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Phenolic Profile, Nutritional Composition, Functional Properties and Antioxidant Activity of Newly Grown Parthenocarpic and Normal Seeded Tomato

Phenolic Profile, Nutritional Composition, Functional Properties and Antioxidant Activity of Newly Grown Parthenocarpic and Normal Seeded Tomato

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Abstract

The aim of the study was to compare the physico-chemical parameters, sugar, vitamin C, and phenolic profiles in five genotypes of local indeterminate tunnel tomato hybrid (LITTH) (LITTH-778, LITTH-784, LITTH-786, LITTH-788 and LITTH-790) of natural parthenocarpic tomato (NPT) and normal seeded tomato (NST). Samples were collected from the experimental fields of Ayub Agricultural Research Institute, Faisalabad, Pakistan. Physical parameters (fruit shape, fruit weight, fruit length, fruit width, number of seeds per fruit, shelf life), chemical composition (moisture, ash, crude fat, crude fibre, total carbohydrate, crude protein, vitamin C), ofNPT and NST were analyzed by reported methods. The methanolic extracts of tomato pulp were prepared by shaking and extracts were assayed for antioxidant activity. Sugars contents and phenolic profile of NPT and NST were estimatedusing HPLC method.Weight and size of NPT were less and smaller than the NST. Moreover, NPT were seedless with longer shelf-life and had more phenolic and flavonoid contents than the NST.HPLC analysis revealed that chlorogenic acid, gallic acid, *p*-coumeric acid were major phenolics in methanol (polar solvent) extracts of NST whereas, caffeic acid, gallic acid, *p*-coumeric acid in NPT extract.NPT contained higher concentration of sugar contents, but lower concentration of vitamin C than NST. In 2,2-diphenyl-1-picrylhydrazyl(DPPH) free-radical-scavenging assay, NPT fruits extracts showed high scavenging activity with the 50% inhibitory concentration (IC_{50})value of 22.56 µg/mL than NSTfruit extracts having IC_{50} 29.49 µg/mL. This study provided useful information for farmers and nutritionists.

Keywords: Parthenocarpy, *Lycopersicon esculentum*, Sugars, Yield, Antioxidant activity.

1. Introduction

Tomato (*Lycopersicon esculentum*) fruits are an essential part of human diet and have extensive health benefits [1]. Tomato fruits are an excellent natural supplement of minerals, essential nutrients and many other secondary metabolites such as lycopene, carotene, vitamin C, and polyphenols [2-3]. Due to these valuable nutrients, utilization of tomatoes can decrease the risk of various fatal diseases such as cancer and coronary artery diseases [4, 5].

Parthenocarpy means 'virgin fruit', in biological term can be introduced naturally or artificially for the development of fruits without the process of fertilization, which results in seedless fruits [6, 7]. Trend for the development of seedless fruits is increasing because seeds are bitter in taste, leathery or hard textured and may accumulate harmful compounds in many instances [8, 9]. According to the consumers demand, and better nutritional quality, absence of seeds and seed cavities from many fruits is required [8, 10]. Moreover, presence of seeds accelerates the deterioration process of the fruits due to various chemicals present in them [10, 11]. Thus, seedlessness may also increase the shelf-life of the fruits [12, 13].

Various parthenocarpy approaches are effective, which involve the specific mutations such as introduction of specific genes and by the use of different chemicals [12]. In Italy, parthenocarpic tomatoes were developed in the Italian variety "Sha-pat" using the temperature effect and pollination method [14]. Utilization of phytohormones such as auxin and gibberellin, especially the auxins is a chemical approach to induce parthenocarpy in fruits [15, 16]. Some adverse environmental factors were also found effective and are in use to introduce parthenocarpy in fruits including low and high temperatures, intensity of light, humidity and rainfall etc [17] among these, temperature is the most effective one to introduce parthenocarpy.

Reported data also explained the development of parthenocarpic fruit, in tomato line, "Oregon T5-4" below 18 ^{o}C [18]. However, not a single report is available on the effect of parthenocarpy on the physio-chemical properties, nutritional quality, phenolic profile, vitamin content and antioxidant potential of selected genotype in comparison with normal seeded fruits.

Thus, in this study we planned to explore the variation in the physical parameters (fruit shape, fruit weight, fruit length, fruit width, number of seeds per fruit, shelf life of fruit), proximate composition, antioxidant activity total phenolic contents (TPC), total flavonoid contents (TFC), 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging activity, reducing power) and nutritional quality parameters (sugars, vitamin C, phenolic, flavonoids) of natural parthenocarpic tomato (NPT) and normal seeded tomato (NST).

