Under these conditions the development of microorganisms harmful to the conservation of the processed products is inhibited (Tigchelaar, 1986; da Silva *et al*., 2008). The higher pH values observed for tomatoes ripened

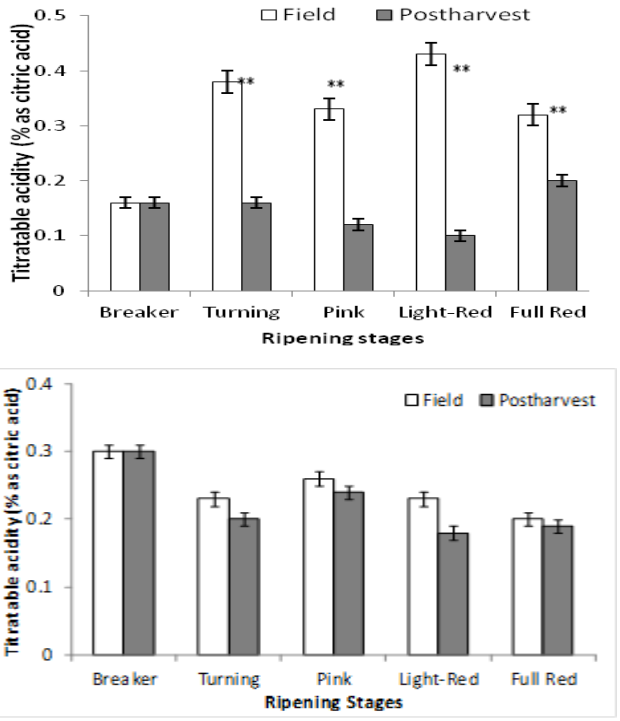

Figure 3. Changes in titratable acidity of (A) Cherry-*Nasmata* and (B) *Var-10* tomato cultivars at different ripening stages under field and post-harvest ripening conditions. Significant differences between the mean values are indicated as in Figure 1

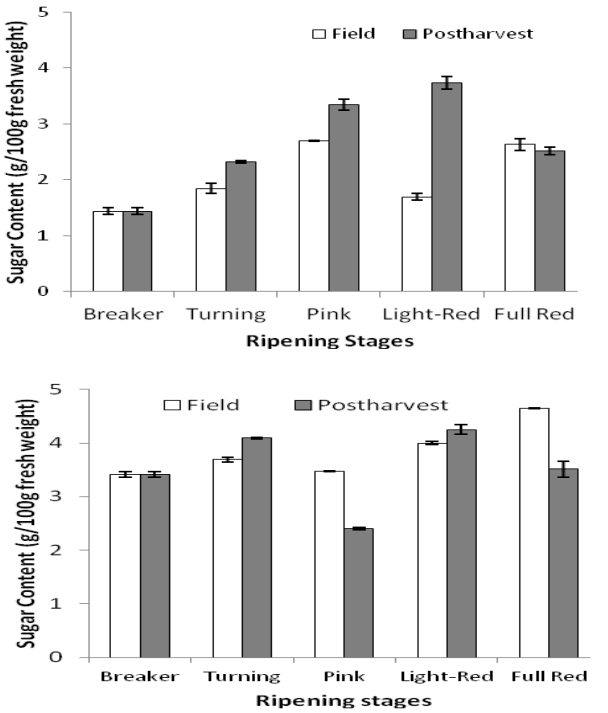

Figure 4. Reducing sugar contents of (A) Cherry-*Nasmata* and (B) *VAR-10* tomato cultivars at different ripening stages under field and post-harvest ripening conditions. Significant differences between the mean values are indicated as in Figure 1

under postharvest method could imply that a greater heating time would be required to concentrate tomato products (Islam and Khan, 2001).

The titratable acidity values Figure 3 range from 0.16 to 0.43 and 0.20 to 0.30% as citric acid for Cherry-*Nasmata* and *Var-10* tomato cultivars respectively under field ripening. At ambient temperature ripening, the respective ranges of 0.20 to 0.30% and 0.18 to 0.30% were observed for the two cultivars. The mean differences in the titratable acidities between the two ripening techniques are extremely significant ($p<0.01$) for all ripening stages in Cherry-*Nasmata* cultivar, moderately significant ($p<0.05$) at turning and light red stages in *Var-10* cultivar but not significant at pink and fully red stages of *Var-10* cultivar. As observed previously (Davies and Hobson, 1981), the trend of the variation of titratable acidity is inconsistent with the ripening stages (Figure 3), but has inverse relationship with pH. These are commonly used in determining the acidity indicators of tomatoes. The most abundant acid and the largest contributor to titratable acidity is citric acid. While malic and glutamic acids also contribute significantly to the titratable acidity, their concentrations in tomatoes are relatively low compared to citric acid (Paulson and Stevens, 1974).

