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Full Length Research Paper

Evaluation of Textural Qualities and Chemical Properties of some Tomato Cultivars

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This study investigated the effect of maturity stage on the textural-chemical properties of fresh tomatoes (*Lycopersicum esculentum* Mill.) fruits. Seven tomato cultivars (*Ibadan local, Beske, Tropimech, UC82B, Kelvin, Nadira* and *Roma*) were harvested at three maturity stages namely; breaker, pink and ripe red. The textural qualities (firmness, springiness, adhesiveness, chewiness, stringiness and gumminess) of the tomato fruits were measured using the Warner-Bratzler shear force (WBS) method. The chemical properties (pH and electrical conductivity) of the fruits were measured by pH and electrical conductivity meters. Results of the texture profile analysis showed that tomato fruits exhibited a strong dependence on the degree of maturity of the fruits at harvest. All the textural qualities determined decrease as the fruits matured from the breaker stage to the ripe red stage. From the results, the *Tropimech* tomato fruits had the highest average skin firmness and springiness of 53.16 N and 1.101 respectively, while *UC82B* tomato fruits had the highest average adhesiveness of 21.47 N.s. The results further showed that breaker tomato fruits exhibited the highest electrical conductivity values than those corresponding to pink and red ones. However, the red tomato fruits exhibited the highest pH values than their corresponding to breaker and pink ones. The average electrical conductively ranged between 0.464 S/m and 0.438 S/m; while the average pH of the tomato fruits ranged between 3.75 and 4.89. The results showed variations in the textural qualities and chemical properties among the seven tomato cultivars studied.

Keywords: Texture profile analysis, chemical properties, tomato fruit, maturity stage

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most consumed berry fruits in the world, with an estimated total production of about 182.3 million tonnes in 2017, and Africa accounting for about 21.5 million tonnes production (FAOSTAT, 2019). Although tomato is considered by many people as vegetable, botanically the tomato is a fruit of the genus *Lycopersicon* (Barrett *et al*., 1998). Tomatoes fruits are in the food industries in the production of juices, purees, ketchup and other derived products (Hernández-Suárez *et al*., 2014). According to Canene-Adams *et al*., (2005) tomato fruit is an important source of vitamins and minerals, including potassium, carboxylic acid, ascorbic acid, citric acid, etc. Apart from its nutritional values, tomato fruit has a lot of medicinal values. Tomato fruit had the ability to reduce the risks of cardiovascular disease and certain forms of cancer (e.g. prostate, lung and stomach cancers). The health benefits of tomato have been attributed to the significant amount of lycopene it contained, which plays significant role in the prevention of different health issues, cardiovascular disorders, digestive tract tumors and in inhibiting prostate carcinoma cell proliferation in humans (Levy and Sharoni, 2004). Tomatoes fruits quality is a function of the variety, farming method, harvest time and method, storage system, and handling operations. The effects of variety, season, harvest time, maturity, as well as environmental factors such as light, water and nutrient supply on the antioxidant content of tomatoes were reviewed by Dumas *et al*. (2003).

Texture is one of the most important criteria of quality evaluation of food products. According to Sadowska, (1983) texture is a set of physical properties, which is perceptible with the sense of touch, and related to deformation, refinement and fluidity of foodstuffs. Fruits quality is highly dependent on the firmness of their tissues (Go³acki, 1998), which is a factor of the fruit's cell wall.

Knowledge of the changes in the textural properties of tomato fruit during maturity and ripening is a vital attribute to food engineers, as textural and quantitative properties of tomato fruit changes during maturity, ripening and storage. Tomato fruit being climacteric can be harvested at early maturity stages (Cantwell and Kasmire, 2002), after which ripening continued, resulting in mechanical, optical and textural properties changes, thus leading to changes in both quantitative and qualitative values of the fruit. Softening of the tomato fruit caused by over ripening during storage causes a lot of problems, not only degradation of quality and consumers acceptability, but also economic value problem, since softening increased tomato fruit susceptibility to physical and mechanical damage (Žnidarčič and Požrl, 2006).

Texture profile analysis (TPA) is one of the methods that have been employed in analyzing the textural properties of food materials (Kajuna *et al*., 1997). Maturity is one of the important factor that determines post-harvest shelf life and qualities (appearance, texture, flavor and nutritive value) of fruits and vegetables (Hassain and Eva, 2014).

Fruits harvested at early maturity stages are susceptible to greater shriveling and mechanical damage, and inferior flavour quality. On the other hand, overripe fruits are likely to become soft and loss their textural rigidity soon after harvest.

The necessity of transporting fruits and vegetables over long distances has encouraged harvesting them at a near full maturity stage, resulting in suboptimal textural qualities to the consumers (Kader, 1996; El-Ramady *et al*., 2015). During ripening of plantain finger, its physical, mechanical and chemical properties are altered. For instance, the finger skin colour changed from green to yellow, the firmness and hardness decreased, while the carbohydrate is converted into sugar (Tapre and Jain, 2012).