2. Materials and Methods

2.1. *Sample Collection.*Mature tomato fruits of five selected genotypes namely local indeterminate tunnel tomato hybrid (LITTH)-778, LITTH-784, LITTH-786, LITTH-788 and LITTH-790) of NST and NPTwere harvested at fully ripens stage fromthe experimental fields of Vegetable Research Department, Ayub Agricultural Research Institute (AARI), Faisalabad, Pakistan. Polythene bags were used to pack fruits and then stored in a refrigerator at 4^{o}C for the preservation of essential nutrients.

2.2. *Physical Parameters of Tomato Fruits.*For the measurement of different physical parameters of the fruits, twelve fully ripened fruits of each tomato genotype were selected randomly. Each fruit was weighed by using electronic balance, reading with the accuracy of 0.001 g to measure the fresh masses. Length and width of the fruits were measured by using the vernier caliper having of 0.01 mm accuracy. Fruits seeds were counted by dissecting it diagonally. Shelf lives of collected tomatoes were measured as reported [19].

2.3*Proximate Analysis.*The moisture contents of tomato fruits were determined as reported by Osbome and Voogt [20]. Pre-weighed crucible 2 g grounded sample was taken and placed in oven for 24 hours at 102 ^{o}C, till last fixed weight was obtained. Estimation of ash contents was performed according to method of AOAC [21]. Pre-weighed empty crucible 2 g of dry sample was taken and then placed in Muffle Furnace this crucible along with sample at 600 ^{o}C till obtained the white ash. For the estimation of crude fibre, AOAC method was used [21]. Briefly, for half an hour, 2 g of each tomato sample was boiled with 0.12 N in250 ml of H_2SO_4. The

obtained residue after filtration was washed with distilled water. After it, for half an hour the residue were boiled with 0.313 N in 250 mL of NaOH follow by the filtration and washing. Weighed the residue after drying them completely and then heated in furnace until ash formed by the residue and then weighed the ash. Crude fiber content was determined according to the method reported [21]. 2 g weighed sample put into thimble and dry it in hot circulating air oven at 98 ^{o}C for overnight. Take sample from the oven and cool it and then prepare extract of it with 100 mL of diethyl ether in a Soxhlet extractor attached with pre weighed round bottom flask for 8 to 12 hours. Total carbohydrate content was measured as reported [22]. Total carbohydrate of tomato sample was measured by subtracting the sum of the % ash, % moisture, crude fiber and crude protein from 100%.Crude protein was estimated by using AOAC method [21]. Briefly, 6.25 g weighed of each tomato sample was put on nitrogen free filter paper. This N_2 free filter was folded properly and then transferred to a Kjeldahl digestion tubes. Digest catalyst ($CuSO_4$+Na_2SO_4) of 3 g and 25 mL of concentrated sulphuric acid was poured to each digestion tube. This digested tube was transfered to Kjeldahl digestion apparatus and then heated at below the boiling point of acid. Resulting mixture after the digestion was poured to separate 100 mL flasks (volumetric) and diluted the mixture it with distilled H_2O to make the volume upto 100 mL. Each digested sample was transferred into distillation jacket of micro-steam distillation apparatus. About 200 mL of NaOH (40% w/v) solution was poured to each digest of distillation jacket then 50 mL of boric acid (40% w/v) solution was poured into another conical flask by the addition of four drop of methyl red indicator. Ammonia was collected through the condenser. The process of distillation was proceeding smoothly unless about 25 mL of distilled water was trapped in boric acid by changing the color from red to yellow. The resulting mixture was titrated against 0.02 M HCl and mean reading was recorded. % Nitrogen was first calculated and crude protein was determined by multiplying the N with a factor of 5-3.

2.4 *Preparation of Methanol Extract.* Methanol (MeOH) extract of NPT and NST fruits were prepared using orbital shaker due to its high polarity [23]. Tomato fruits were dried at room

temperature for about two weeks till a constant weight was achieved. After grinding, 80 mesh 50 g material soaked 500 mL absolute MeOH for 24 h using orbitrary Shaker (Gallen Kamp, England) at 140 rpm. All the extracts were filtered using Whatman No. 1 filter paper and resolute using rotary vacuum evaporator (BRE-225 Robus Technologies) and then weighed for yield estimation. The extracts were stored at 4 ^{o}C until used for analysis.

