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Assessment of Nutritional, Antioxidant and Pro-Vitamin A Indices of Tomatoes under Field and Postharvest Ripening Conditions.

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ABSTRACT

Qualities of locally-bred tomatoes in developing countries are seemingly unraveled, despite the controversies surrounding adoption and use of genetically-modified crops. This work focused on the nutritional quality of fruits of two tomato cultivars monitored under two ripening conditions. Variations in total solid, pH, citric acid level, sugar, lycopene and beta-carotene contents were determined. Total solid contents ranged from 4.09% at turnings stage under postharvest to 7.30% in light-red stage of field ripening for *Ajindi-Kerewa* (AKC) and *Beske* (BC) cultivars respectively. Both cultivars had the lowest pH during field ripening and postharvest conditions with the highest titratable acidity of 0.30% (as citric acid) at breaker stage in AKC, and 0.32% at both fully red and light-red stage in BC. Sugar content was highest (4.64 g / 100 g) when pink in AKC and BC during field and postharvest conditions. Lycopene was highest in AKC and BC cultivars (13.11 and 17.18 µg/g respectively) at light-red stage only under field conditions. Beta-carotene contents were higher in tomatoes ripened under field than postharvest condition. Therefore, tomatoes ripened under field conditions are of high quality in term of nutrient bioavailability and should be adopted simultaneously with postharvest method at mature green stage.

Keywords: Tomato firmness, Antioxidant, lycopene, beta-carotene, nutrition, genetic engineering.

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INTRODUCTION

Consumption of fruits provides essential vitamins that are associated with reduced incidences of heart diseases and different types of cancers. Fruits form important parts of a healthy diet [1] of which tomato is one of the most commercially important vegetables whose production has been transformed into a large agricultural industry. It is almost impossible to dissociate tomato from the recipe of fast foods and pizza parlours, since its use in the modern diet is so extensive. Its per capita worldwide consumption in fresh and processed form exceeds 20 kg/yr [2]. The physical, physiological and biochemical changes, which make tomato fruits attractive for consumption, affect the quality parameters such as colour, texture, flavour, and bioactive compounds, which can occur during development on plant and after harvest. As the fruit ripens, the content of fructose and glucose increases while acidity decreases [2]. Protective activity of tomato products on *in vivo* markers of lipid oxidation has been reported [3]. Moreover, the consumption of tomato products has been connected with a lower risk of developing digestive tract and prostate cancers [4]. These protective effects may be due to the ability of lycopene and other antioxidant components to prevent cell damage through synergistic interactions [5,6]. Report shows that at least 85% of human dietary lycopene originated from tomato fruits and tomato based products, with the remainder being obtained from water melon, pink grapefruit, guava and papaya [7].

Existing data on the nutritional and health significance of tomato diet indicated that intake of tomato or tomato products may be associated with a lower risk of prostate cancer [8], but it is not certain that lycopene is the only compound in the tomato that contribute to this effect. This is simply because other carotenoids and phytochemicals in the fruit may also play very crucial roles [4,9]. Chen et al. [10], provided information that linked a high tomato diet to reduced leucocyte oxidative DNA damage and prostate tissue oxidative damage in patient already diagnosed with prostate cancer. In developed countries, more than 80% of tomatoes produced are consumed in the form of processed products such as juice, paste, puree, ketchup, sauces and soups while evidence suggested higher consumption of tomato fruits than the products in developing countries [11]. Quality of fresh market is determined by appearance, firmness and flavor, whereas processing tomato quality is mainly determined by total soluble solids content, color, pH and firmness. However, the parameters that influence these attributes are often the same: sugars and organic acids are the major components of dry matter weight, but also contribute to the flavor of the product. Events occurring during ripening (ethylene biosynthesis, cell wall modifications) also control texture traits, which are important for both organoleptic quality and processed tomato quality [12,13].

Genetic modifications (GM) have been directed towards improving either the quality of the fruit and /or agronomical aspect of tomato cultivar. Biochemical and physiological changes in tomatoes occur relatively quickly after harvest and the fruits reach an over-ripe state considered unmarketable. Thus, most post-harvest storage technologies are focused on controlling the biosynthesis and action of ethylene in order to delay these changes and to extend the shelf-life with optimum quality before consumption [14]. However, conventional post-harvest methods such as field and postharvest ripening, to maintain tomato quality during