Fruits maturity and ripening processes are coordinated developmental processes that coincides with seed maturation, with changes in colour, flavour, texture, nutritional values and pathogen susceptibility (Klee and Giovannoni, 2011; Radzevičius *et al*., 2016). The green to red colour transition of tomato fruit during maturity and ripening is largely due to the conversion of chloroplasts to chromoplasts, as photosynthetic membranes are degraded, chlorophyll is metabolized, and carotenoids, including β-carotene and lycopene accumulate (Giovannoni, 2001; Radzevičius *et al*., 2016). Organic acids are widely distributed in fruits and vegetables, and are extensively used as food acidulates in the manufacturing of beverages, fruit and vegetable drinks, or juices (Shui and Leong, 2002). The pH of tomato fruit is influenced by organic acid and potassium contents and needs to be below a threshold value to prevent microbial spoilage after processing (Powers, 1976).

Electrical conductivity is the ability of agricultural materials to conduct electric current. Thus, the electrical conductivity of agricultural material is considered to be one of the important parameters during the design of ohmic heating process (Sastri and Palaniappan, 1992). Electricity conductivity of fruits and vegetables is highly dependent on their cellular composition, sugar and salt content, pH and the environmental temperature.

Some researchers have studied the electrical properties ad textural profile of fruits during ripening and post-harvest storage. Mustaffa *et al.* (1998), investigated the texture profile of banana (cv. *Montel*) during development and maturation by means of penetrometric studies, and reported that the texture values of the fingers decreased significantly during maturation.

Žnidarčič and Požrl, (2006) reported that the titrable acidity of tomato fruit (cv. *Malike*), decline from 5 g/l to 4 g/l during 28 storage days. Will *at al*, (1981) recorded decrease in the organic acid content of fruits and vegetables during maturity, which he attributed to respiration of the fruits. During ripening of tomato fruit, the malate and citrate declined substantially (Thorne and Efiuvwevwevre, 1988). Gupta, 1992 modeled electrical conductivity of fruit juice as a function of both temperature and total soluble solids (TSS), and reported an increasing effect of the fruit juice TSS on electrical conductivity.

Darvishi *et al*., (2013) studied electrical conductivity and pH change in pomegranate juice, and reported that the electrical conductivity of the juice increased with increase in temperature rise. The textural changes of bayberries during storage were investigated by Chen *et al*., (1994) and recorded declined in the stress yield point during storage and developed a regressive equation for the process.

The effect of maturity stage on the textural qualities of Nigeria grown tomatoes fruits had not been studied extensively. This is partly on the fact that instrumental texture profile analysis of fruits and vegetables a new research area, recently gaining general recognition. Therefore, the objective of this research was to study the variations in the textural qualities of seven tomato cultivars (*Ibadan local, Beske, Tropimech, UC82B, Kelvin, Nadira* and *Roma*) harvested at different ripening stages.

Results obtained from the research can be applicable for the design and development of systems for food processors.

MATERIALS AND METHODS

Tomatoes plants cultivation

The study was carried out with seven tomato cultivars, namely (*Ibadan local, Beske, Tropimech, UC82B, Kelvin, Nadira* and *Roma*). The tomatoes seeds were obtained from the National Horticultural Research Institute (NIHORT), Ibadan, Nigeria, and Technisem seed company sales outlet, Kano State, Nigeria. The tomatoes seeds were nursed at the Research Station of the Delta State Polytechnic, Ozoro, Nigeria. Transplanting of the tomatoes seedlings was done in February, 2019 at a spacing of 60 cm by 50 cm; and 1 m between experimental plots, at the Research Station of the Delta State Polytechnic, Ozoro, Nigeria. During the growing period, approved agricultural practices of tomatoes plants were strictly adopted. Organic soil conditioner and manure were applied to the soil to increase the soil pH and nutrient. Staking was done to help increase the yield and maximizes quality potential of the plant. Weeding was done manually, and irrigation was carried out twice weekly during the growing period to meet up with tomatoes water demand.

Sample collection and preparation

The tomatoes fruits were harvested for testing at three maturity stages (Breaker, pink, and ripe red), based on their external colour according to the United States Department for Agriculture Standards (USDA, 1991). USDA categorized tomato fruit into six maturity stages, which are:

(i) Mature green
(ii) Breaker
(iii) Turning
(iv) Pink
(v) Light red
(vi) Ripe Red

The harvested fruits were selected based on uniformity of size (extremely large or small tomatoes fruits were rejected), freedom from mechanical injuries, insects/pests damage or disease attack. After that, the selected fruits were coded and transported immediately in perforated paper cartons to the laboratory for the texture profile analysis. The fruits were arranged in single layer per carton to prevent relaxation and other mechanical damages being done to the fruits during the course of the transportation. At the laboratory, the fruits were further inspected to remove any fruit showing any sign of mechanical damage.

Texture profile analysis, (TPA)

Texture profile analysis, (TPA), of the intact tomatoes fruits was done by using the Warner-Bratzler shear force (WBS) method, with the aid of the Universal Testing Machine (Testometric model) with accuracy of 0.001N. The operating parameters were as follows: cylindrical puncture probe diameter = 8 mm, preload speed of 200 mm/min and test-speed = 105 mm/min. For each test, a single tomato fruit was placed into the machine, and was punctured with a probe to a set depth, and returned to the point where pre-load was reached on the first cycle. The probe then waited for a short time which is supposed to represent the time between chews, before the second puncture (Nyorere and Uguru, 2018a).

