Nile Valley University Publications
Nile Journal for Agricultural Sciences (NJAS)
(ISSN: 1585 – 5507)
Volume 10, NO. 02, 2025
nilevalley.edu.sd

Physiochemical assessment of released tomato (*Solanum lycopersicum* L) varieties to Sudanese environment

Amani Ahmed Abd-Elwahid Gabr, Ahmed Elgaili Ibrahim, Mohamed Suliman Mustafa and Abdelazim Mohamed Ali
Faculty of Agriculture, Nile Valley University
Corresponding author: aalgaili@gmail.com

Received : 21. Aug. 2025 **Accepted :29. Oct. 2025** **Published : 23. Nov. 2025**

Abstract

This study aimed to perform comparative evaluation for physical, chemical, nutritional and sensory parameters with three released tomato (Lycopersicon esculentum) varieties for Sudan climate; Castle Rock, Dar-mali and Zahrat Elneel. There was some variation observed in chemical and physical characteristics between the three varieties. The three varieties were medium-size to small, round to ellipsoid, red to orange-red in colour. In terms of chemical composition, the dry matter was 6.0, 5.7 and 5.0%, total soluble solids was 5.1, 5.1 and 4.5%, ash was 5.48, 5.8 and 7.78%, fiber was 9.72, 6.43 and 14.66%, total sugars were 20.94, 20.0 and 20.3%, titratable acidity was 0.26, 0.2 and 0.3% for Dar-mali, Castle Rock and Zahrat Elneel, respectively. The level of lycopene and β-carotene were assessed in the three varieties in the levels of 12.877-15.63 and 7.92-8.87 mg/100g, respectively. The mineral composition of tested varieties was obtained and compared to their RDA. The most abundant mineral was K (299-416 mg/100g) which was more than its RDA. Appropriate amounts of Na and Mg were found. However, varieties were low in Ca. Among micro-elements, appropriate amounts of Mn, Cu, Fe and Zn were also detected. Fruits were organoleptically assessed. The three tested fruits gained high level of overall acceptability (91.1-92.71%).

Keywords: *Tomato, Released varieties, Physiochemical, Sensory evaluation*

تقييم فيزيوكيميائي لثلاث من اصناف الطماطم أجيزت للبيئة السودانية

(Lycopersicon esculentum)

أماني أحمد عبد الواحد جبر، أحمد الجيلي إبراهيم، محمد سليمان مصطفى، وعبد العظيم محمد علي

كلية الزراعة، جامعة وادي النيل

المستخلص

هدفت هذه الدراسة إلى إجراء تقييم مُقارن للخصائص الفيزيائية والكيميائية والتغذوية والحسية لثلاثة أصناف من الطماطم (Lycopersicon esculentum) اجيزت تتناسب مناخ السودان هي: كاسل روك، دار مالي، وزهرة النيل. لوحظ وجود بعض التباين في الخصائص الكيميائية والفيزيائية بين الأصناف الثلاثة. تراوحت أحجام الأصناف الثلاثة بين المتوسطة والصغيرة، من دائرية إلى بيضاوية، وتراوح لونها بين الأحمر والبرتقالي المحمر. من حيث التركيب الكيميائي، بلغت نسبة المادة الجافة 6.0%، و5.7%، و5.0%، وإجمالي المواد الصلبة الذائبة 5.1%، و5.1%، و4.5%، والرماد 5.48%، و5.8%، و7.78%، والألياف 9.72%، و6.43%، و14.66%، والسكريات الكلية 20.94%، و20.0%، و20.3%، والحموضة القابلة للمعايرة 0.26%، و0.2%، و0.3% في أصناف دار مالي، وكاسل روك، وزهرة النيل، على التوالي. قُيِّم مستوى الليكوبين وبيتا كاروتين في الأصناف الثلاثة بمستويات تراوحت بين 12.877 و15.63 ملغم/100 غرام، و7.92 و8.87 ملغم/100 غرام، على التوالي. وتم الحصول على محتوي العناصر للأصناف المختبرة ومقارنته بالكمية الغذائية الموصى بها. كان البوتاسيوم (299-416 ملغ/100 غرام) أكثر المعادن وفرةً، وهو ما يفوق الكمية اليومية الموصى بها. وُجدت كميات مناسبة من الصوديوم والمغنيسيوم. ومع ذلك، كانت الأصناف منخفضة في الكالسيوم. ومن بين العناصر الدقيقة، وُجدت أيضًا كميات مناسبة من المنغنيز والنحاس والحديد والزنك. قُيّمت الثمار حسيًا. وقد حظيت الثمار الثلاث المختبرة بقبول عام مرتفع (91.1- 92.71 %).

الكلمات المفتاحية: *طماطم، أصناف مُصدرة، كيميائي حيوي، تقييم حسي*

Introduction

Tomato (*Solanum lycopersicum* L.), which is indigenous to South America, is now grown worldwide for its edible fruits and considered as one of the most popular vegetable fruits in the world. It is an economically important crop grown in tropical and sub-tropical parts of the world. Tomato is a good source of fiber and believed to be health promoter and supplementary sources of minerals and vitamins as well as disease fighting phyto chemicals especially lycopene within human diets (Charanjeet *et al.* 2004). It is consumed either fresh or processed in products such as tomato juice, soup, paste, puree, ketchup, sauce and salsa (Helyes *et al.*, 2009; Ray *et al.*, 2011).

China, India, Turkey, United States and Eygypt are the leading tomato growing countries (FAOSTAT, 2025). In Sudan, tomatoes constitutes one of the most important vegetables were it is used for fresh consumption, cooked, paste or dried. Tomato is the second important vegetable crop in the Sudan after onion with an estimated production of 633000 metric tons during 2022.

At present, there are a large number of tomato varieties with a wide range of morphological and quality characteristics which determine their use (Fernandez-Ruiz *et al.*, 2011; Pinela *et al.*, 2012). In Sudan, releasing new varieties is progressing for different uses and to fit mainly climatic conditions of the country. Therefore, it is becoming increasingly important to assess their nutritional value in terms of content.

The main objective of the present study is to evaluate three released tomato fruit varieties, “Castle Roke”, 'Dar-malli" and "Zhrat Elneel" for their physicochemical and nutritional properties.

Materials and Methods

Materials:

Fresh, fully ripped tomato fruits from three varieties; Castle Rock, Dar-mali and Zahrat Elneel, were collected from El-Hudaiba Research Station Farm, River Nile State, season 2014-2015. Hundred fruits selected randomly from each cultivar. Five fruit selected for the physical analysis.

Physical characteristics:

Fruit colour:

The fruit color was determined using a Hue Chart (Fig. 1) as described by Glynn (2005).

Fruit shape:

The fruit shape for the three varieties was assessed according to Visa *et al*. (2014) who classified tomato fruit shapes into 9 categories (classes) as: Class1 round; class2 rectangular; class3 ellipsoid; class4 flat; class5 heart; class6 obovoid; class7 oxheart; class8 long rectangular; class9 long) (Fig.2).

Fruit weight:

Five fruits taken randomly in three lots from ripe fresh fruits were weighted on a top pan balance and average weight of fruit was calculated (in 0.00 grams).

Fruit volume

Fruit volume was estimated by water displacement method described by Jahromi *et al*. (2007) and Ibrahim (2009). Individual fruits were lowered in a measuring cylinder containing distilled water and the water displaced recorded.

Fruit density

The average whole tomato fruit density (g/cm^3) was estimated as the average fruit weight/ average fruit volume.