storage and marketing are most common among subsistent farmers in Nigeria. While the existence of GM food is unavoidable in places like Thailand's market, food processors have more information on the presence of GM than the consumers [15]. Most African countries, like many other poor countries, cannot advance GM crop research because their national policies or regulatory systems are not prepared to deal with safety requirement for approving general use [16]. Not only corporations are the drivers of GM foods, but also a few African countries (like Nigeria) have vibrant public biotech research programs, despite their limited financial and technical resources. This research often targets improvements of indigenous plant varieties (such as tomatoes at National Biotechnology Development Agency, NABDA, in Nigeria) relevant for local use by small-scale farmers. However, such improvement effort is still at its lowest ebb.
Considering the vast importance of tomato in human diet, the present study was designed to evaluate the nutritional, antioxidant and provitamin A indices with ripening stages in two widely cultivated local cultivars of Nigerian tomatoes (*Ajindi-Kerewa* and *Beske*) ripened under field and postharvest conditions. This is with a view to examine the variation pattern of the various indices with the five ripening stages employed for the two cultivars. An attempt was made to suggest a better and appropriate ripening practice that will enhance not only the bioavailability of the various nutritional components but the quality of tomato for the benefit of the consumer.

MATERIALS AND METHODS

Sample preparation

The seeds of the two cultivars of tomatoes were collected from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria and were planted on an open farmyard in Ogbomoso, Nigeria between May and September rainy season. The fruits were identified at National Horticultural Institute (NIHORT), Ibadan, Nigeria. The tomato fruits were independently and randomly selected at various stages of maturity, packed into nylon bags and then taken into the laboratory, where they were rinsed with double distilled water and left to drain. Tomatoes subjected to postharvest ripening were harvested at the breaker stages and ripened under ambient temperature. Individual tomatoes were sliced, cut into small pieces and 200- 500 g of fresh tomato samples was homogenized.

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

The titratable acidity (TA) (expressed as % citric acid) and total solid content (TS) were determined according to AOAC [17]. The pH was determined using 30 g samples of tomato serum with a digital pH-meter. The reducing sugar content was determined as reported previously [18,19].

Extraction and quantification of lycopene and β-carotene

Conventional solvent extraction methods [20,21] were employed for carotenoid extraction. Lycopene and β-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 double distilled water, methanol and 20 % KOH/methanol (1:1:1) to saponify any triglyceride present. The extract was then washed with double distilled water and re-dissolved in hexane. The absorbance of the hexane extracts were measured at 450 nm and 502 nm using Genesys 10S V1.200 spectrophotometer (Buck Scientific, USA). The lycopene and β-carotene concentrations were determined using previously reported protocol [22,23].

Data analysis

The values as presented are means of 5 measurements ± Standard deviation (SD) on fresh weight basis. The data were analyzed and subjected to student t-test on GraphPad QuickCalcs Software (GraphPad Software Inc. USA) while the differences between the mean values with the corresponding P-values were as shown in the tables.

RESULTS AND DISCUSSION

Quality characteristics of tomatoes such as improved soluble solids, pH, total acidity and colour are the major traits of interest to breeders in order to obtain cultivars with high acceptance in the market for consumption in fresh as well as processed form [24]. The percent total solids of two commonly consumed tomato varieties in Nigeria as investigated vary between 5.16 and 6.95 % for *Ajindi-Kerewa* cultivar and between 5.65 and 7.30 % for *Beske* cultivar (Table 1). It is of highest value in the breaker stage of *Ajindi-Kerewa* cultivar ripened on the parent plants, while the highest value was recorded at the light-red stage of the *Beske* cultivar. On the contrary, the fruits harvested at breaker stage and ripened under postharvest condition recorded the highest values of 6.34 and 6.14 % in *Ajindi-Kerewa* and *Beske* tomato cultivars respectively at the pink stages and the values reduced drastically as the fruits ripen further. These mean differences between the two conditions of ripening are significant ($P < 0.01$, but $P < 0.05$ at the pink stage of *Beske* cultivar).

Observing the changes in total solid contents of the two tomatoes cultivars, it is evident that the total solid contents ranging from 4.09 - 6.54 % and 4.43 - 7.30 % for *Ajindi-Kerewa* and *Beske* cultivars respectively, are in agreement with previous findings [25,26]. The report showed that tomatoes are composed of 93 - 95 % water while other constituents (5 - 7 %) include inorganic compounds, organic acids (citric and malic), sugars (glucose, fructose and sucrose), solids insoluble in alcohol (proteins, cellulose, pectin, polysaccharides), carotenoids and lipids [24,27]. The commercial motive of postharvest methods of ripening is to have higher total solid contents of tomatoes. Tomatoes harvested at mature green stage and allowed to ripe at ambient temperature tend to tolerate rough handling and have longest shelf-life in storage, shipping, and on the supermarket shelf [25]. Present finding further revealed that harvesting at breaker stage rather than mature green stage is undesirable and could lead to higher shrinkage rate of tomatoes [26].