The probe depth was set to 50% of each fruit's diameter because; deeper depth can caused fluctuations that will significantly affect some TPA parameters, like hardness, gumminess and chewiness. From the force–time graph of two cycles developed by the machine, the following TPA parameters; hardness, springiness, adhesiveness, gumminess, stringiness and chewiness were determined. At each maturity stage, the TPA of the fruits was done at ambient temperature (22 ± 5°C) with ten replications.

The hardness (also expressed as the firmness) of the tomato fruit is the maximum force the fruit can withstand during the first compression (Szczesniak, 1990). Springiness (elasticity) is the distance of compression cycle during the second bite, i.e. rate at which the deformed tomato fruit reforms; adhesiveness is the rate at which the tomato flesh pulls away from probe or roof of mouth/teeth (organoleptic); Chewiness is the energy required to chew the tomato fruit until it is ready for swallowing; Stringiness is the distances tomato fruit flesh extends before it breaks away from probe or roof of mouth/teeth (organoleptic); Gumminess (mealy, pasty and gummy) is the energy required to disintegrate a semisolid food until it is ready to swallow (Steffe, 1996; Nyorere and Uguru, 2018a).

Electrical parameters determination

The electrical conductivity and pH analysis of the tomatoes fruits were measured at the Biomaterial Laboratory of Delta State Polytechnic, Ozoro, Nigeria. Tomato fruit pH was determined with digital pH meter (model PHS-25), manufactured in China. The tomato fruit was blended with Panasonic Blender (model MX GM1011), manufactured in Japan, and the juice extracted. The pH meter probe was inserted into the juice and reading was read from the screen of the pH meter. The pH meter was standardized by using a buffer solution prior to use for each reading.

Electrical conductivity of the tomato fruit was measured using an electronic electrical conductivity meter (model DDS-307) manufactured in China. The tomato fruit was blended with Panasonic Blender (model MX GM1011), manufactured in Japan, and the juice extracted, using standard method. The electrical conductivity meter probe was inserted into the juice, and reading was read from the screen of the meter at constant temperature of 25°C, because electrical conductivity is a function of temperature. The electrical conductivity meter was standardized by using distil water prior to use for each reading. All tests were replicated five times and the average value recorded.

Statistical analysis

The experimental design of this research was based on ten replicates of the entire process and tomatoes fruits for each process were harvested approximately 10 days apart. The analysis of variance (ANOVA) of TPA parameters of samples with different maturity stage and storage period was applied in order to determine if there was a significant difference between the means (P ≤0.05). Duncan Multiple Range Test was used to compare the means using IBM SPSS statistic software, version 20.

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) of the effect of maturity stage on the textural qualities of the tomatoes fruits is presented in (Table 1). The ANOVA results showed that maturity stage and tomato cultivar had significant (P ≤0.05) on all the six textural parameters tested for in the tomato fruit. In addition, the interaction of maturity stage by tomato cultivar had significant (P ≤0.05) on all the six textural parameters tested for in the tomato fruit. The values of the textural parameters together with their mean separation are presented in (Table 2). From the results presented in (Table 1 and Figures 1 to 5), there were established distinctions between the texture qualities of the seven tomato cultivars studied in this research, as they decreased with increase in maturation.

Firmness

From the results presented in (Table 2), there was significant decline in the tomato fruit pericarp (skin) firmness across the seven tomato cultivars investigated, as the fruit maturity progresses from breaker stage to ripe red stage. This portrayed major changes within the fruit's cellular makeup during maturity.

In addition, *Tropimech* tomato fruits recorded the highest skin firmness (average of 53.16 N) among the seven tomato cultivars studied, while *Ibadan Local* had the lowest skin firmness (average of 29.23 N), as presented in (Figure 1). As shown in (Figure 1), no significant (P ≤0.05) difference existed between the skin firmness of *Ibadan Local*, *Beske* and *Roma* tomatoes fruits; while significant (P ≤0.05) difference existed between the skin firmness of *Ibadan Local*, *Beske*, *Roma*, *UC82B* and *Tropimech* tomato fruits. Softening of the tomato fruit skin firmness during maturity result from the drop in the fruit's turgor pressure, increase moisture moisture content and polysaccharides degradation of the fruit's pericarp (Ealing, 1994; Femenia *et al*., 1998). According to Nirupama *et al*. (2010), the decline in fruit's firmness can be accredited to the cell wall carbohydrate metabolism during storage which further increases the susceptibility of the fruit to decay. Our results are in similarity with the study of Barrett *et al*. (1998). Barrett *et al*. (1998) researched on eight tomato varieties fruits in two lots, (i) those that were picked green and allowed to ripen, and (ii) that that were picked red ripe. They reported that, in five cultivars the green fruit were firmer (about 12 Ibs) than the red (about 2.72 Ibs), while in two other cultivars the green and red fruit did not differ significantly in firmness (Barrett *et al*., 1998).