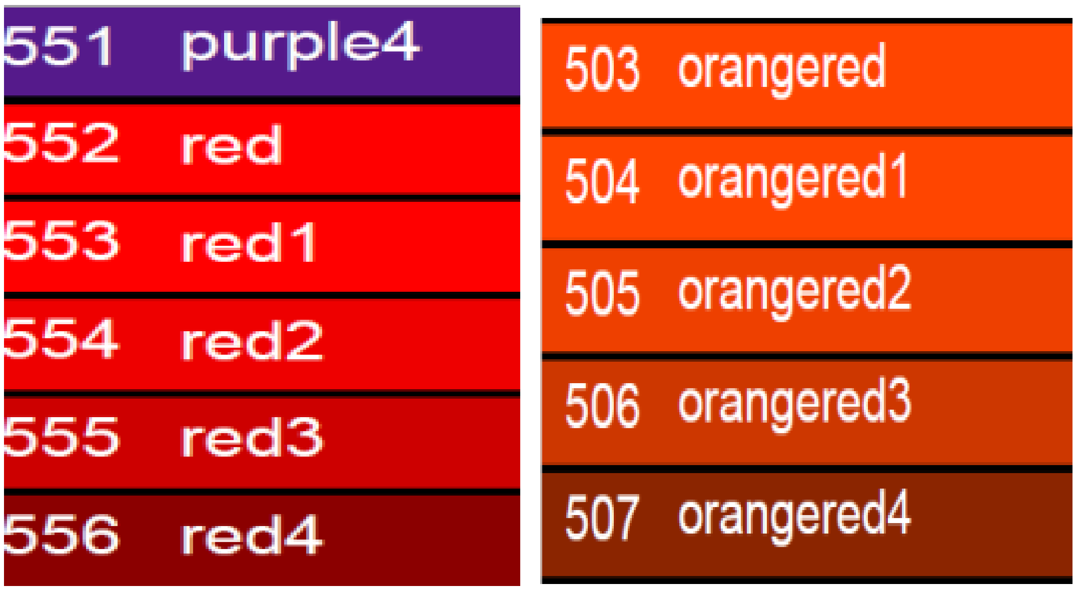

Fig.1: Hue chart for tomato fruits

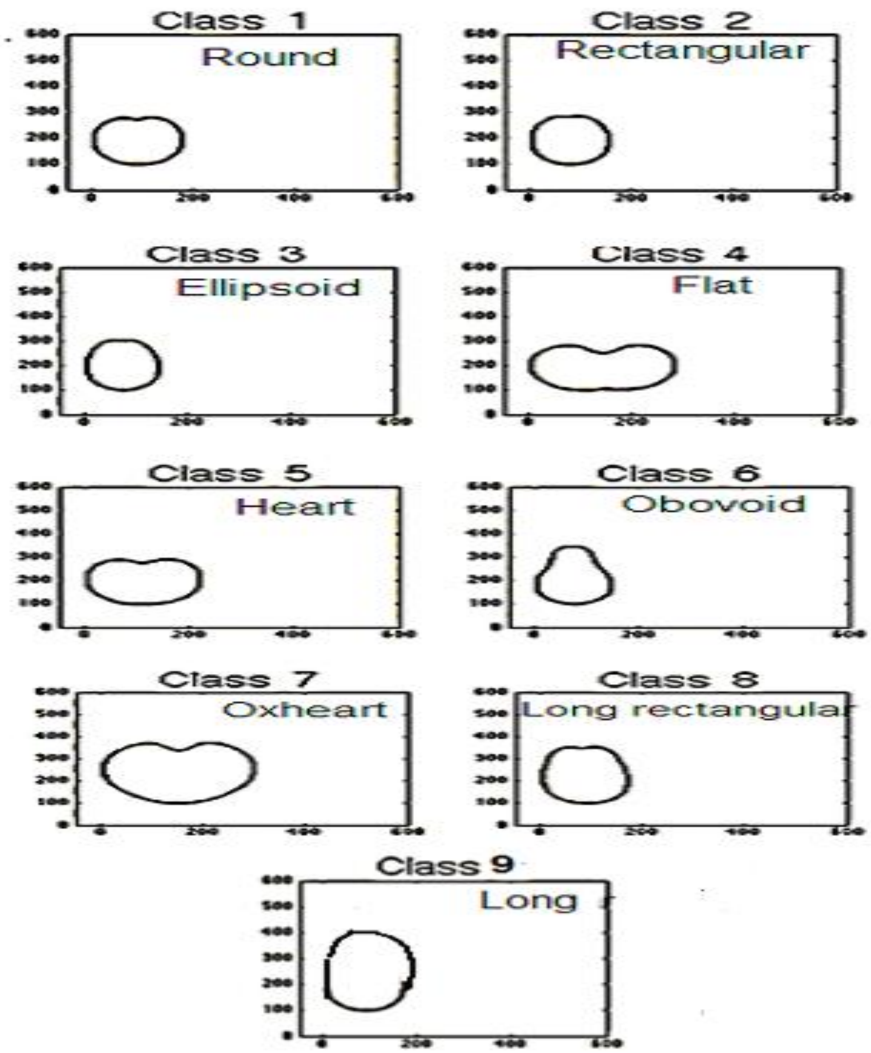

Fig.2. Tomato fruit shape classes

Fruit dimensions:

Fruit length and width

Fruit dimensions (length, width) for the individual fruits were measured by a vernier caliper (0.00cm).

Geometric mean diameter, surface area and sphericity

Geometric mean diameter (Dg), fruit mean surface area (S) and sphericity (φ) values were found using the following formulae (Jahrome *et al.*, 2007 and Ibrahim, 2009):

Geometric mean diameter (Dg) = $(LW^2)^{0.33}$

Fruit surface area $S = \pi Dg^2$

Fruit sphericity (φ) = $(LW^2)^{0.33} / L$

Where:

L= mean fruit length (cm),

W= mean fruit width (cm)

Circumference

The fruits circumference for the three varieties was assessed in cm using a cotton thread.

Fruit pulp and skin thickness

The thickness of pulp and skin was measured by a vernier caliper (0.00cm).

Fruit cavities

Fruit cavities (locules) were counted in each fruit sample. The mean of five fruits was deduced.

Number of fruits per kilogram

The mean number of fruits per kg for each tomato cultivar was obtained.

Seed weight

The weight of seeds for a single fruit was obtained using a digital balance (0.00g). The seeds% for each fruit was obtained as follows:

$$\text{Seed \%} = \frac{\text{Weight of seed in fruit} \times 100}{\text{Weight of fruit}}$$

Taste index

Taste index is estimated by using Brix and acidity (Suarez *et al.*, 2008):

$$\text{Taste index} = \frac{\text{Brix degree} + \text{Acidity}}{20 \times \text{acidity}}$$

Fruit shelf life

Fruit shelf-life was determined in terms of fruit firmness, curliness, weight loss% and decay according to the methods applied by Jan *et al.* (2012) and Parker and Maalekuu (2013) with some modifications. Fruits of three tomato varieties (castle rock, Darmally and Zahrat-Elneel) stored at room temperature (about 27^0C) and in refrigerator (10-12^0C) for 1-15 days. Quality parameters; fruit weight loss, fruit firmness, curliness and decay were evaluated.

Fruit firmness

Fruit firmness was determined by feeling how hard or soft the fruit was. The fruits were rated on a scale of 1-5 with; 5-4= very firm, 4-3= firm, 3-2= soft, 2-0 = very soft

Fruit weight loss%

Five fruits in each variety were separated for weight loss test. The initial weight of each fruit was noted daily with the help of electronic balance. The average loss of weight was calculated at day's intervals. The weight loss (%) was calculated as:

$$\text{Weight loss \%} = \frac{\text{Weight of fresh fruits} - \text{Weight after interval} \times 100}{\text{Weight of fresh fruit}}$$

Fruit curliness

Fruit curliness was determined visually. The fruits were rated on a scale of 1-4;

1-2= non, 2-3= very little, 3-4= little, 4 to above= much

Decay or rotting

Fruit decay was determined by the visual observation. Development of spots on the fruit's skin and softening and rotting of fruits were rated on a scale of 1-4;

1-2= non, 2-3= very little, 3-4= little, 4 to above = much

Chemical analysis of the fruit

Moisture content

Moisture content of each sample was determined by drying method according to AOAC (2000):

$$\text{Moisture Content \%} = [W_1 - W_2) \backslash (W_1)] \times 100$$

Where

W_1 = Original weight of sample

W_2 = Weight of sample after drying.

Fruit juice pH

The pH of the fruit juice was determined by a pH-meter (in 5 fruits juice) in triplicate.

Total soluble solids (^{0}Brix)

The amount of total soluble solids (TSS) of samples was determined by a hand refractometer.

Total ash

Crude ash was determined as described by AOAC (2000). Incineration is accomplished with a muffle furnace at 550 0C using porcelain crucibles.

$$\text{Total ash\%} = \frac{(Wt_1 - Wt_2) \times 100}{\text{Weight of sample}}$$

Where:

Wt=Weight of crucible with ash.

Wt_2= Weight of empty crucible.

Sugars content

The diluted extract of the tested sample was firstly clarified by adding lead acetate to precipitate non sugars, then excess lead acetate precipitated by adding potassium oxalate and filtration followed to remove all non-sugars.

Reducing sugars

The reducing sugars (fructose and glucose) were assessed by titrating the clarified, de-leaded sample extract with mixed Fehling A and B solutions using Lane and Eynon volumetric method (AOAC, 2000 official method). The reducing sugars content was calculated according to the following equation:

$$\text{Reducing sugar \%} = \frac{\text{factor for Fehling's solution} \times \text{Dilution} \times 100}{\text{Titration} \times \text{Sample weight}}$$

Total sugars

Twenty five ml of the clarified solution was inverted by HCL (50%) at 70^{0}C for 24hrs. The solution was neutralized by NaOH (40%) and assayed for total sugars using Lane and Eynon method (AOAC 2000 official method).

Non reducing sugars

Non-reducing sugars were estimated as:

$$\text{Non-reducing sugars \%} = [\text{Total sugar} - \text{Reducing sugar}] \times 0.95$$

Crude fiber

Crude fibre was analyzed according to the AOAC (2000) as the residual of sequential extraction of a defatted sample with 1.25% H_2SO_4 and 1.25% NaOH. The insoluble residue is collected by filtration, dried, weighed and ashed to correct for mineral contamination of fiber residue.

$$\text{Crude fiber } \% = [(W_1-W_2)/S] \times 100$$

Where

W_1 = Weight of sample before ignition

W_2 = Weight of sample after ignition

S = Original Weight of sample.

Titratable acidity

Titratable acidity was measured by the titrimetric method (AOAC, 2000). The filtered tomato fruit extract (juice) was titrated with 0.1N sodium hydroxide in the presence of phenolphthalein as indicator. Titratable acidity of tomato was expressed as % citric acid:

$$\frac{\text{Titre} \times \text{Normality of alkali} \times 64 \times \text{Volume made up} \times 10}{\text{Ml of filtrate taken for titration} \times \text{wt of sample} \times 100}$$

Carotenoids and lycopene

Carotenoids and lycopene in tomato ethanol/acetone fresh pulp extract were determined following the procedure described by Nagata and Yamashita (1992) and Barros *et al.* (2010), measuring the absorbance at 453, 505, 645, and 663 nm. Contents were calculated according to the following equation:

Lycopene (mg /100ml) = A663 + A645+ A505- A453.

β- Carotene (mg/100ml) = A663- A645- A505+ A453.

(A663, A645, A505 and A453 are absorbance reading at 663, 645, 505 and 453nm)

Minerals

Eight minerals namely; potassium, sodium, calcium, manganese, zinc, copper, magnesium and iron in tomato fruit were determined using atomic absorption method. The ash was dissolved in a 5ml HCl (20%), filtered and the volume of the solution was completed to 50ml. Samples were transferred to atomic absorption to determine the minerals:

$$\text{The element in } \mu g/g = \frac{R \times V}{Wt}$$

Where:

R= reading in mg/g

V= volume of dilution

Wt = weight of sample

Tannins content

Tannins in tomato juice were estimated using Lowenthal-Procter method as applied by Tafti and Fooladi (2006) and Ibrahim (2009). Tomato fruit diluted extract was titrated vs 0.1N $KMNO_4$ with the presence of indigo Carmine indicator. A blank sample (free of tannins) which was prepared by treating fruit diluted extract with gelatin/charcoal was also titrated versus 0.1N $KMNO_4$ to correct for the actual tannin content.

Sensory evaluation of fruits

The sensory evaluation for the parameters of shape, taste, odor, color, firmness and overall acceptability was carried by a panel of 10 judges according to the ranking test method as described by Ibrahim *et al*. (2014). The fruit for the three varieties under the study were evaluated by the panelists for the described parameters by giving a score. The data were tabulated and statistically analyzed to compare the means.

Statistical analysis

Analysis of variance was used to test the significance of treatment effects. LSD Test was used to compare treatment means using the computer program .The data were analyzed by Two-way ANOVA. Significance levels were portrayed (Statistics version 8.0 Software Inc., 1986).

Results and discussion

Tomato fruits physical properties:

Fruit dimensions:

Fruit length and width

The three investigated varieties were significantly different in terms of their fruit length (Fig.3). Castle Rock has the longest fruit (6.46cm), followed by Dar-mali (5.8cm) and Zhrat Elneel (5.36 cm), respectively. While in terms of fruit width, the three varieties were not significantly different. According to USDA (1991) tomato fruits classification (Table 1), Dar-mali and Zhrat Elneel could be classified as medium size fruits, while Castle Rock could be classified as small size fruit.

Geometrical mean diameter:

No significant difference (P≥0.05) in fruit geometrical diameter between the three varieties as illustrated in Fig.4. Among the three varieties, however, Dar-mali possessed the larger geometrical diameter (5.91cm).