Sugars (fructose and glucose) and organic acids (citric and malic) are major factors which determine the sweetness, sourness, and overall flavor intensity of most tomato varieties (Dorais *et al*., 2001). Figure 4 shows how the sugar contents of the tomatoes vary with ripening stages under the two ripening techniques. The sugar contents are in the range of 1.44 to 2.63 g per 100 g fresh weight and 1.44 to 3.73 g per 100 g fresh weight in Cherry-*Nasmata* cultivar for field and ambient temperature ripening respectively while the values range from 3.41 to 4.65 and from 3.41 to 4.25 g per 100 g fresh weight in *Var-10* tomato cultivars for the two techniques respectively. The sugar contents are higher at light-red and fully red stages than in other ripening stages. This implies that ripe tomatoes may have better flavour than the unripe ones. The values obtained for *Var-10* tomato cultivar agree with that observed with other cultivars previously studied (Pagliarini *et al.*, 2001; Abdul-Hammed *et al.*, 2012). The low sugar contents under field ripening observed for Cherry-*Nasmata* cultivar is in complete disagreement with previous report on high sugar contents (2.87 to 3.65 g/100 g) of cherry tomatoes (Raffo *et al.*, 2002). The commercial importance of cherry tomatoes is continuously increasing in Italian region of Sicily and constitute more than 25% of the market of tomatoes for fresh consumption (Leonardi *et al*., 2000). However, its consumption in Nigeria is unpopular and unattractive, due to its small sizes. The difference is in agreement

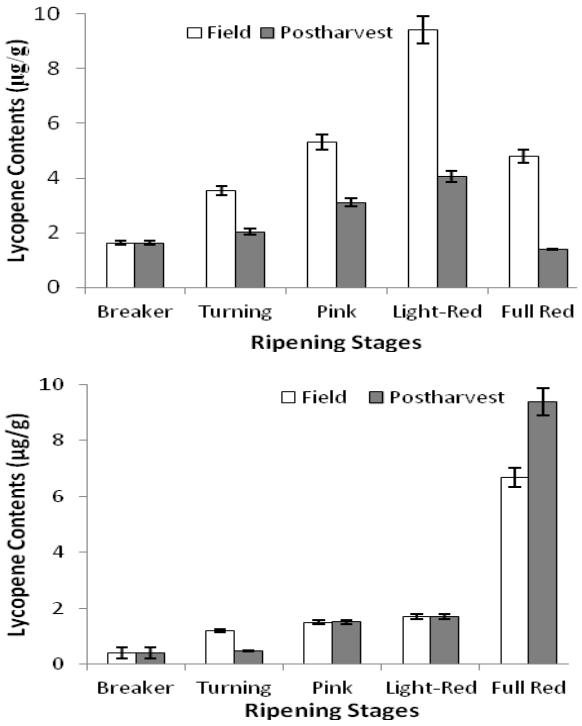

Figure 5. Accumulation pattern of lycopene in (A) Cherry-Nasmata and (B) VAR-10 tomato cultivars at different ripening stages under field and post-harvest ripening conditions. Significant differences between the mean values are indicated as in Figure 1

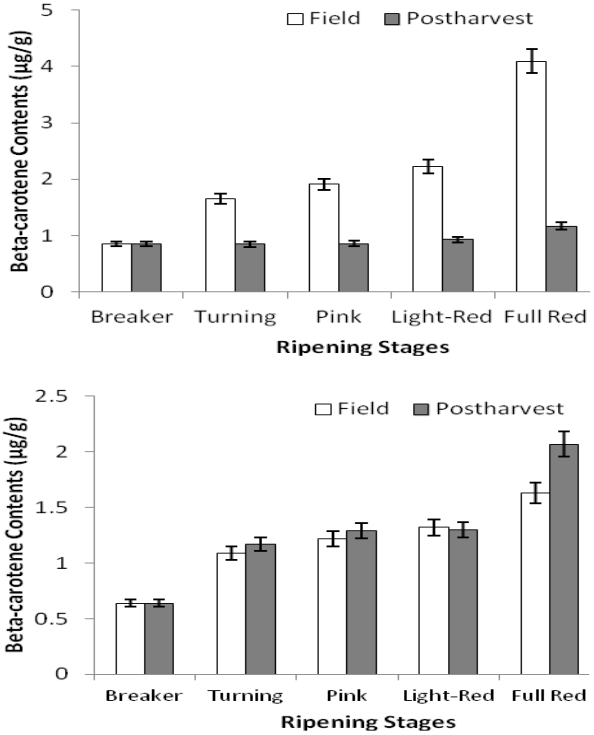

Figure 6. Accumulation pattern of beta-carotene in (A) Cherry-*Nasmata* and (B) *VAR-10* tomato cultivars at different ripening stages under field and post-harvest ripening conditions. Significant differences between the mean values are indicated as in Figure 1