Springiness

As presented in (Table 2), the tomatoes fruits springiness changes with maturity, decreasing as the tomatoes fruits matured from the breaker stage to the ripe red stage. The average highest springiness (1.101) was recorded in the *Tropimech* tomato fruits, while the lowest springiness (0.67) was recorded in the *Nadira* tomato fruits, as shown in (Figure 2). The chart in (Figure 2) showed that the springiness of *Nadira* and *UC82B* looks statistically similar, also the springiness of the *Beske* and *Kelvin* tomatoes fruits looked statistically similar. It can be deducted from the results that lesser mastication energy will be required to chew the tomato fruit flesh as maturity progressed from the breaker stage to the ripe red stage. Fruit with high springiness is elastic and has the ability to return to its original shape after compression; whereas, fruit with low springiness is unable to return to its original shape after compression, thereby resulting in tissue damage (Ansari *et al*., 2014). Similar results were reported by Soltani *et al*. (2011) on plantain and banana fingers, where they observed general declined in the textural qualities of banana fingers during maturity. According to Barrett *et al*. (1998) tomatoes fruits pericarp and inner epidermis strength decreased maturation of the fruits, more rapidly during the green to late colour break stages, and then slowed down to the ripe red stages; while the skin strength fell more progressively.

Chewiness

The effect of the fruit maturity stage and tomato cultivar on the fruit's chewiness are expressed in (Table 2) and (Figure 3). The increased maturity of the tomato fruit reduced the fruit's chewiness across the seven tomato

Table 1. Analysis of variance of effect of tomato cultivar and maturity stage on the textural qualities of tomato fruit.

Source	Firmness	Springiness	Chewiness	Gumminess	Stringiness	Adhesiveness
C	9.43E-22*	1.47E-10*	3.61E-09*	1.94E-05*	9.71E-25*	1.03E-25*
M	6.03E-34*	9.86E-1*1	8.22E-19*	2.36E-19*	1.63E-10*	2.13E-16*
C x M	1.11E-03*	8.86E-07*	3.93E-04*	5.06E-04*	8.81E-15*	1.11E-09*

C = Cultivar; M = maturity stage; * = significant at p ≤ 0.05; ns = not significant

Table 2. Textural profile characteristics of tomato fruit at different stages of maturity.

Tomato cultivar	Maturity stage	Firmness (N)	Springiness	Gumminess (N)	Chewiness (N)
Tropimech	Breaker	65.91^{a}±4.76	1.27^{d}±0.05	5.01^{j}±0.28	7.42^{h}±0.75
	Pink	54.61^{b}±6.92	1.15^{e}±0.04	3.41^{k}±0.60	3.93^{g}±1.79
	Ripe Red	33.98^{c}±5.55	0.89^{f}±0.11	2.45^{l}±0.31	2.32^{l}±0.44
Nadira	Breaker	52.48^{a}±8.29	0.85^{d}±0.18	4.19^{j}±0.55	6.68^{g}±0.82
	Pink	39.32^{b}±2.82	0.72^{e}±0.03	3.67^{k}±0.17	5.37^{h}±0.87
	Ripe Red	27.00^{c}±1.15	0.46^{f}±0.02	1.05^{l}±0.02	1.31^{l}±0.16
Beske	Breaker	43.07^{a}±5.17	1.19^{d}±0.23	2.38^{j}±0.43	3.96^{g}±0.78
	Pink	31.55^{b}±1.31	0.96^{e}±0.08	1.82^{k}±0.55	3.23^{h}±0.52
	Ripe Red	21.34^{c}±1.84	0.83^{f}±0.09	0.93^{l}±0.31	1.73^{l}±0.59
Ibadan	Breaker	41.08^{a}±6.85	0.88^{d}±0.10	6.53^{j}±2.23	8.60^{g}±1.32
Local	Pink	32.32^{b}±6.53	0.88^{e}±0.27	3.13^{k}±2.18	4.97^{h}±2.29
	Ripe Red	18.30^{c}±1.27	0.67^{f}±0.07	1.31^{l}±0.22	1.95^{l}±0.16
Kelvin	Breaker	49.14^{a}±3.57	1.22^{d}±0.16	2.93^{j}±0.10	4.31^{g}±0.37
	Pink	40.71^{b}±2.69	0.95^{e}±0.11	2.19^{k}±0.19	3.64^{h}±0.26
	Ripe Red	24.66^{c}±3.60	0.60^{f}±0.10	1.51^{l}±0.26	2.44^{l}±0.42
UC82B	Breaker	57.53^{a}±2.52	0.92^{d}±0.09	4.93^{j}±0.60	6.52^{g}±1.85
	Pink	46.49^{b}±2.34	0.72^{e}±0.01	4.08^{k}±0.37	5.70^{h}±2.52
	Ripe Red	32.49^{c}±2.66	0.64^{f}±0.04	2.16^{l}±0.04	2.88^{l}±0.24
Roma	Breaker	41.25^{a}±0.70	0.83^{d}±0.07	4.17^{j}±0.45	5.29^{g}±0.46
	Pink	33.73^{b}±2.59	0.67^{e}±0.04	3.24^{k}±0.23	4.16^{h}±0.30
	Ripe Red	20.20^{c}±4.33	1.09^{f}±0.29	1.88^{l}±0.50	2.79^{l}±0.75

Values are mean ± standard deviation; Rows with the same common letter superscript are not significantly different at (p ≤0.05), according to Duncan Multiple Range Test.