Fruit circumference (cm):

As illustrated in Fig.5. The fruit circumference of the three varieties (Dar-mali, Zhrat Elneel and Castle Rock) ranged between 19.18 and 20cm, with no significant difference between them (P≥0.05).

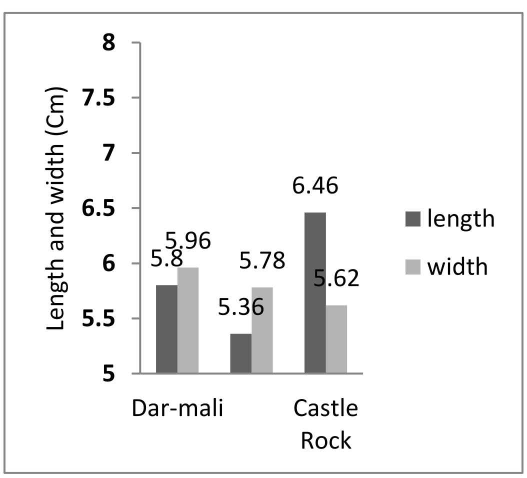

Fig.3. Tomato fruits length and width (cm)

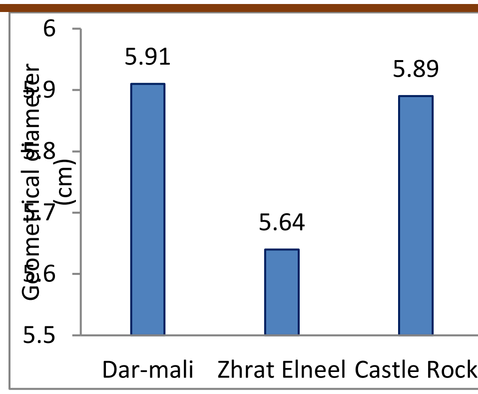

Fig.4. Tomato fruit geometrical diameter (cm)

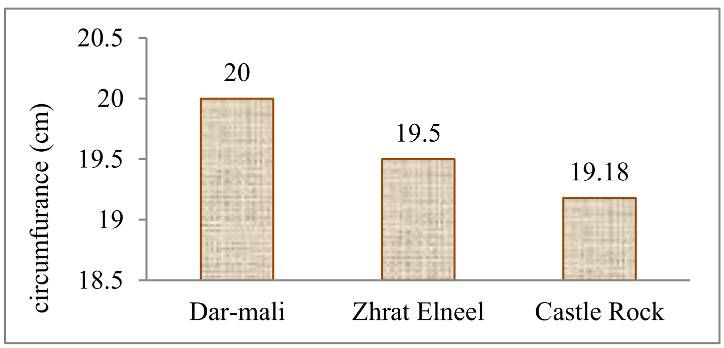

Fig.5. Tomato fruits circumference

Fruit shape and sphericity

Fruit sphericity is an important quality criterion for both consumer and food processers. Sphericity of the three tested tomato varieties was graphically depicted in Fig.6. Among the three varieties, Zhrat Elneel and Dar-mali were rather spherical (1.05 and 1.02, respectively), while Castle Rock was less spherical (0.91). According to Visa *et al.* (2014) shape classification (Fig.3) Dar-mali could be classified as round with little flatness, Zhrat Elneel nearly round, while Castle Rock was ellipsoid (Plate 1).

Fruit surface area

Measuring fruit surface area aid in the estimation of drying, cooling, coating and packing media and machine design (Ibrahim, 2009). It is evident from Fig.7 that Dar-mali has the biggest surface area (109.73cm^2) followed by Castle Rock (108.99cm^2) and Zhrat Elneel (99.93 cm^2), respectively.

Fruit color:

In reference to Hue chart (Fig.1), it could be established that the skin color of Dar-mali fruit was red (552), Zhrat Elneel red1 (553) and Castle Rock was orange-red (503). The red color is good maturity index for harvesting and processing, and as a major factor in the consumer preference for fresh tomatoes.

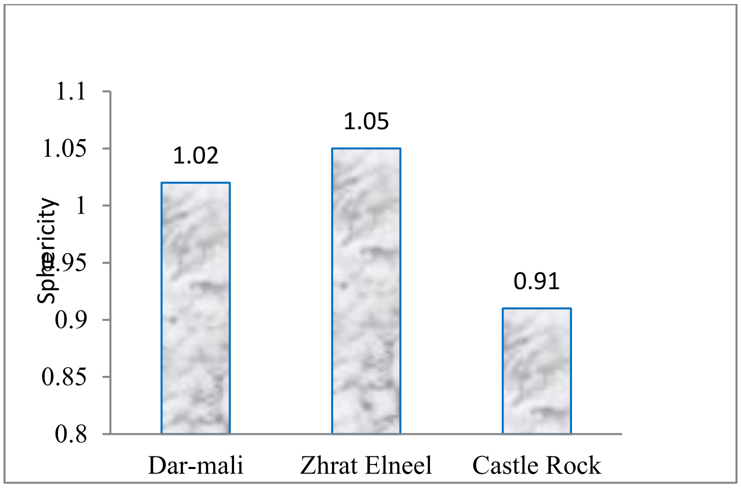

Fig.6. Tomato fruits sphericity

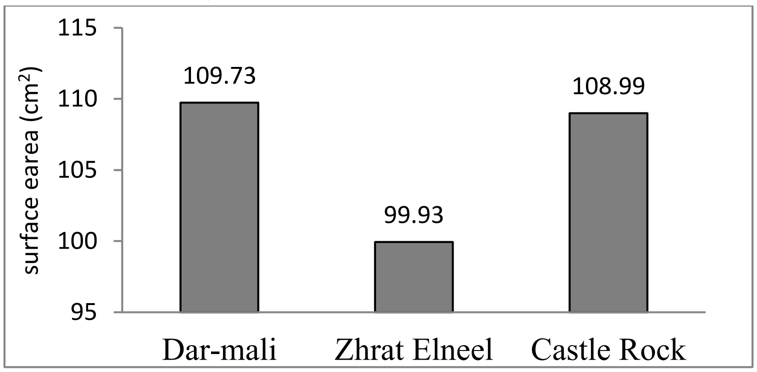

Fig.7. Tomato fruit surface area (cm^2)

Plate 1: Tomato fruit profile

Fruit weight and fruit number per kg

The fruit number/Kg and fruit weight were illustrated in Fig.8. and Fig.9. Among the three varieties, Dar-mali variety recorded heavier fruit weight and least fruit number/Kg, followed by Castle- Rock, while Zhrat Elneel showed the lowest value. There was no significant difference between the 3 varieties in fruit weight and fruit number/Kg. These results are in accordance with those obtained by Suarez *et al.* (2008) in 5 tomato varieties with weight ranged between 61.5 and 195 g. Ben Aoun *et al*. (2013) recorded far different values (324.25-15.5g).

Fruit volume

The fruit volume of the three tested tomato varieties ranged between 144.4 and 123.2cm^3 (Fig.10). However, Castle Rock had the largest volume, followed by Dar-mali and Zhrat Elneel, respectively. Hawever, differences were not significant (P≥0.05. These results were higher than the findings of Sulieman *et al*. (2011) regarding Sudanese tomato genotypes with fruit volume ranging between 86.3 and 72.8 cm^3. This could be attributed to the inherited properties, climate and cultural practices.

Fruit density

Results in Fig. 11 revealed that the fruit density of the three tested varieties ranged between 0.9-0.98gm/cm^3. Zahrat Elneel fruit was the densest (0.98 g/cm^3), followed by Dar-mali (0.97g/cm^3) and Castle Rock (0.9g/cm^3), respectively.

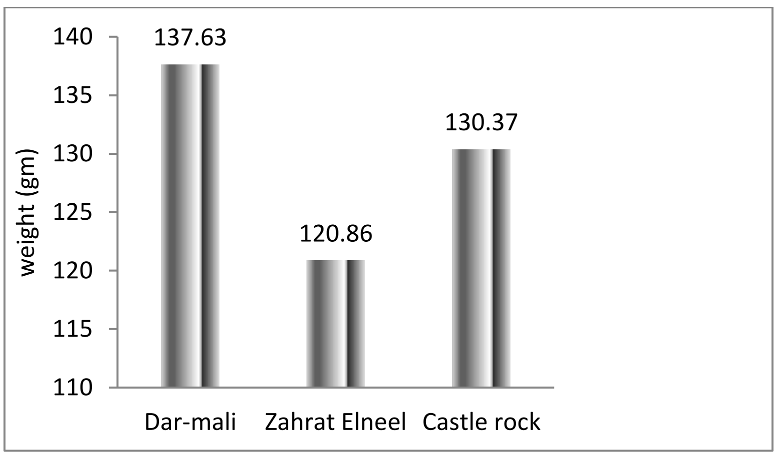

Fig.8. Fruit weight (gm)

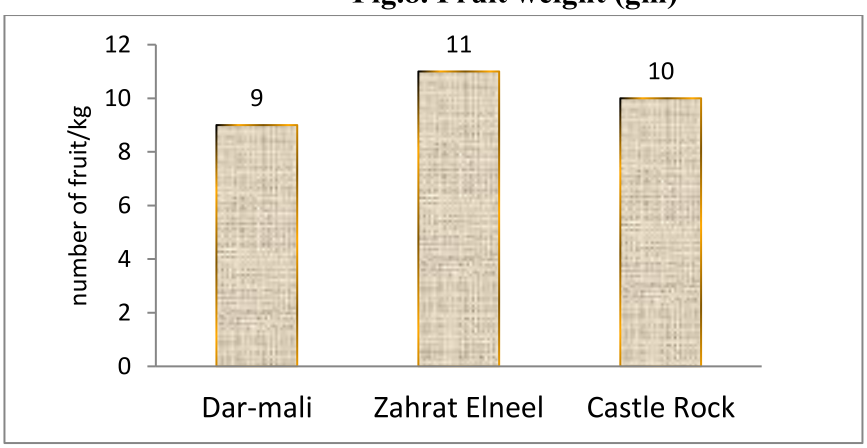

Fig.9. Number of fruit per kg

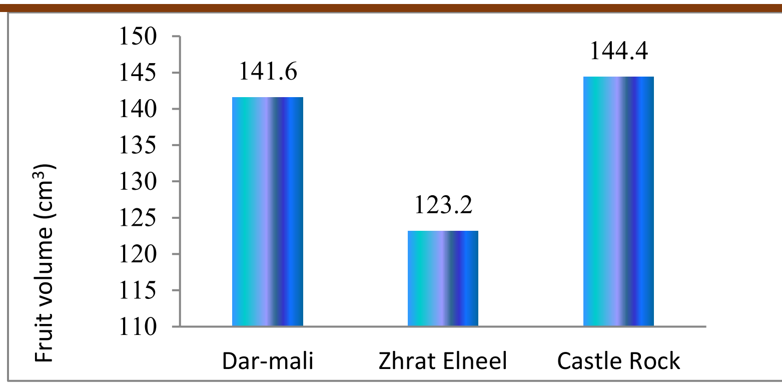

Fig.10. Tomato fruit volume (cm^3)