2.5 *Evaluation of the Antioxidant Activity of the Extracts.* Amount of total phenolic content (TPC) from tomato extracts were calculated using Folin Ciocalteu phenol reagent as reported [24]. The method reported by Hussain et al. [24] was followed for the measurement of total flavonoid content (TFC) of the tomato extracts. To measure the free-radical-scavenging activity of tomato extracts, the DPPH assay was followed as reported [24].

2.6 *Qualitative and Quantitative Analysis of Phenolic Acids and Flavonoids Using HPLC.* The hydrolysis of tomato fruit extracts was achieved as reported previously [24]. Briefly, dissolve 1 g of crude tomato extract in 10 mL of methanol (50% v/v) solution containing ascorbic acid (0.04% w/v) which act as antioxidant. Three drops of 1.2 M of HCl were added to the solution and the resulting mixture was refluxed for 2 h at 80 ^{o}C. After the completion of hydrolysis, the resulting mixture was allowed to cool and then made volume upto 10 mL with MeOH. The resulting hydrolyzed extract was then filtered, using 0.45µm non-pyrogenic filters before subjected to injection. Fresh stock solutions of standards were obtained by dissolving pure standard in analytical grade MeOH (1000 µg/mL). For the preparation of working standard solutions gradual dilution was required with MeOH having concentration of 0.4-400 µg/mL. Calibration curve for each standard was obtained by plotting the concentration against the obtained peak area. Identification and quantification of phenolic acids and flavonoids were performed on an HPLC system (PerkinElmer, USA), facilitated with Flexer Binary LC pump, UV/VIS LC detector (Shelton CT, 06484 USA), oven assisted column at 30 ^{o}C, degasser (DG-20A5), equipped with C_{18} column (with the specification of 5 µm, × 250 mm × 4.6 mm), working with gradient elution with two solvents [(glacial CH_3COOH:H_2O 0.5%) and

(MeOH:acetonitrile 35:65)] using software, version 4.2. 6410 for data analysis. Gradient elution was employed for the better separation of phenolic acids and flavonoids. Identification and estimation of phenolics and flavonoids were achieved by measuring the retention time of peaks developed from sample in comparing with external standards.

2.7 *Estimation of Ascorbic Acid (vitamin C).* Ascorbic acid contents in tomato fruits were determined using the method reported by Barros et al. [25]. Absorbance of the sample was recorded at 515 nm, using double beam spectrophotometer (Spectrophotometer Analytik Jena, Germany). For the qualitative and quantitative analysis the sample absorbance was compared by the calibration curve of vitamin C (5-200 µg/mL)

2.8 *HPLC Analysis of Sugars in Tomatoes.* Solutions of extract (4 mg/mL) were prepared using MeOH and demineralized by using cation and anion resins as reported by Alasalvar et al. [26]. Estimation of sugars was done on a Shimadzu HPLC LC-20A framework (Singapore). The HPLC framework comprised a siphon (demonstrate LC20AT Prominence), a dissolvable degasser (display G1322A), a segment broiler (show CT 020A/20AC), equipped with a refractive record locator (display RID10A) and was constrained by Shimadzu LC Solution programming. The framework was likewise helped by CBM 20A/20A light framework controller. Starch partition was completed on a Bio-Rad Aminex HPX-87K 300 × 7.8 mm segment (Cat # 1250142) with Bio-Rad protect section with ultra-unadulterated H_2O as versatile stage at a stream rate of 0.50 mL/min and 20 µL test was infused. Refractive file identifier kept up at 40 °C was utilized for recognition purposes. External standard was employed for the estimation of sugars by comparing the retention time with standards.

2.9 *Statistical Analysis.*Three samples of each tomato genotype were collected and analyzed in triplicate and the values were expressed as mean ± SD. The significance differences among the numerical values of NPT and NST were analyzed using one way analysis of variance (ANOVA) followed by Tukey's test, using Minitab version 18. The level of significance was set at $p \leq 0.05$.