Variation in pH values of tomato fruits with ripening stages under the two conditions are as shown in Table 2. The pH values changed in an irregular manner. The pH values (3.58 to 4.07

for *Ajindi-Kerewa* cultivar and 3.49 to 4.52 for *Beske* cultivar) observed under field ripening technique were slightly lower than those observed for the postharvest ripening technique. This indicates that the fruits ripened under the field tend to be more acidic than those ripened under the postharvest condition. The pH differences between the two ripening methods are significant ($P < 0.01$ at all the ripening stages) except at the turning and light-red stage of *Ajindi-Kerewa* cultivar. The pH values as observed are also in agreement with reports for other cultivars [25,28].

Titratable acidity values of the two cultivars of tomatoes vary with the ripening stages under the two conditions. The values range between 0.21 and 0.30 % for *Ajindi-Kerewa* cultivar and between 0.19 – 0.32 % for *Beske* cultivar under field ripening while the values range from 0.15 to 0.25 % and from 0.20 to 0.32 % for *Ajindi-Kerewa* and *Beske cultivars* under postharvest ripening condition respectively (Table 3). The mean differences between the two methods of ripening are significant ($P < 0.01$) with exceptions at the turning and fully-red stages of the *Ajindi-Kerewa* and *Beske* varieties respectively.

The changes in the titratable acidity follow no simple trend as previously reported [12]. Citric and malic acids are the main acids in the tomato fruit, and the former predominate over the latter [29]. The flavor of tomatoes is altered by the content of titratable acid and any change in the contents of citric and/or malic acid will alter the degree of acidity of the fruit. In general, tomato pulps with pH values lower than 4.5 are desirable due to the inhibition of the development of microorganisms harmful to the conservation of the processed products under highly acidic conditions [24,30]. The more alkaline pH observed at ambient temperature ripening of the two cultivars of tomatoes imply that a greater heating time will be required in processing, especially for the sterilization of tomato by-products [31].

The reducing sugar contents of the tomatoes vary under the conditions of ripening with respect to the ripening stages (Table 4). Highest reducing sugar concentration (4.64 g per 100g fresh tomato weight) was observed at the pink stage of both cultivars while lower values were observed in tomatoes ripened under postharvest ripening condition. These manifest in the observed all time positive mean differences in the reducing sugars between the ripening methods These mean differences are highly significant ($P < 0.01$ but $P < 0.05$ at fully red of *Ajindi-Kerewa cultivar*) except at the pink stage of the *Ajindi-Kerewa* variety.

The range of reducing sugar contents in this work are in agreement with previous findings [25,28]. The concentration of sugars may vary from 1.66 to 4.65 % of the fresh matter, as a function of the cultivar and cultivation conditions, respectively [32]. As with the sugars, the organic acids are crucial to the flavour of the fruits and characteristics related to processing. Changes in antioxidant activity during ripening of tomato fruits were previously reported [33,34,35,36]. The major quality attributes depend on the end uses of tomato (processing or fresh market). Quality of fresh market is determined by appearance, firmness and flavor, whereas processing tomato quality is mainly determined by total soluble solids content, color, pH and firmness. The colour of the fruits is an essential parameter for consumption of fresh fruit as well as for the industry. Consumers associate the colour characteristics of foods with

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other quality attributes such as flavour and nutritional value. The colouring of the tomato is due to chlorophylls (green pigments), carotenoids (mainly lycopene and β-carotene) and xanthophylls (yellow pigments) [30]. Carotenoids are also important to humans because of their nutraceutic property [37].

Table 1: Variation in total solid contents of *Ajindi-Kerewa* and *Beske* tomato cultivars at different ripening stages under field and post-harvest ripening conditions.