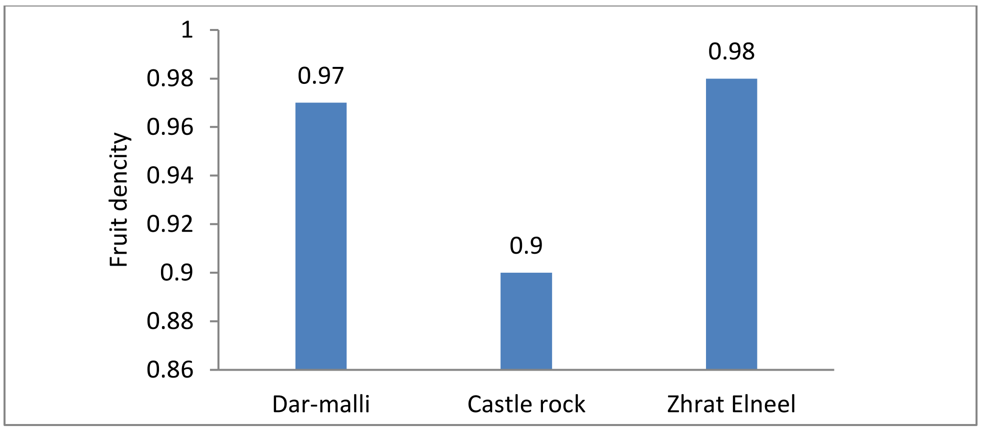

Fig.11. Whole tomato fruit density (g/cm^3)

Seed weight

The average seeds weight/fruit of the tested varieties ranged between 0.1 and 0.4g. Dar-mali variety had significantly heavier seeds, than Zhrat Elneel and castle Rock (Fig.12). However, the less seed weight of the cultivar, the higher will be the product yield for processing tomatoes.

Number of cavities (locules)/fruit

Number of fruit cavities of the three varieties was significantly different ($P<0.05$). Zhrat Elneel had the highest mean number of cavities per fruit (4.4), followed by Dar-mali (3.4) and Castle Rock (2.8), respectively (Fig.13). Ho and Hewitt (1986) classified tomato fruits according to their locules number. They described fruits with 2 locules as cherry and plum or pear types (processing tomatoes), fruits with four-six locules as commercial varieties for fresh marketing and more than six were large beefsteak type for garden or greenhouse production. Accordingly, varieties under this study could be classified as followed:

1- Dar-mali as fresh market and processing tomatoes
2- Zhrat Eneel as fresh market variety
3- Castle Rock as processing tomatoes

Pulp thickness (cm)

The flesh thickness of Dar-mali, Castle Rock and Zhrat Elneel varieties was 0.42, 0.34 and 0.42cm, respectively with no significant deference (P>0.05). Fleshy fruits are considered as processing varieties (Fig. 14).

Skin thickness (cm)

As shown in Fig. 15, the fruit skin thickness of the three tomato varieties was similar (0.034cm). However, the thicker fruit skin needs more technical effort in milling and filtration operations. The skin also produces more processing waste.

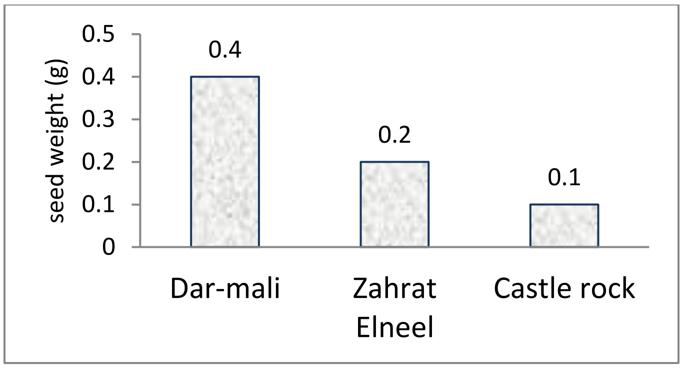

Fig.12. Seed weight (g)/fruit

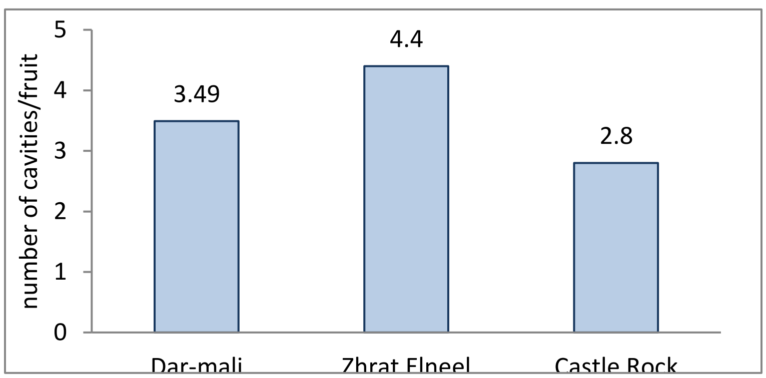

Fig.13. Number of cavities per fruit

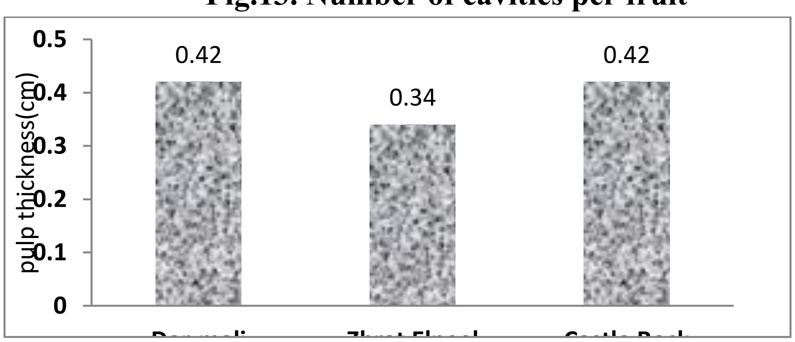

Fig.14. Pulp thickness (cm)

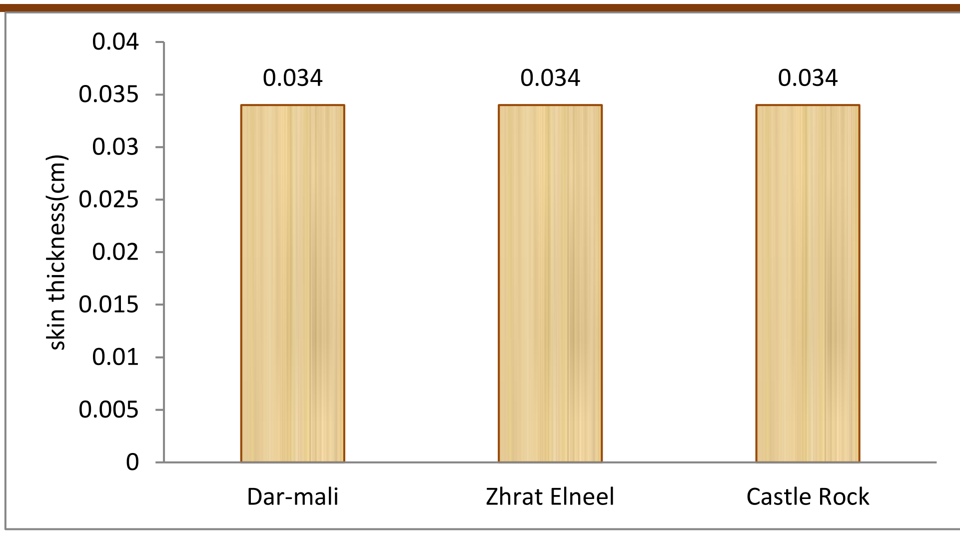

Fig.15. Skin thickness (cm)

Chemical characteristics

The chemical composition of tomato fruit depends on genetics, environment, varieties, plant growth regulators, ripening stage at harvest, training and irrigation system, and on post-harvest conditions (Borguini and Da Silva, 2009; Marsic *et al.*, 2011; Vinkovic *et al.*, 2011).

Moisture content

The fruit moisture content of the three varieties apparently ranged from 94 to 95% (Fig.16). These results were nearly in agreement with the findings of Sulieman *et al*. (2011). He found that the moisture content of 4 Sudanese tomato genotypes ranged between 92-94%. Also Gupta *et al*. (2011) found that the moisture content of tow tomato varieties was 94.45 and 92.27%.

Ash content

As shown in Fig.17., Zhrat Elneel possessed higher ash level (7.7%) than Castle Rock (5.8%) and Dar-mali (5.48%). These results are within the range of the findings of Suarez *et al.* (2008), Gupta *et al.* (2011) and Abdullahi *et al.* (2016).

Fiber content

Dietary fibers in tomato and other fruits had high physiological value as they can reduce constipation and fight many diseases. It is evident from results that the three tested varieties possessed appropriate quantities of fibers (Fig.18.). Among the three varieties, Zhrat Elneel possessed significantly higher fiber level (14.67%) than Dar-mali (9.72%) and Castle Rock (6.43%). Gupta *et al*. (2011) found that the crude fiber content in 2 tomato genotypes was 7.58 and 8.69 %.