Table 2. Continued

Tomato cultivar	Maturity stage	Adhesiveness (N.s)	Stringiness (mm)
Tropimech	Breaker	6.82^{a}±0.93	30.11^{d}±0.90
	Pink	5.63^{b}±0.17	29.37^{e}±0.34
	Ripe Red	4.14^{c}±0.51	27.31^{f}±0.70
Nadira	Breaker	16.01^{a}±2.52	19.84^{d}±3.14
	Pink	12.09^{b}±0.45	17.45^{e}±0.23
	Ripe Red	3.24^{c}±1.22	15.55^{f}±0.17
Beske	Breaker	1.83^{a}±0.33	30.89^{d}±2.90
	Pink	1.33^{b}±0.12	27.90^{e}±2.19
	Ripe Red	0.56^{c}±0.27	27.07^{f}±0.45
Ibadan	Breaker	7.76^{a}±1.53	30.08^{d}±2.13
Local	Pink	6.81^{b}±1.67	28.57^{e}±0.27
	Ripe Red	3.79^{c}±0.79	19.18^{f}±0.28
Kelvin	Breaker	11.02^{a}±0.83	33.61^{d}±1.09
	Pink	8.88^{b}±1.06	28.41^{e}±2.79
	Ripe Red	5.93^{c}±0.70	18.95^{f}±0.52
UC82B	Breaker	33.41^{a}±11.24	17.84^{d}±0.55
	Pink	22.06^{b}±0.83	17.27^{e}±0.04
	Ripe Red	8.95^{c}±0.79	15.18^{f}±1.21
Roma	Breaker	17.32^{a}±1.33	19.90^{d}±1.61
	Pink	13.20^{b}±1.76	17.53^{e}±1.19
	Ripe Red	8.71^{c}±2.33	15.99^{f}±1.29

Values are mean ± standard deviation; Rows with the same common letter superscript are not significantly different at (p ≤0.05), according to Duncan Multiple Range Test.

cultivars investigated (Table 2). As shown in (Figure 3), statistical difference occurred between the chewiness of the various tomato cultivars studied. From the results, there was no significant (p ≤0.05) difference between the chewiness of *UC82B* and *Ibadan Local* tomatoes fruits; likewise, there was no significant (p ≤0.05) difference between the chewiness of *Kelvin* and *Beske* tomatoes fruits (Figure 3). But significant (p ≤0.05) difference existed between the chewiness of *Tropimech* and *Ibadan Local* tomatoes fruits, same with *Kelvin* and *Nadira* tomatoes fruits.

The chart in (Figure 3) showed that *UC82B* had the highest chewiness (3.74 N) among the seven tomato cultivars studied, while *Beske* had the lowest chewiness (1.71 N) among the seven tomato cultivars investigated. The variation between the chewiness of the tomato cultivars can be attributed to the difference in their mesocarp cellular makeup. Similar trends were reported by Tapre and Jain, (2012) and Nyorere and Uguru, (2018b) on the chewiness of banana and plantain fingers during maturity.

Tapre and Jain, (2012) reported that the chewiness of banana finger declined from 4.8 N to 2.68 N during the ripening. While Nyorere and Uguru, (2018b) in their study reported that the chewiness of plantain's finger decreased from 2 N to 1.7 N as the plantain finger matured from maturity stage 5 to stage 7. Tomato fruit's texture is an important quality characteristic which is essential in the consumer's evaluation (Brashlyanova *et al*., 2014).

Gumminess

In reference to the results presented in (Table 2), tomatoes fruits gumminess decreased with increase in maturation. The results further showed that the tomato cultivars differed in their fruits' gumminess during maturity, in all tomatoes fruits evaluated (Table 2), with *Ibadan Local* being the highest among the seven tomato cultivars, and *Beske* being the lowest. The average gumminess of the tomatoes fruits varied from 8.62 N for the *Ibadan Local* fruits at the breaker stage to 1.73 N for the *Beske* fruits at the red ripe stage.

The decrease in the tomatoes fruits gumminess during maturity may be attributed to the biological processes that the fruits undergo during maturation. Nyorere and Uguru, (2018b) evaluated the gumminess of plantain (*Musa paradisiaca* Linn) finger during maturity by means of puncture tests. They reported that the gumminess of the plantain finger significantly decreased during maturity. Chauhan et al. (2006) recorded persistence decline in the gumminess of banana (Var. *Pachbale*) during the ripening. But on the contrary Nyorere and Uguru, (2018a) reported increment in the gumminess of cucumber (Var. *Nandini*) fruits during maturity. This variation in the fruit's gumminess among the tomato cultivars can be attributed to the differences in the mesocarp structural make-up and moisture content tomato fruit during maturation.

Adhesiveness

Considering the tomatoes fruits adhesiveness during maturity, the results (Table 2) showed that fruits' adhesiveness decreased as the maturation. The adhesiveness values of the tomatoes fruits in the seven tomato cultivars generally decreased from breaker stage to the ripe red stage (Table 2). From the adhesiveness values presented in (Table 2), the *UC82B* tomatoes fruits were observed to have the highest average adhesiveness of 21.47 N.s among the seven tomato cultivars studied, while the *Beske* tomatoes fruits had the least average adhesiveness of 1.27 N.s. This result showed that the force used to overcome the adhesive forces between the *Beske* tomato fruit, and the surface of the other material in contact with is very low, compared to the other tomato cultivars. The decline in the adhesiveness of the tomatoes fruits may be attributed to the changes in the textural structure of the fruits as they ripened caused my maturity process. Fruit adhesiveness is highly affected by the differences in the physical and biochemical characteristics of the fruit cuticle (Jackman and Stanley, 1995). According to Jackman and Stanley, (1995) and Požrl *et al*. (2010) loss of cell adhesion of fruits is a processes associated with ripening of the fruits, and it is closely related to cell wall structure and composition.