with that in another report (Dorais *et al*., 2001) which associated it as a function of cultivation conditions, greenhouse condition in Italy and open farming practices (as in Nigeria). The mean differences in sugar contents between the two ripening techniques are extremely significant ($p<0.01$) for all ripening stages in both cultivars but not significant at fully red stage of Cherry-*Nasmata* cultivar.

The concentrations of lycopene, the ripening and antioxidant index of tomatoes increased from the breaker stage (1.63 and 0.40 µg/g) to the light red (9.42 µg/g) and fully red (6.68 µg/g) stages in Cherry-*Nasmata* and *Var-10* cultivars respectively under field ripening (Figure 5). However, at ambient temperature ripening conditions, these values are drastically lower for Cherry-*Nasmata* but higher for *Var-10* tomato cultivars, especially in the fully red stage. The mean differences of lycopene contents between the two ripening techniques are extremely significant ($p<0.01$) except at pink and light red stages of *Var-10* tomato cultivars. Lycopene has a strongest antioxidant activity and exhibit the highest physical quenching rate constant with singlet oxygen, compared to other carotenoids as well as vitamin C, vitamin E and phenolic compounds (Di Mascio *et al*., 1989). Absorption of lycopene from processed tomato has been reported to be greater than the absorption of lycopene from raw tomato (Porrini *et al.*, 1998).

Figure 6 shows the beta-carotene contents of the two tomato cultivars. Beta-carotene contents of Cherry-*Nasmata* tomato cultivar vary from 0.86 to 4.09 µg/g under field ripening but the values are lower (0.86 to 1.17 µg/g) under ambient temperature ripening, with the highest value recorded at fully red stage in both ripening methods. The carotenoid accumulation pattern in *Var-10* cultivar is quite the opposite with higher values observed in tomatoes ripened subjected to post-harvest handling than those allowed to self-ripe on the parent plants. This contradicts what has been observed earlier for tomato cultivars such as Ibadan-local, Roma, Ajindi-Kerewa, Beske, big local and 3-lobes (Abdul-Hammed *et al*., 2009; 2012). The mean differences in beta-carotene contents between the two ripening techniques are significant ($p<0.01$) except at turning and pink stages in Var-10 cultivar ($p<0.05$). Beta-carotene is of special interest due to its pro-vitamin A activity (Sies, 1991). Although tomatoes and watermelon are the main sources of lycopene, other dietary sources contribute to the daily intake of these carotenoids. However, tomatoes are also the reservoirs of other potentially healthy molecules, such as ascorbic acid, vitamin E and phenolic compounds, particularly flavonoids (Beecher, 1971; Raffo *et al*., 2002). The beta-carotene contents obtained in Cherry-*Nasmata* tomato in this study was close to the beta-carotene

contents (6.16 µg/g) reported for red watermelon (Charoensiri *et al*., 2009).

It is hereby hypothesized that about 10% of the average daily recommendation of 25.2 mg of lycopene in diet could be obtained by consuming 268 g of light-red stage of Cherry-*Nasmata* tomato cultivars. This may form part of the recommendations of at least, five portions of fresh fruits and vegetables (average size per one is 30 - 40 g) by health organizations to be eaten on daily basis as part of balance diet, though many consumers do not eat this quantity regularly. Equivalents amount could only be acquired by consuming higher quantities (about 622 g) of fully-red tomatoes of Cherry-*Nasmata* tomatoes ripened under postharvest method. However, these equivalents are reversed in *Var-10* tomato cultivars with 377g and 269 g for tomatoes ripened at field and under postharvest methods, respectively.

Conclusion

This study showed that the carotenoids content of tomato depends on the tomato cultivar, the ripening stage and the ripening condition. Tomatoes allowed to ripe on the field seems to be of higher quality in terms of sweetness which appeases customers and are better sources of antioxidants than those ripened at ambient temperature. Also, postharvest method by harvesting at mature green stage may be a better practice than harvesting at the breaker stage of tomatoes. Regular consumption of the recommended amounts of tomatoes, either in raw or processed form, could help to achieve the health benefit of carotenoids.

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