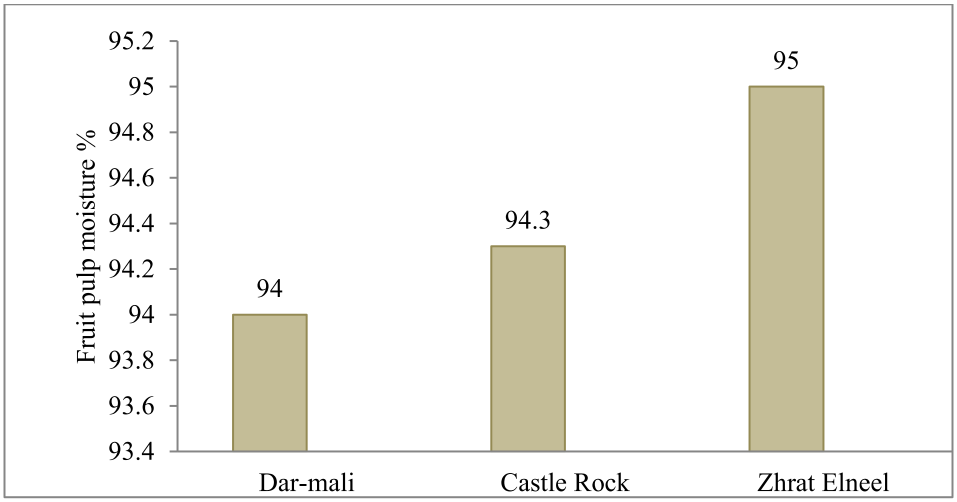

Fig.16. Moisture content%

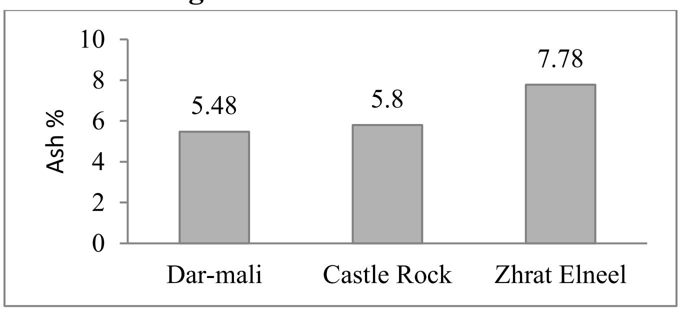

Fig.17. Tomato fruits ash content

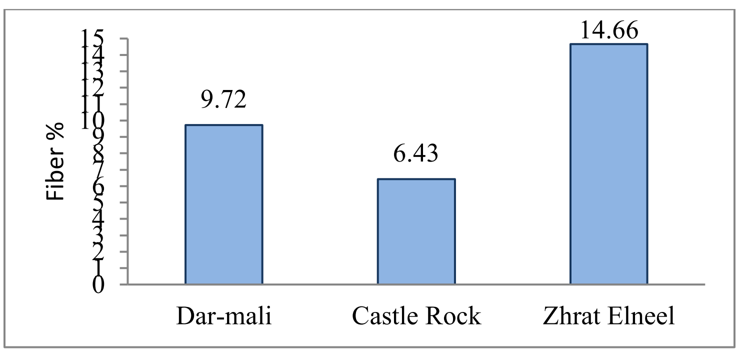

Fig.18. Tomato fruits fiber content (%)

Total soluble solids

Soluble solids (TSS) are a key parameter in tomato products such tomato paste and Ketchup. As illustrated in Fig.19, the mean total soluble solids in the fruit of Dar-mali, Castle Rock and Zhrat Elneel were 5.1, 5.1 and 4.5%, respectively. However, Difference (P<0.05) were not significant. These results are lower than Caliman *et al.* (2010) findings, but nearly agreed with the findings of Gupta *et al*. (2011) and lies within the range of Violeta *et al*. (2013) and slightly higher than the values obtained by Ilic *et al*. (2013) in conventional system tomatoes.

Fruit Juice pH

Results revealed that the pH of Dar-mali, Castle Rock and Zhrat Elneel fruits was 5.04, 5 and 4.5, respectively (Fig. 20). These are slightly higher than Ben Aoun *et al*. (2013) findings in 13 traditional tomato varieties (4. 21-4.49).

Titratable acidity

Acidity tends to decrease with fruits maturation while the sugar content increases (Raffo *et al.*, 2002). Fig.21. showed that the mean of the titratable acidity (as citric acid) were 0.26, 0.2 and 0.3 in Dar-mali, Castle Rock and Zhrat Elneel, respectively. These results are lower than the findings of Gupta *et al*. (2011) (0.54 and 0.50). The differences in fruits acidity could be attributed to variety dependent and soil characteristics.

Taste index

Among the three varieties, Castle Rock had the highest value of taste index (1.48) followed by Dar-mali (1.24) and Zhrat Elneel (1.05), respectively (fig.22). Felföldi *et al*. (2022) grade each trait on a hedonic scale, with grades from 1 ("Extremely Dislike") to 9 ("Extremely pleasant"). the tomato is considered as having little taste (not tasty) if taster judged it not tasty. Accordingly, the tested tomato fruits (with taste index higher than 0.85) could be considered as "tasty". These results are higher than the findings of Ilic *et al*. (2013).

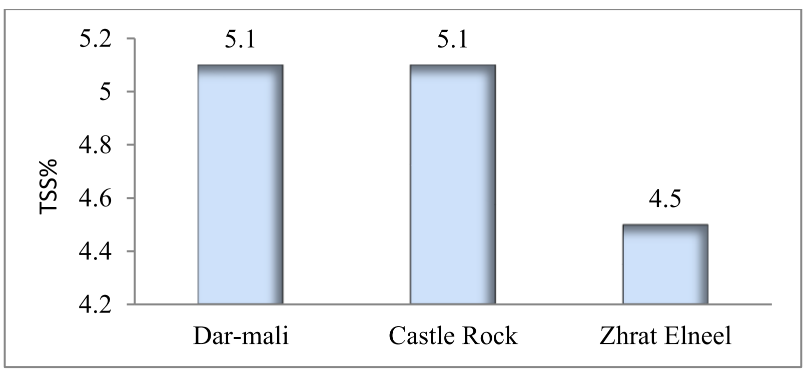

Fig.19. Total soluble solids (TSS%)

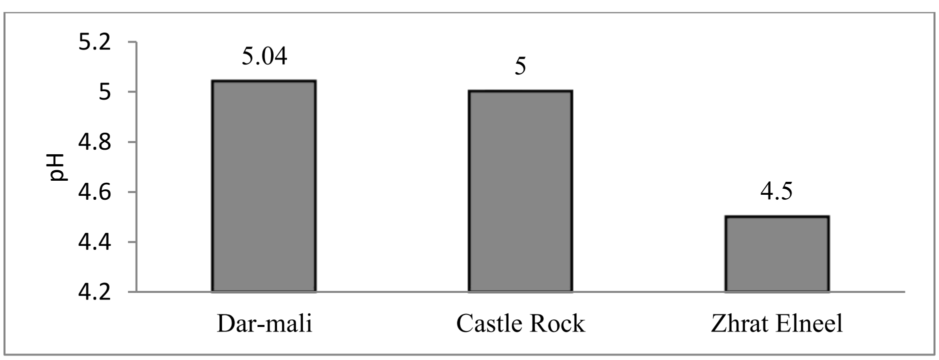

Fig.20. The pH values of tomato fruit pulps

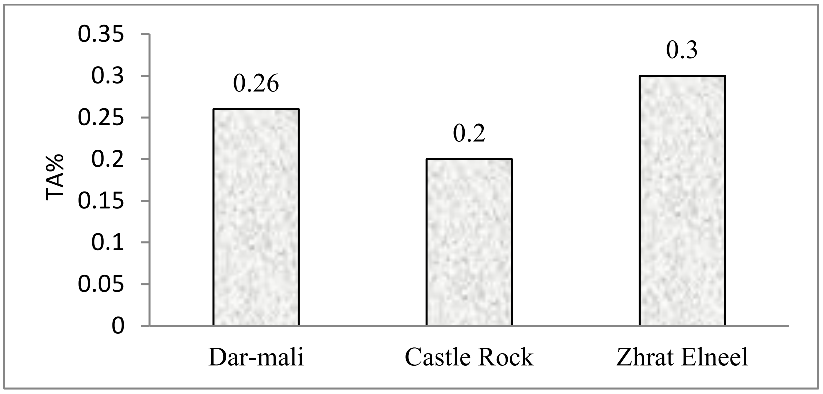

Fig.21. Titratable acidity (TA) %

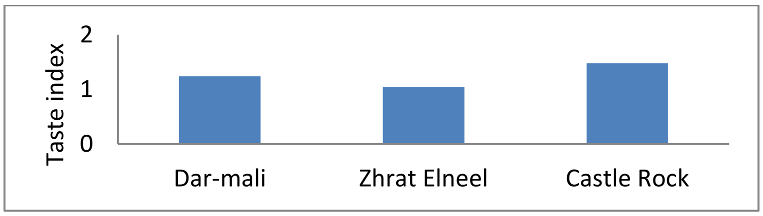

Fig. 22 Tomato fruits taste index

Sugars content

Dar-mali varieties contained the highest percentage of total sugars (20.83) followed by Zhrat Elneel (20.3) and Castle Rock (20.0), respectively (Fig. 23). Most sugars in tested verities are of reducing type. Reducing sugars were 20.1, 20.06 and 19.3% in Dar-mali, Zhrat Elneel and Castle Rock, respectively. The non-reducing sugar highest level was found in Zhrat Elneel (0.74%). The three varieties are significantly different in their sugars content, except in reducing sugars. Results obtained were lower than those obtained by Gupta *et al*. (2011). However, Suarez *et al.* (2008) stated that the mean content (wet basis) of glucose in 5 tomato varieties was 0.93% and fructose 1.02%.

Lycopene and β - carotene

The level of lycopene and β-carotene in the three tested tomato varieties was assessed spectrophotometrically and portrayed in Fig.24.

The lycopene content of the three varieties was significantly different. The highest level of lycopene (mg/100g, wet basis) was found in Zhrat Elneel (15.63), followed by Dar-mali (13.353) and Castle rock (12.877). These results were higher than the findings of Nguyen and Schwartz (1999), Alda *et al*. (2009), Violeta *et al*. (2013) and Suwanaruang (2016).

Level of β-carotene was 8.87, 7.92 and 8.07mg/100g in Dar-mali, Castle Rock and Zhrat Elneel varieties, respectively with high significant difference between them. However, these results were higher than the results obtained by Gupta *et al*. (2011).

Tannin content

The polyphenols (tannins) present in tomato is the principal constituent responsible for providing the typical astringent taste, odour and colours. As shown in Fig.25 the level of tannins in studied fruit samples ranged between 0.7 and 0.9%. Among the three varieties, Castle Rock contains higher level of tannins compared to other varieties with significant deference ($p < 0.05$).