Stringiness

In relation to stringiness of the tomatoes fruits, the results presented in (Table 2) shown that the stringiness of the tomatoes fruits decreased with maturity across the seven tomato cultivars. From the statistical results presented in (Figure 4), *Beske* tomato fruit had the average highest stringiness (29.28 mm), while the lowest stringiness (17.76 mm) was recorded in the UC82B tomato fruits (Figure 4). The chart in (Figure 4) showed that no significant (P ≤0.05) differences existed between the stringiness of *Tropimech* and *Beske* tomatoes fruits. In the same vein, no significant (P ≤0.05) differences existed between the stringiness of *Kelvin* and *Ibandan Local* tomatoes fruits, but significant (P ≤0.05) differences existed between the stinginess of *Roma* and *Nadira* tomatoes fruits. As seen in the results, the parenchymatous tissue of the tomato fruit becomes more gelatinous with fruit maturation; this happens as the results of the cell walls becoming thinner and eventually ruptures to produce the locular gel as stated by Barrett *et al.,* (1998). According to Jackman, (1995) these factors; fruit cultivar, maturity at harvest, degree of ripeness, chemical composition of the cell wall, farming practices

Table 3. Electrical conductivity and pH of tomatoes fruits.

Tomato cultivar	Maturity stage	pH	Electrical conductivity (S/m)
Tropimech	Breaker	3.75[a]±0.24	0.508[a]±0.055
	Pink	4.33[b]±0.23	0.437[b]±0.014
	Ripe Red	4.91[c]±0.15	0.382[c]±0.013
Nadira	Breaker	3.48[a]±0.20	0.499[a]±0.017
	Pink	4.34[b]±0.29	0.449[b]±0.015
	Ripe Red	4.89[c]±0.16	0.397[c]±0.016
Beske	Breaker	3.49[a]±0.16	0.506[a]±0.011
	Pink	4.33[b]±0.18	0.471[b]±0.009
	Ripe Red	4.71[c]±0.07	0.409[c]±0.010
Ibadan Local	Breaker	3.74[a]±0.19	0.517[a]±0.013
	Pink	4.41[b]±0.23	0.468[b]±0.014
	Ripe Red	4.63[c]±0.18	0.407[c]±0.013
Kelvin	Breaker	3.97[a]±0.15	0.501[a]±0.011
	Pink	4.51[b]±0.05	0.463[b]±0.011
	Ripe Red	4.94[c]±0.11	0.402[c]±0.014
UC82B	Breaker	3.91[a]±0.04	0.493a±0.012
	Pink	4.52[b]±0.19	0.452[b]±0.003
	Ripe Red	4.74[c]±0.11	0.392[c]±0.011
Roma	Breaker	3.71[a]±0.16	0.494[a]±0.006
	Pink	4.36[b]±0.12	0.457[b]±0.011
	Ripe Red	4.68[c]±0.22	0.385[c]±0.031

Values are mean ± standard deviation; Rows with the same common letter superscript are not significantly different at (p ≤0.05), according to Duncan Multiple Range Test.

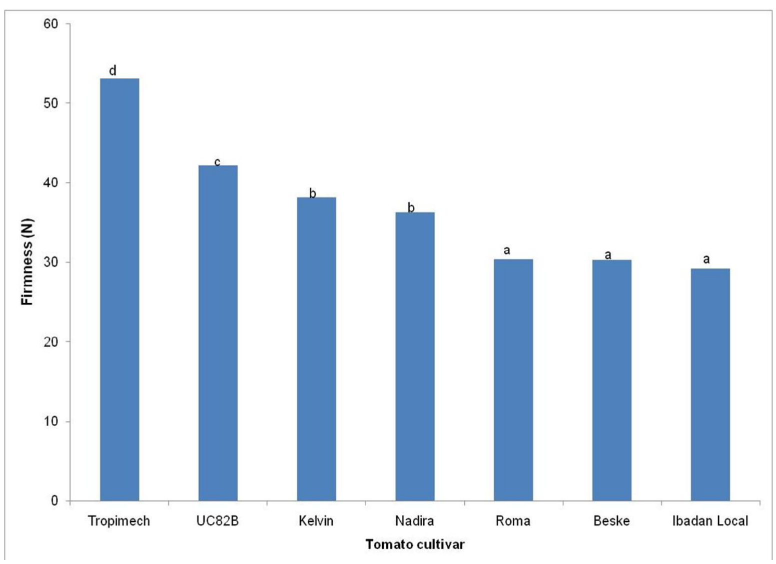

Figure 1. Firmness of raw tomatoes fruits as evaluated by puncture test. Columns with the same common latter are not significantly different (p ≤0.05) according to Duncan's multiple ranges test.