Ripening Stages	*Ajindi-Kerewa* Cultivar		*Beske* Cultivar		* Mean differences between the ripening methods (P values for mean differences)	
	Field Ripening	Ambient Temperature	Field Ripening	Ambient Temperature	*Ajindi-Kerewa* Cultivar	*Beske* Cultivar
Breaker	6.95 ± 0.01		5.65 ± 0.01		Not computed	
Turnings	6.54 ± 0.19	4.09 ± 0.12	6.04 ± 0.18	4.43 ± 0.13	2.45 (0.0003)[c]	1.61 (0.0002)[c]
Pink	6.47 ± 0.19	6.34 ± 0.19	6.65 ± 0.20	6.14 ± 0.18	0.07 (0.0005)[c]	1.98 (0.0307)[b]
Light-Red	5.16 ± 0.22	5.71 ± 0.17	7.30 ± 0.21	5.29 ± 0.16	-0.55 (0.0003)[c]	2.01 (0.0002)[c]
Fully-red	5.63 ± 0.24	5.72 ± 0.19	7.03 ± 0.02	5.77 ± 0.17	-0.09 (0.00031[c]	1.26 (0.0002)[c]

* This indicates the mean values of tomato fruits at field ripening minus the mean values of those at ambient temperature ripening. Negative values indicate highermean values for tomato fruits at ambient temperature ripening. P-values are in parentheses.

[a] Not significant [b]Significant at P<0.05 [c]Significant at P<0.01

Table 2: Variation in pHof *Ajindi-Kerewa* and *Beske* tomato cultivars at different ripening stages under field and post-harvest ripening conditions.

Ripening Stages	*Ajindi-Kerewa* Cultivar		*Beske* Cultivar		* Mean differences between the ripening methods (P values for mean differences)	
	Field Ripening	Ambient Temperature	Field Ripening	Ambient Temperature	*Ajindi-Kerewa* Cultivar	*Beske* Cultivar
Breaker	3.98 ± 0.01		3.96 ± 0.01		Not computed	
Turnings	3.58 ± 0.01	3.49 ± 0.12	3.98 ± 0.12	4.07 ± 0.12	0.09 (0.5000)[a]	-0.09 (0.0012)[c]
Pink	4.06 ± 0.06	4.42 ± 0.31	4.01 ± 0.07	4.44 ± 0.14	-0.35 (0.1835)[a]	-0.43 (0.0005)[c]
Light-Red	3.95 ± 0.02	4.52 ± 0.08	3.92 ± 0.12	3.68 ± 0.11	-0.57 (0.00041)[c]	0.24 (0.0002)[c]
Fully-red	4.07 ± 0.01	4.50 ± 0.02	3.97 ± 0.12	3.75 ± 0.11	-0.57 (0.0010)[c]	0.22 (0.0002)[c]

* As defined under Table 1 [a,b, c] Same as in Table 1

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Table 3: Changes in percent titratable acidity (as % citric acid, mean ± SD) of *Ajindi-Kerewa* and *Beske* tomato cultivars at different ripening stages under field and post-harvest ripening conditions.

Ripening Stages	*Ajindi-Kerewa* Cultivar		*Beske* Cultivar		* Mean differences between the ripening methods (P values for mean differences)	
	Field Ripening	Ambient Temperature	Field Ripening	Ambient Temperature	*Ajindi-Kerewa* Cultivar	*Beske* Cultivar
Breaker	0.30 ± 0.01		0.24 ± 0.01		Not computed	
Turnings	0.26 ± 0.01	0.25 ± 0.01	0.25 ± 0.01	0.20 ± 0.01	0.01 (0.3739)[a]	0.08 (0.0019)[c]
Pink	0.29 ± 0.01	0.22 ± 0.01	0.19 ± 0.01	0.26 ± 0.01	0.07 (0.0010)[c]	-0.07 (0.0010)[c]
Light-Red	0.30 ± 0.02	0.25 ± 0.01	0.24 ± 0.01	0.32 ± 0.02	0.05 (0.0036)[c]	-0.08 (0.0019)[c]
Fully-red	0.21 ± 0.01	0.15 ± 0.01	0.32 ± 0.02	0.28 ± 0.01	0.06 (0.0018)[c]	-0.07 (0.1276)[a]

* As defined under Table 1 [a,b,c] Same as in Table 1

Table 4: Sugar contents (g per 100 g Fresh weight, mean ± SD) of *Ajindi-Kerewa* and *Beske* tomato cultivars at different ripening stages under field and post-harvest ripening conditions.