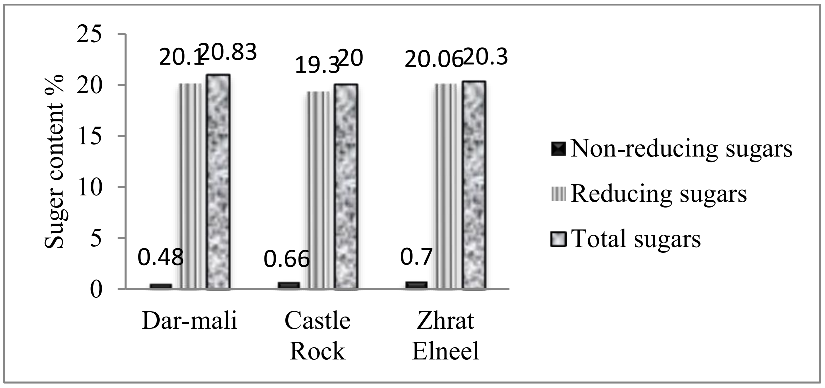

Fig.23. Tomato fruits sugar content %

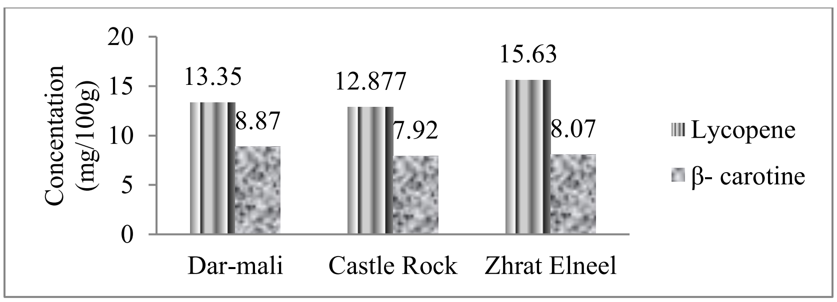

Fig.24. Lycopene and β carotene

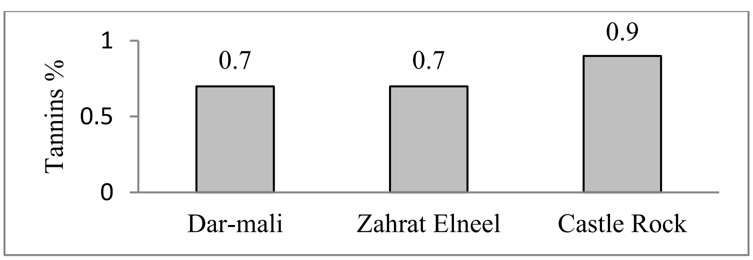

Fig.25. Tannin concentration %

Fruit mineral composition

The mineral content of tomato fruits was obtained and compared to the recommended daily allowances (RDA) set for each mineral by the American Society for Nutritional Sciences (ASNS, 2004) and the Joint FAO/WHO Expert Committee (FAO/WHO, 1989) (Fig28). Further, the %cover and the quantity (g) of tomato fruit which is expected to cover the recommended dietary allowances of individual minerals were also calculated (Table 3).

Macro-elements

Potassium (K)

Potassium is the most abundant mineral element in tomato fruits under this investigation. Its level is 399, 299, 416 mg/100g in Dar-mali, Castle Rock and Zhrat Elneel, respectively. These values were higher than the data reported by USDA (2010) (292 mg/100g), Daniela *et al*.(2013), within the range of Violeta *et al*. (2013) and far higher than Ilic (2013).

Further, the concentration of this element in each of the three varieties exceeds the recommended dietary intake (RDA= 100mg/100g) (Fig. 28) by 299-416%. However, eating 24-33g of a tomato fruit will be satisfactory to meet the RDAs of this element.

Sodium (Na)

Results (Fig.28) showed that sodium concentration was 66.6, 62.2 and 53.3mg/100g in Dar-mali, Castle Rock and Zhrat Elneel, respectively. These values are close or within the values obtained for local tomato varieties by Sulieman *et al*. (2011) and higher than those obtained by Abdullahi *et al*. (2016) and Violeta *et al*. (2013).

It is evident from results that sodium content of the three varieties was lower than its RDA (120-500mg/100g) (Fig.28). Further, the level of sodium in 100g of Dar-mali, Castle Rock and Zhrat Elneel tomato fruits will cover 13.32- 55.5, 12-52 and 11-44% of the upper and lower limits of sodium RDA, respectively. Furthermore, it is expected that by eating 180-751, 193-804 and 225-938g fruit from Dar-mali, Castle Rock and Zhrat Elneel, respectively, the recommended lower and upper limits of sodium metal will be reached.

Magnesium (Mg)

The magnesium concentration in the three varieties ranged between 18.7 and 24.1mg/100g (Fig.28). The largest amount of this element is being present in Dar-mali and the lowest in Castle Rock fruits. These results are higher than those obtained by Ordonez *et al*. (2013) and Violeta *et al*. (2013). Further, 100g of Dar-mali, Castle Rock and Zhrat Elneel will supply 5.7-7.5, 4.6-5.8 and 5.7-7.4% of the lower and upper limits of magnesium RDA, respectively. However, consuming 133-172, 171-225 and 134-176 of Dar-mali, Castle Rock and Zhrat Elneel, respectively will supply the RDA of magnesium.

Calcium (Ca)

The studied varieties contained between 25.17-29.15 mg/100g (Fig.28). The calcium value obtained for Castle Rock is the highest and that obtained for Dar-mali is the lowest. These results are higher than the findings of Ordonez *et al*. (2011) and Violeta (2013), but lower than those by Gupta *et al*. (2011). Furthermore, the three varieties contain calcium in amounts far lower than its RDA (Fig. 28). The amount of calcium provided by 100g of Dar-mali, Castle Rock and Zhat Elneel fruits will cover only 1.94-2.52, 2.24-2.92 and 2.09-2.72% of upper and lower limits of its RDA, respectively. However, consuming 397-516, 343-446 and 368-479g of Dar-mali, Castle Rock and Zhrat Elneel fruits could afford the lower and the upper limits of calcium RDA, respectively.

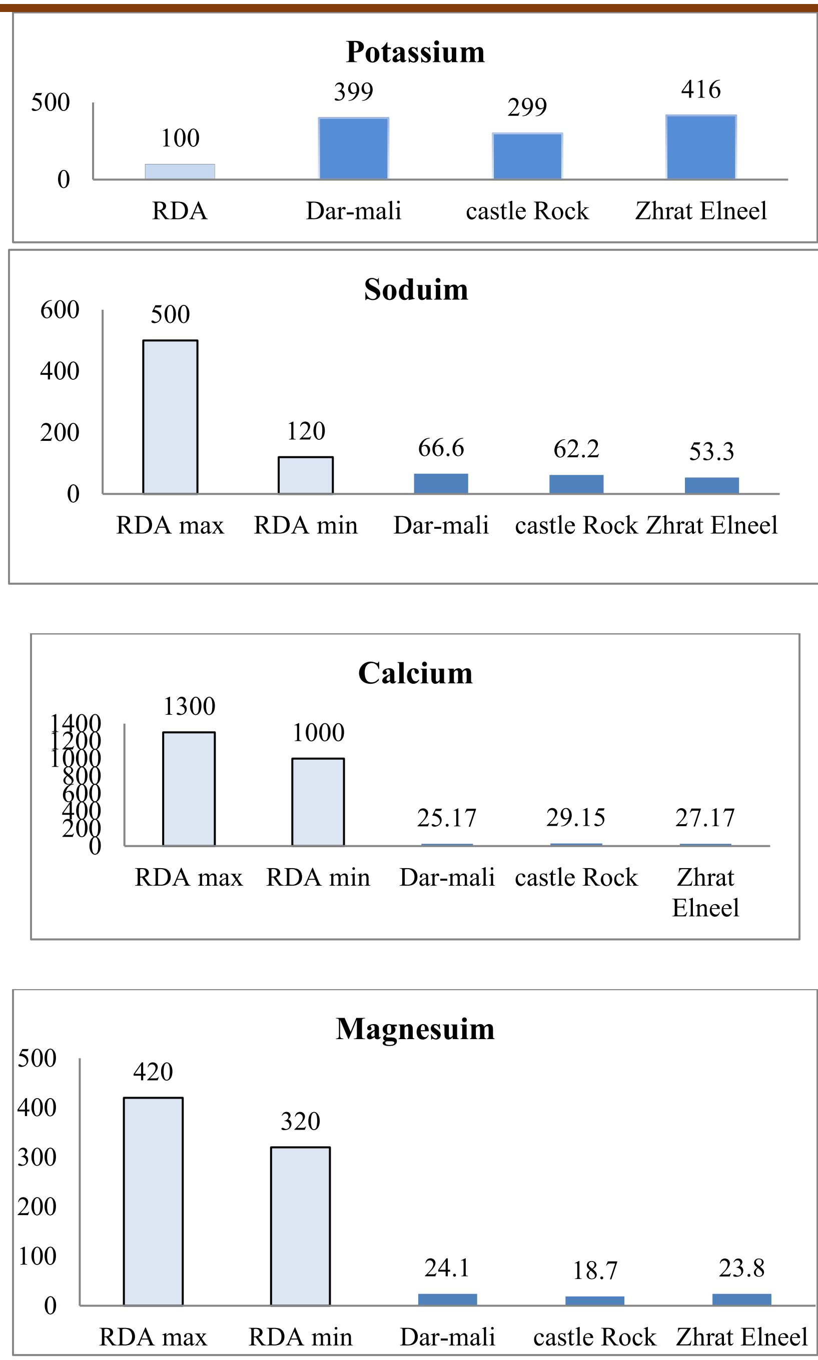

Fig.26. Macro-element concentration (mg/100g) compared to recommended daily allowance (RDA).

Micro-elements

Manganese (Mn)

Castle Rock contains the highest amount of manganese (0.47mg/100g) followed by Zhrat Elneel (0.4mg/100g) and Dar-mali (0.36mg/100g), respectively (Fig.27.). These results are higher than those obtained by Violeta *et al*. (2013).

The concentration of manganese in the three tomato varieties was far lower than the higher limits, but close to the lower limit of the RDA of Mg (Fig.27). In addition, 100g of the Dar-mali, Castle rock and Zhrat Elneel fruits could supply 15.7-60, 20-78 and 17.4-66.7% of the lower and upper limits of Mn RDA, respectively. Consequently, consuming 167-639, 127.7-489 and 150-575g of Dar-mali, Castle rock and Zhrat Elneel fruits, respectively, will supply the lower and upper limits of the RDA of manganese, respectively.

Cupper (Cu)

Cupper level in the three tomato varieties ranged from 0.31 to 0.37mg/100g which was below its RDA limits (Fig.27). Dar-mali contains the highest amount of cupper, followed by Zhrat Elneel and Castle Rock, respectively. These results were higher than the findings of Violeta (2013) and Ordonez - Santos *et al.* (2011). Consuming 100g from Dar-mali, Castle Rock and Zhrat Elneel should provide 24.7-12, 20.7-10.3 and 21.3-10.7% of the lower and the upper limits of cupper RDA, respectively. Accordingly, eating 405-811, 483.9-968 and 469-938 of Dar-mali, Castle Rock and Zhrat Elneel, respectively, could supply the body with the lower and upper limits of cupper RDA.