(application of certain hormones, amount of water and degree of sun exposure), turgor pressure (as dictated by water status, presence of salt gradients and/or cell membrane integrity), the amount and distribution of intercellular spaces, testing temperature and environmental stresses (drought, salinization, water, chilling, freezing) prior to harvesting period affect the textural properties of tomatoes fruits (Barrett *et al.*, 1998). The results showed that tomato fruits harvested at the breaker and the pink stage were able to withstand more

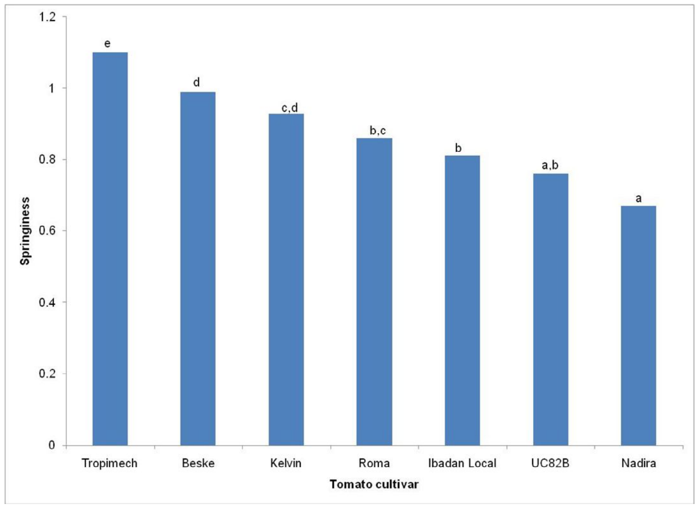

Figure 2. Springiness of raw tomatoes fruits as evaluated by puncture test.
Columns with the same common latter are not significantly different (p ≤0.05) according to Duncan's multiple ranges test.

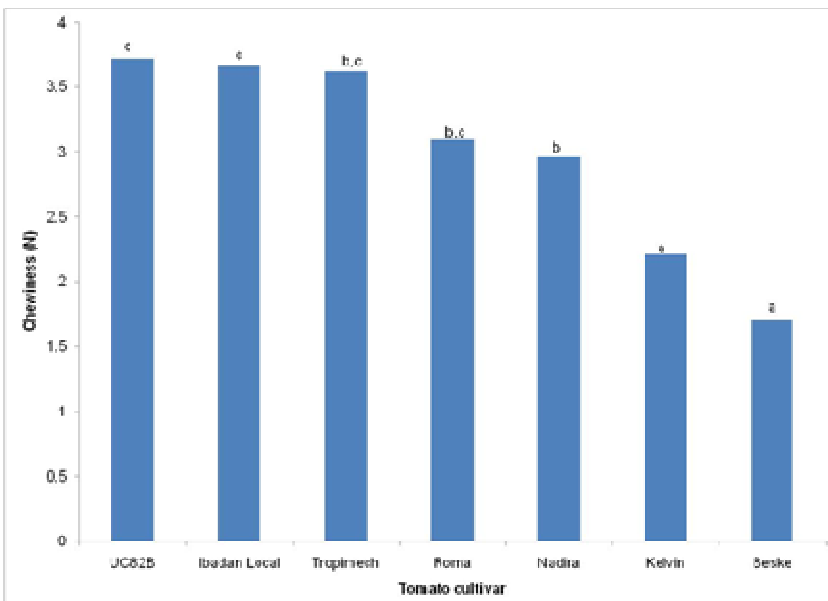

Figure 3. Chewiness of raw tomatoes fruits as evaluated by puncture test. Columns with the same common latter are not significantly different (p ≤0.05) according to Duncan's multiple ranges test.

mechanical injuries than the fruits harvested at the ripe red stage.

Fruit pH and electrical conductivity

The results of the tomatoes fruits pH and electrical conductivity with their separated means are presented in (Table 3). The results showed that the fruits pH increased gradually during maturity across the seven tomato cultivars. In addition, the results showed that the electrical conductivity of the tomatoes fruits decreased gradually during maturity, in all the seven tomato cultivars evaluated (Table 3). From the results it can be seen that the acidity of tomatoes fruits was highly dependent on