Ripening Stages	*Ajindi-Kerewa* Cultivar		*Beske* Cultivar		* Mean differences between the ripening methods (P values for mean differences)	
	Field Ripening	Ambient Temperature	Field Ripening	Ambient Temperature	*Ajindi-Kerewa* Cultivar	*Beske* Cultivar
Breaker	1.38 ± 0.04		2.78 ± 0.05		Not computed	
Turnings	3.70 ± 0.20	2.93 ± 0.03	3.21 ± 0.05	4.07 ± 0.01	0.78 (0.0025)[c]	-0.86 (0.0014)[c]
Pink	4.64 ± 0.22	4.09 ± 0.03	4.64 ± 0.09	2.97 ± 0.09	0.55 (0.0606)[a]	1.67 (0.0034)[c]
Light-Red	3.85 ± 0.01	3.34 ± 0.10	4.43 ± 0.12	2.35 ± 0.07	0.51 (0.0010)[c]	2.08 (0.0002)[c]
Fully-red	4.17 ± 0.16	3.61 ± 0.11	4.45 ± 0.01	3.35 ± 0.07	0.56 (0.0211)[c]	1.10 (0.0018)[c]

* As defined under Table 1 [a,b,c] S same as in Table 1

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Table 5: Lycopene contents (µg per g Fresh weight, mean ± SD) of *Ajindi-Kerewa* and *Beske* tomato cultivars at different ripening stages under field and post-harvest ripening conditions.

Ripening Stages	*Ajindi-Kerewa* Cultivar		*Beske* Cultivar		* Mean differences between the ripening methods (P values for mean differences)	
	Field Ripening	Ambient Temperature	Field Ripening	Ambient Temperature	*Ajindi-Kerewa* Cultivar	*Beske* Cultivar
Breaker	0.54 ± 0.03		0.46 ± 0.02		Not computed	
Turnings	3.17 ± 0.16	0.64 ± 0.03	5.50 ± 0.28	1.42 ± 0.07	2.53 (0.0011)[c]	4.08 (0.0008)[c]
Pink	4.42 ± 0.22	0.85 ± 0.04	6.50 ± 0.33	2.13 ± 0.11	3.56 (0.0011)[c]	4.37 (0.0006)[c]
Light-Red	13.11 ± 0.67	1.82 ±0.09	17.18 ± 0.88	7.74 ± 0.40	9.44 (0.0010)[c]	9.43 (0.0009)[c]
Fully-red	7.40 ± 0.38	5.73 ± 0.29	14.05 ± 0.72	7.09 ± 0.37	1.67 (0.0009)[c]	6.96 (0.0009)[c]

* As defined under Table 1 [a,b, c] Same as in Table 1

Table 6: Beta-carotene contents (µg per g Fresh weight, mean ± SD) of *Ajindi-Kerewa* and *Beske* tomato cultivars at different ripening stages under field and post-harvest ripening conditions.

Ripening Stages	*Ajindi-Kerewa* Cultivar		*Beske* Cultivar		* Mean differences between the ripening methods (P values for mean differences)	
	Field Ripening	Ambient Temperature	Field Ripening	Ambient Temperature	*Ajindi-Kerewa* Cultivar	*Beske* Cultivar
Breaker	0.78 ± 0.04		0.55 ± 0.03		Not computed	
Turnings	2.47 ± 0.13	0.84 ± 0.04	0.80 ± 0.04	0.82 ± 0.04	1.63 (0.0009)[c]	-0.02 (0.0006)[c]
Pink	2.76 ± 0.14	0.87 ± 0.04	1.33 ± 0.07	1.03 ± 0.05	1.90 (0.0009)[c]	0.30 (0.0008)[c]
Light-Red	2.86 ± 0.15	1.35 ± 0.07	2.87 ± 0.15	1.13 ± 0.06	1.51 (0.0009)[c]	1.74 (0.0009)[c]
Fully-red	4.84 ± 0.25	2.22 ± 0.11	3.64 ± 0.19	2..81 ± 0.14	2.62 (0.0009)[c]	0.83 (0.0009)[c]

* As defined under Table 1 [a,b, c] Same as in Table 1

Lycopene contents, the ripening and antioxidant indices of tomatoes, vary from one ripening stage to the other and the variations were also observed with the field and postharvest ripening methods used (Table 5). The lycopene concentration increases from breaker stage to light-red stage in the two cultivars ripened on the field but decrease at fully red stage (due to its

conversion to beta-carotene).The highest values of 13.11 and 17.18 µg per g fresh tomato weight were observed for *Ajindi-Kerewa* and *Beske* varieties respectively at the light red stage of the field ripening condition. The mean differences in the lycopene concentrations between the ripening methods are in the range 1.67 to 11.29 µg per g fresh tomato weight and 4.08 to 9.43 µg per g in *Ajindi-Kerewa* and *Beske* cultivars respectively. These mean lycopene contents differences between the two ripening techniques are at all times extremely significant ($P < 0.01$) with higher antioxidant indices obtained at field ripening conditions than in tomatoes subjected to ambient temperature ripening.