Iron (Fe)

The concentration of iron in three tomato varieties ranged between 2.76 and 3.11 mg/100g (Fig.27.). Zhrat Elneel contains the highest amount of this mineral followed by Dar-mali and Castle Rock, respectively. Results obtained were higher than the values obtained by Ordozen *et al*. (2011). A weight of 100g from Dar-mali, Castle rock and Zhrat Elneel could supply 19.6-29.4, 20-78 and 18.4-27.6% of the lower and upper limits of iron RDA, respectively. Consequently, consuming 350-510, 362-543 and 322-482gm of Dar-mali, Castle Rock and Zhrat Elneel, respectively will supply the lower and upper limits of the RDA of iron.

Zinc (Zn)

The concentration of zinc was 1.18, 1.11 and 1.21 mg/100g in Dar-mali, Castle Rock and Zhrat Elneel varieties, respectively (Fig. 27). These results nearly agreed with the findings of Ordonez *et al*. (2011) and Ilic (2013). Results of Zn obtained in the three varieties were lower than the limits of its RDA (Fig.27). Further, 100g from Dar-mali, Castle rock and Zhrat Elneel fruits could supply the body with 24.1-16.9, 22.7-15.9 and 24.7-17.3% of the lower and upper limits of zinc RDA, respectively. Consequently, consuming 415-593, 441-630 and 404-578g of Dar-mali, Castle Rock and Zhrat Elneel, respectively will supply the lower and upper limits of zinc RDA.

Sensory evaluation

The quality characters assessed organoleptically were appearance, shape, taste, colour, odour, firmness and overall acceptability. In terms of overall acceptability, tomato fruits from the three varieties obtained high level of acceptance (91.1-92.71%) (Fig.28). However, Dar-mali was the most acceptable, followed by Castle Rock and Zhrat Elneel, respectively. There was no significant difference in the overall acceptability between Dar-mali and Castle Rock varieties.

The mean ratings for sensory attributes are depicted in Fig.29. Statistically, the taste score given to Dar-mali variety was just slightly (P<0.05) higher than the Castle Rock, but significantly (P<0.05) higher than Zhrat Elneel variety, also the firmness score showed that there was no significant deference between Dar-mali and Castle Rock but, they were significantly higher than Zhrat Elneel. In addition, Zhrat Elneel had the best score of colour.

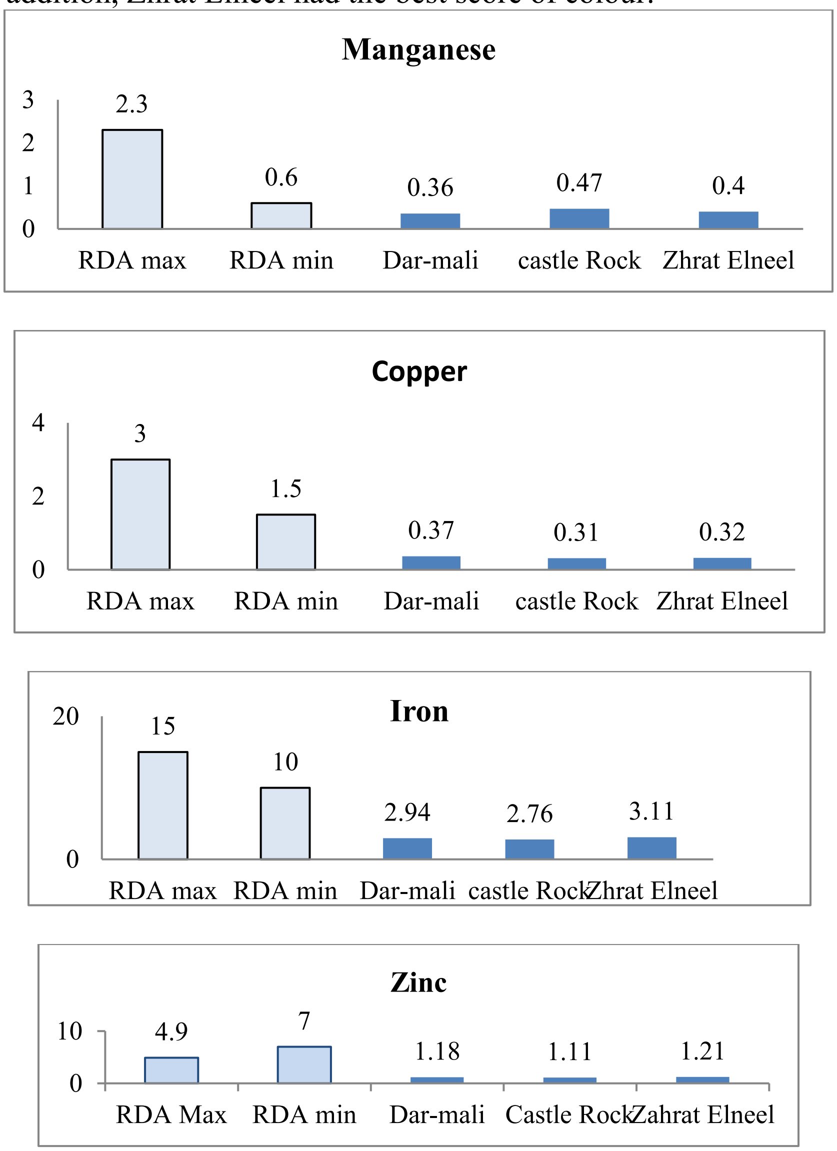

Fig. 27: Micro-element concentration (mg/100g) of tomato fruits compared to RDA

Table (3): The % cover and the quantity (g) expected to cover the recommended dietary allowances (RDA) of individual minerals (ASNS, 2004).

Minerals	**Tomato varieties**			**RDA**
	Dar- mali	**Castle Rock**	**Zhrat Elneel**	mg/100g
Potassium				100
Mg/100g	399	299	416	
Cover%	399	299	416	
expected (g)	25	33	24	
Sodium				120-500
Mg/100g	66.6	62.2	53.3	
Cover %	55.5-13.32	52-12	44-11	
expected (g)	180 – 751	193-804	225-938	
Magnesium				320-420
Mg/100g	24.1	18.7	23.8	
Cover%	7.5-5.7	5.8-4.6	7.4-5.7	
Expected (g)	1327-1742	1711-2246	1344-1764	
Calcium				1000-1300
Mg/100g	25.17	29.15	27.17	
Cover%	2.52-1.94	2.92-2.24	2.72 - 2.09	
Expected (g)	3972 - 5.164	3431- 4459	3680 - 4785	
Manganese				0.6-2.3
Mg/100g	0.36	0.47	0.4	
Cover%	60 -15.7	78 – 20	66,7 – 17.4	
Expected (g)	167 – 639	127.7 – 489	150 – 575	
Cupper				1.5-3
Mg/100g	0.37	0.31	0.32	
Cover%	24.7 – 12	20.7 – 10.3	21.3 – 10.7	
Expected(g)	405 – 811	483.9 – 968	469 – 938	
Iron				10-15
Mg/100g	2.94	2.76	3.11	
Cover%	29.4 – 19.6	27.6 – 18.4	31 – 20.7	
Expected (g)	340 – 510	362 – 543	322 - 482	
Zinc				4.9-7
Mg/100g	1.18	1.11	1.21	
Cover%	24.1-16.9	22.7-15.9	24.7-17.3	
Expected (g)	415- 593	441-630	404 - 578	

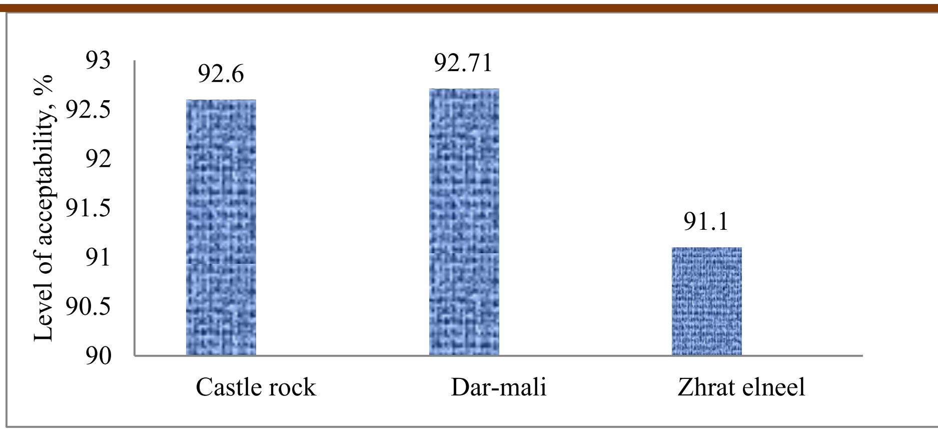

Fig.28. Tomato fruits overall acceptability

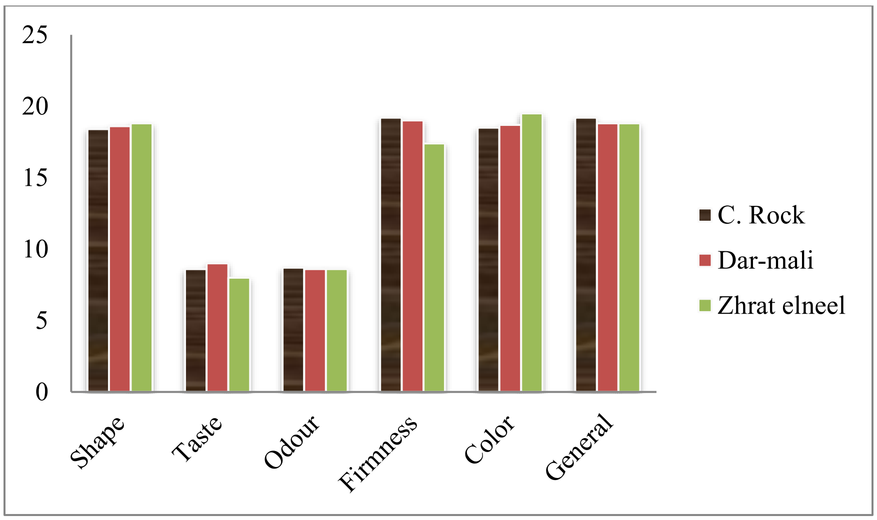

Fig.29. Tomato fruits sensory attributes

Conclusion and Recommendations

Three tomato fruit varieties; Castle Rock, Dar-mali and Zahrat Elneel were physically, chemically as well as organoleptically evaluated.