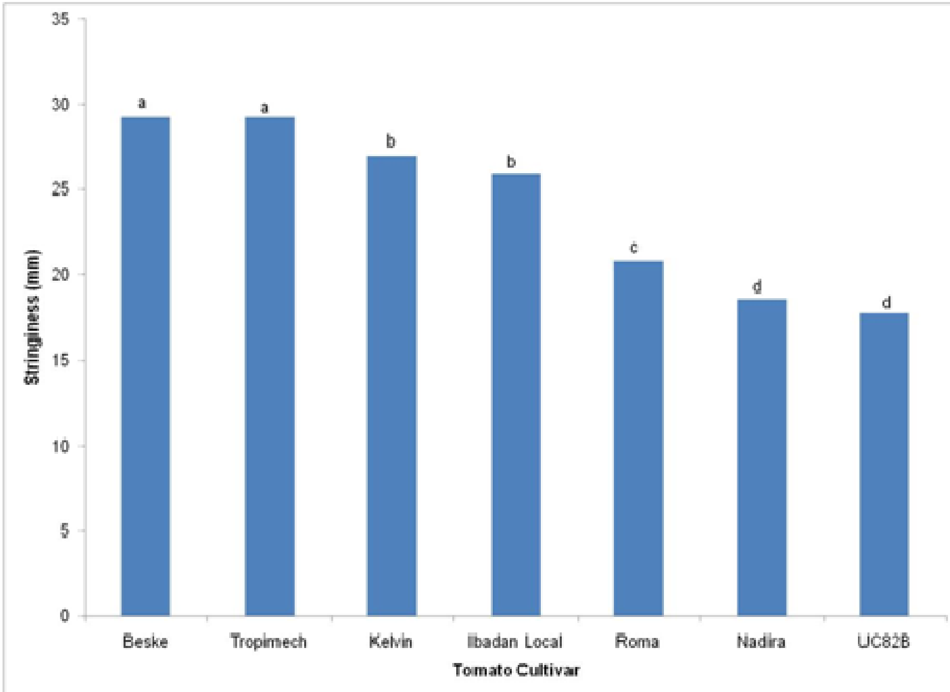

Figure 4. Stringiness of raw tomatoes fruits as evaluated by puncture test.
Columns with the same common latter are not significantly different (p ≤0.05) according to Duncan's multiple ranges test.

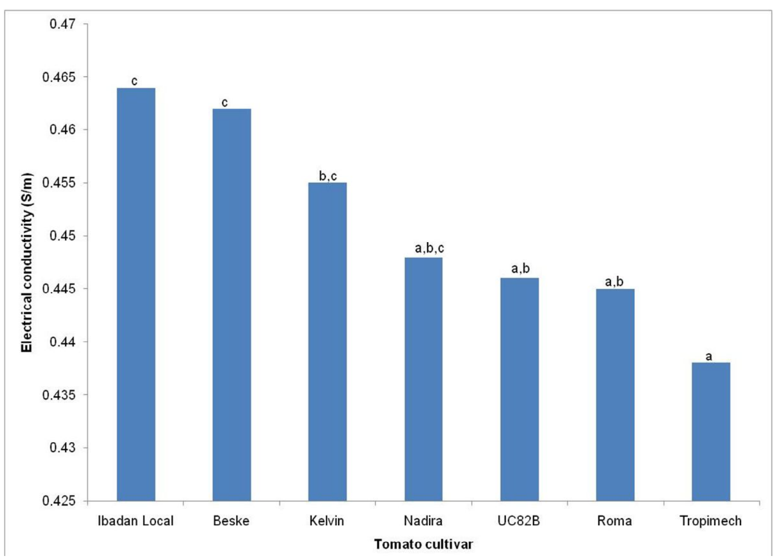

Figure 5. Electrical conductivity of raw tomatoes fruits.
Columns with the same common latter are not significantly different (p ≤0.05) according to Duncan's multiple ranges test.

their degree of maturity. The fruits harvested at the breaker stage had the highest level acidity than the fruits harvested at the ripe red stage. The chart in (Figure 5) showed that the electrical conductivity of *Ibadan Local* and *Beske*, *Roma* and *UC82B* tomatoes fruits looks statistically similar. But significant (P ≤0.05) difference occurred between the electrical conductivity of *Beske* and *kelvin*, *Roma* and *Tropimech.* Generally, *Ibadan Local* tomato fruit had the average highest electrical conductivity (0.464 S/m), while *Beske* the average lowest electrical conductivity (0.438 S/m) among the seven tomato cultivars studied (Figure 5). Alhassan *et al*. (2014) reported similar results, when the pH value of a fully ripe citrus fruit. Heflebower and Washburn, (2010) investigated the pH of five tomato cultivars and reported that the pH ranged between 3.83 and 4.22 for the breaker tomatoes fruits, and between 3.92 and 4.32 for the ripe red tomatoes fruits. Thorne and Efiuvwevwere, (1988) reported that organic acids and their derivatives affect tomato flavor, as well as storage and processing quality, and depend on cultivars and ripeness, storage and processing conditions.

Conclusion

This study was carried out to investigate the effect of maturity stage on the textural properties and chemical properties of seven Nigeria grown tomato cultivars. The results showed that tomato cultivar and maturity stage had significant effect on the textural qualities and the chemical properties of the tomatoes fruits. Among the tomato cultivars, all the textural qualities studied decreased with increase in maturity stage. From the results, the *Tropimech* tomato fruits had the highest average skin firmness (53.16 N), while *Ibadan Local* had the lowest average skin firmness (29.23 N); *Tropimech* tomato fruits recorded the average highest springiness (1.101), while *Nadira* tomato fruits, recorded the lowest springiness (0.67). The *UC82B* tomatoes fruits recorded the highest average adhesiveness (21.47 N.s), while the *Beske* tomatoes fruits had the least average adhesiveness (1.27 N.s). Tomatoes fruits harvested at the breaker stage had the lowest pH and highest electrical conductivity across the seven tomato cultivars studied. While tomatoes fruits harvested at the ripe red stage had the highest pH and lowest electrical conductivity across the seven tomato cultivars studied in this research. The results obtained from this research will be useful to food processors, as the data will assist in effective planning of harvesting, transportation, processing operations of tomatoes fruits.

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Authors' Declaration

We declared that this study is an original research by our research team and we agree to publish it in the journal.

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