The carotenoid lycopene is responsible for the red colour of the fruit and constitutes 75 - 83 % of the total carotenoids. Tomato is the main source of lycopene, containing high amounts, which, however, vary as a function of time of harvest, geographic location and plant genotype. In this work, the lycopene contents increase with ripening stages, with the highest concentrations of 13.11 and 17.18 µg/g fresh weights obtained at light-red stage of *Ajindi-Kerewa* and *Beske* cultivars respectively. Only maxima of 5.73 and 7.74 µg lycopene per g fresh weight of tomatoes were obtained at the fully red stage of *Ajindi-Kerewa* and *Beske* tomato cultivars respectively. It was reported earlier that a massive accumulation of lycopene occurs during tomato ripening, which was attributed to an increase of flux through the initial stages of the lycopene synthetic pathway and a restriction to end products that are typically found in vegetative tissues [38]. The lycopene concentration in tomatoes was reported to be affected by the season of the year [39], the condition of growth and method of ripening [40]. Carotenoid concentrations in fruits and vegetables also vary with plant variety, degree of ripeness, time of harvest and growing and storage conditions [41]. The highest concentrations are found in wild cultivars, up to double the concentrations found in commercial cultivars. In the human organism, lycopene is present in high concentrations in the blood plasma, seemingly an essential fraction acting as a natural defense pathway, and acting as an antioxidant and anti-mutagenic agent.

β-carotene contents (pro-vitamin A indices) of the tomatoes (Table 6) were relatively higher in the tomatoes ripened in the field than those ripened under postharvest condition. The concentrations of β-carotene (0.78 to 4.84 µg per g fresh tomato weight in *Ajindi-Kerewa* cultivar and 0.55 to 3.64 µg per g for *Beske* cultivar) increase as tomato fruits ripened. The β-carotene concentrations reach the maximum at the fully-red stage for both varieties ripened in the field and this trend was also observed at postharvest ripening condition, Mean differences in β-carotene concentrations of the tomato fruits between field and postharvest ripening methods are in the range 1.51 to 2.62 and 0.02 to 1.74µg per g fresh tomato weight in *Ajindi-Kerewa* and *Beske* cultivars respectively, and are highly significant ($P< 0.01$) at all the ripening stages in both tomato cultivars.

The beta-carotene pigment is responsible for the yellowish colour of tomatoes and represents 3 - 7 % of the serum [32]. The content of beta-carotene determines the activity of vitamin A, which has been cited as important biomolecule in the prevention of coronary diseases and cancer [42]. The concentration of beta-carotene varies considerably among species, cultivars or lineages. The concentrations are up to 100 times as high in progeny

obtained from the crossing of the cultivated species of the tomato plant *L. esculentum* and the wild species *L. hirsutum* [43]. In tomatoes, the effect of genotypic variation on carotenoid content has been studied and breeding effort has resulted in a wide range of varieties with different carotenoid profiles, many of which await full nutritional exploitation. For instance, two species of tomatoes such as *L. cheesmanni* and *L. pimpinellifolium* have been discovered to yield ripe fruits containing no chlorophyll but beta-carotene and lycopene respectively. Incidentally, these two species are the phylogenetically closest to *L. esculentum*, which has ripe fruit containing both lycopene and beta-carotene [44]. This suggests the existence of high potential for nutritional exploitation of the wild species of tomatoes to improve the cultivated ones. While the controversies surrounding the adoption of GM organisms and means of alleviating concerns over consumption of GM food continue, breeders should once again redirect their focus towards the use of conventional breeding methods to explore varietal differences in carotenoid of tomatoes in the development of new cultivar that will not only be widely adopted by farmers but also meet the nutritional requirement of the populace.

Many people were able to recognize both the benefits and risks associated with food safety issues surveyed [45]. If the technologies of genetic modification were seen as beneficial even though there were some risks associated with them, the risks will be more acceptable and people will not totally reject the technology. It could be deduced that about 10 % of the average daily recommendation of 25.2 mg of lycopene in diet as claimed previously [28,46] could be obtained by consuming 190 g and 145 g of light-red stage of *Ajindi-Kerewa* and *Beske* tomato cultivars. This corresponds to 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 436 g and 352 g) of fully-red tomatoes of *Ajindi-Kerewa* and *Beske* cultivars ripened at ambient temperature postharvest method.

CONCLUSION

This study shows that the tomatoes allowed to 'field -ripe' 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.

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