The three varieties were different in their physical characteristics and chemical composition. In terms of fruits colour, Dar-mali and Zhrat Elneel are red, while Castle Rock was orange-red. Dar-mali variety could be classified as round with little flatness, Zhrat Elneel nearly round, while Castle Rock was ellipsoid. Dar-mali and Zhrat Elneel could be classified as medium size fruits, while Castle Rock could be classified as small size fruit. Further, the three tomato varieties had a mean value of 2.22-4.4 fruit locules (cavities). The fruit geometric mean diameter was 5.91, 5.64 and 5.89cm, sphericity was 1.02, 1.05 and 0.91, surface area was 109.73, 99.93 and 108.99cm^2, volume was 141.6, 123.2 and 144.4cm^3 and weight was 137.63, 120.86 and 130.37gm for Dar-mali, Zahrat Elneel and Castle Rock, respectively.

In terms of chemical composition (dry basis), the dry matter was 6.0, 5.7 and 5.0%, total soluble solids was 5.1, 5.1 and 4.5%, ash was 5.48, 5.8 and 7.78%, fiber was 9.72, 6.43 and 14.66%, total sugars (mostly reducing sugars) were 20.94, 20.0 and 20.3%, titratable acidity was 0.26, 0.2 and 0.3% for Dar-mali, Castle Rock and Zhrat Elneel, respectively.

The level of lycopene and β-carotene were assessed in the three tested varieties in the levels of 12.877-15.63 and 7.92-8.87 mg/100g, respectively. The mineral composition of tested varieties was obtained and compared to their RDA. The most abundant mineral was K which was more than its RDA. Other minerals detected included Na, Mg, Ca, Mn, Cu, Fe and Zn.

In terms of level of acceptability, the three tested fruits gained high level of overall acceptability (91.1-92.71%).

References

A.O.A.C. (2000). Vitamins and other nutrients (Chapter 45). In Official Methods of Analysis (17th ed.), Washington, D.C., pp: 16-20.

Abdullahi, I. I.; Abdullahi, N; Muhammad A. A. and Salisu, I. A. (2016). Proximate, mineral and vitamin analysis of fresh and canned tomato. Biosciences Biotechnology Research Asia, 13(2): 1163-1169.

Alda, L. M.; Gogoasa, I.; Bordean D.M., Gergen, I; Alda, S.; Moldovan C. and Nita, L. (2009). Lycopene content of tomatoes and tomato products. Journal of Agroalimentary Processes and Technologies, 15 (4): 540-542.

ASNS (2004). American Society for Nutritional Sciences. 2004.

Barros, L.; Carvalho, A.M; Ferreira, I.C.F.R. (2010). Leaves, flowers, immature fruits and leafy flowered stems of *Malva sylvestris*: A comparative study of the nutraceutical potential and composition. Food and Chemical Toxicology, 48: 1466-1472

Ben Aoun, A.; Belgacem, L.; Leila, B. and Ali, F. (2013). Evaluation of fruit quality traits of traditional varieties of tomato (*Solanum lycopersicum*) grown in Tunisia. African Journal of Food Science, 7 (10): 350-354.

Borguini, G. and DaSilva, F. (2009). Tomatoes and to¬mato products as dietary sources of antioxidants. Food Reviews International, 25(4): 313-325.

Caliman, F. R. B.; Silva, D. J. H. da; Stringheta, P. C.; Fontes, P.C. R.; Moreira, G. R. and Mantovani, E. C. (2010). Quality of tomatoes grown under a protected environment and field conditions. IDESIA (Chile) 28(2): 75-80.

Charanjeet, K; George, B.; Deepa, N.; Singh, B. and Kapoor, H.C. (2004). Antioxidant status of fresh and processed tomato. Journal of Food Science and Technology, 41(5): 479-486.

Daniela, M.; Cristina, C.; Albert R.; Rafaela, C.; Oriol, M. (2013). Nutritional value of tomatoes grown in greenhouse by different agronomic techniques. J. Food Composition and Analysis, Elsevier, 31 (2): 245-251.

FAO/WHO (1989): Thirty-third report of the Joint Food and Agricultural Organization of the United Nations and World health Organization Expert Committee on Food Additives. WHO Technical Report No. 776.

FAOSTAT. (2025). Crop statistics. Food and Agriculture Organization of the United Nations.

Fernandez-Ruiz, V.; Olives, AI.; Camara, M.; Sanchez-Mata, C. and Torija, M.E. (2011). Mineral and trace elements content in 30 accessions of tomato fruits and wild relatives (*Solanum pimpinellifolium L., Solanum cheesmaniae L. Riley*, and *Solanum habrochaites S. Knapp* and *D.M. Spooner*). Biological Trace Element Research, 141:329-339.

Felföldi,Z.; Ranga, F.; Roman, J.A.; Sestras, A.E.; Vodnar, D.C.; Prohens, J.; Sestras, R.E. (2022). Analysis of Physico-Chemical and Organoleptic Fruit Parameters Relevant for Tomato Quality. Agronomy 2022, 12, 1232. https://doi.org/10.3390/agronomy12051232

Gupta, A.; Kawatra, A. and Sehgal, S. (2011). Physical-chemical properties and nutritional evaluation of newly developed tomato genotypes African Journal of Food Science and Technology 2(7): 167-172.

Helyes, L.; Lugasi, A.; Pogonyi, A. and Pek, Z. (2009). Effect of variety and grafting on lycopene content of tomato fruit. Acta Aliment Hung 38(1):27-34.

Ibrahim, A. E. A., Yahia, M. and Ramadan, B.R. (2014). Development of date fruits-based ready meal products. Sudanese Journal of Agricultural Sciences, Azhari University, Khartoum Sudan. 1: 46-54.

Ibrahim, A. Elgaili (2009). Technological studies on some Sudanese date varieties. PhD thesis, Nile Valley University, Sudan.

Ilic, Z.S; Kapoulas, N. and Milenkovic, L. (2013). Micronutrient composition and quality characteristics of tomato from conventional and organic production. Indian Journal of Agricultural Sciences, 83 (6): 651–5.

Jahromi, M. Keramat; Jafari, A.; Rafiee, S.; Keyhani, A. R.; Mirasheh, R. and Mohtasebi, S.S. (2007). Some physical properties of date fruit (cv. Lasht). Agricultural Engineering International, Vol. IX. Pp07-19.

Jan, I.; Abdur Rab; A.; Muhammad,A. and Ali, A. (2012). Response of Apple varieties to different storage durations. Sarhad Journal of Agriculture, 28(2): 191 95.

Marsic, N.K.; Gasperlin, L.; Abram, V.; Budic, M. and Vidrih, R. (2011). Quality parameters and total phenolic content in tomato fruits regarding cultivar and microclimatic conditions. Turkish Journal of Agriculture, 35:185-194.

Nagata, M.; Yamashita, I. (1992). Simple method for estimation of chlorophyll and carotenoids in tomato fruit. J. Japanese Society for Food Science and Technology, 39 (10), 925-928.

Nguyen, M. L. and Schwartz, S. J. (1999). Lycopene chemical and biological properties. Food Technology, 53: 38-45.

Ordonez - Santos, L. E.; Vazquez - Oderiz, M. L. and Romero - Rodrıguez M. A. (2011). Micronutrient contents in organic and conventional tomatoes. International Journal of Food Science and Technology.46: 1561–1568.

Parker, R.; Maalekuu, B. K. (2013). The effect of harvesting stage on fruit quality and shelf-life of four tomato varieties. Agriculture and biology Journal of north America, 4(3): 2151-7517.

Peralta, I.E. and Spooner, D.M. (2007). History, origin and early cultivation of tomato (*solanaceae*). In: Razdan, M.K., Mattoo, A.K. (eds.), Genetic Improvement of Solanaceous Crops, Vol. 2. Enfield, USA: Science Publishers. p. 1-27.

Pinela, J.; Barros, L.; Carvalho, A.M. and Ferreira, I.C. (2012). Nutritional composition and antioxidant activity of four tomato (*Lycopersicon esculentum L.*) farmer varieties in Northeastern Portugal homegardens. Food Chemistry and Toxicology, 50 (3-4):829-834.

Raffo, A., Leonardi, C. and Fogliano, V. (2002). Nutritional value of cherry tomatoes (*Lycopersicon esculentum* Cv. Naomi F1) harvested at different ripening stages. J. Agricultural and Food Chemistry. 50: 6550–6556.

Ray, R.C.; Sheikha, E.l.; Panda, A.F. and Montet, S.H. (2011). Anti-oxidant properties and other functional attributes of tomato: An overview. International Journal of Food and Fermentation Technology,1(2):139-148.

Shi, J. and Maguer, L.E. (2000). Lycopene in tomatoes: chemical and physical properties affected by food processing. Critical Reviews in Biotechnology, 20(4): 293–334.

Suarez, H. M.; Rodriguez, R. E.M. and Diaz, Romero C. (2008): Chemical composition of tomato (*Lycopersicon esculentum*) from Tenerife, the Canary Islands. Food Chemistry.106: 1046-1056.

Sulieman, A.M. E.; Awn, K. M. A. and Yousif, M.T. (2011). Suitability of some tomato (*Lycopersicon esculentum Mill.*) genotypes for paste production. Journal of Science and Technology, 12 (2):45-52.

Suwanaruang, T. (2016). Analyzing lycopene content in fruits. Agriculture and Agricultural Science Procedia, 11: 46 – 48.

Tafti, A.G. and Fooladi, M.H. (2006). Changes in physical and chemical characteristics of Mozafati date fruit during development. J. Biol. Sci., 5(3): 319-322.

USDA (1991). U.S. Standards for Grades of Fresh Tomatoes. USDA, Agriculture. Mktg. Serv., Washington, DC.

USDA (2005). United States Department of Agriculture. Economic Research Service (ERS). Briefing Room..

Vinkovic, V. I.; Samobor, V.; Bojic, M.; Medic-Saric, M.; Vukobratovic, M., Erhatic, R.; Horvat, D. and Matotan, Z. (2011). The effect of grafting on the antioxidant properties of tomato (*Solanum lycopersicum* L.). Spanish Journal of Agricullture Research, 9(3):844-851.

Violeta, N.; Ion, T.; Mira, I. E. (2013). Antioxidant Compounds, Mineral Content and Antioxidant Activity of Several Tomato Varieties Grown in Southwestern Romania. Not Bot Horti Agrobo, 2013, 41(1):136-142. Print ISSN 0255-965X; Electronic 1842-4309.

Visa, S.; Chunxue, C.; Gardener, B. M. and van der Knaap, E. (2014). Modeling of tomato fruits into nine shape categories using elliptic fourier shape modeling and Bayesian classification of contour morphometric data, Euphytica, 200:429-439.