3 Results and discussion

3.1 *Physical Parameters.*Results for physical parameters of different genotype of NPT and NST are given in Table 1. It was observed that the NPT fruits were of round shapes, while NST fruits were of elongated shapes (Figure 1). Furthermore, NPT fruits were of less weights had (18.5-26.2 g), smaller in length (27.85-34.11 mm) and width (29.17-33.65 mm) than those of the NST fruits, respectively, 109.6-127.8 g, 71.85-75.95 mm, and 51.85-64.74 mm (Table 1). Variation was not significant (p>0.05) regarding fruit size among the NST genotypes, but the significant ($p\leq 0.05$) reduction in fruit size were observed for NPT as compared with NST. Fruit weight, length and width of NPT fruits were reduced to the 1/3 of the NST as given in Table 1. Similar results about the fruit shape deformation were observed by the introduction of parthenocarpy [12]. Parthenocarpy effect can reduce the weight and diameter of tomato fruits significantly [27]. The decrease in fruit size in NPT can be compared with the previous literature about parthenocarpic cucumber in which decrease in fruit size was significant due to the introduction of parthenocarpy [28]. Our results were in line with the previously described data about 28-30 % reduction in fruit size due to parthenocarpic effect [27].

NPT fruits had no seeds in all studied genotypes, but the NST fruits of all the genotypes possessed many seeds, 25-32 seeds per fruit (Table 1 and Figure 1). Due to the introduction of parthenocarpic character, the shelf-lives of the NPT increased from 10-12 to 13-22 days than NST. Increased shelf-life of the NPT fruits might be due to reduce the production of ethylene by seeds [7]. Variations of number of seeds per plant and shelf-life among the genotypes of NPT and NST were significantly ($p\leq 0.05$) different. Experimental results regarding seeds in NPT fruits were comparable with the studies of [10], where about 10-fold less seeds in parthenocarpic tomato were observed as compared with the control. Reported data described that vitamin C could reduce the shelf-life of the fruits by thinning the pericarp [19].

3.1 *Proximate Composition.* The results of proximate analysis for NPT and NST fruits are presented in Table 1. Moisture and ash contents ranged in 92.41-94.72 g/100g and 0.59-0.79

g/100g, respectively in NST, 81.67-86.80 g/100g and 0.92-2.06 g/100g, respectively in NPT fruits. NST fruits showed significantly ($p \leq 0.05$) higher moisture and lower ash contents than the NPT fruits. The results regarding the crude fat and fiber contents are also recorded and given in Table 1. Highest moisture and ash contents were found for LITTH-784, LITTH-788, respectively, from NST and LITTH-790, LITTH-786 from NPT. Moisture and ash contents with minimum concentrations were found in LITTH-786, LITTH- 790 from NST and LITTH-778 and LITTH-790, respectively, from NPT. Genotype LITTH-778, LITTH-784, LITTH-786, LITTH-788 and LITTH-790 of NST fruits had crude fat 0.32, 0.30, 0.27, 0.29 and 0.28 g/100g, respectively, which were less than the crude fat of NPT fruits. Similarly genotype of NST showed less fiber contents than NPT (Table 1). Variations in crude fat and crude fiber contents among the genotypes of NPT and NST were found significant ($p \leq 0.05$). Similarly, the total carbohydrates were also high in NPT fruits having no seeds. It might be due to the accumulation of more starch and its subsequent conversion to sugar that is one of the most striking differences between the NPT and NST as observed in present studies. High amount of total carbohydrate was observed LITTH-778 (1.33 g/100g) from NST and LITTH-788 (3.93 g/100g) from NPT.

For the proper growth and maintenance of human body, proteins play key role and along with lipids and carbohydrates, act as energy source. It also controls the vital body function such as nutrients transport, enzymatic activity and other biological compound across the cell membrane[39]. The crude fruits proteins of NST genotypes of LITTH-778, LITTH-784, LITTH-786, LITTH-788 and LITTH-790 were 2.65, 1.72, 3.75, 2.77, 1.69 g/100g which were lower than crude protein of NPT fruits (Table 2). The variation of crude protein in NPT and NST fruits were found to be significantly different of ($p \leq 0.05$). Our findings regarding fruits proximate composition of NPT and NST genotypes were comparable with earlier findings in different tomato varieties as studied by different researches [28, 29, 30].

3.2 *Extracts Yields.* The percent yields of MeOH extracts of NST and NPT fruits are presented in Table 2, which ranged from 42.51-49.33 g/100g of dry fruits (W/W) and 44.16-53.53

g/100g of dry fruits (W/W), respectively. Difference in the percent yields of MeOH extract might be due to variation in different extractable compounds. Previously reported data revealed that polar solvents are used for the extraction polyphenols because of their polarity and compatibility [31].

3.3 *TPC, TFC and Antioxidant Activity of the Extracts.*Total phenolic contents (TPC) of NST and NPT fruit extracts were measured and reported as gallic acid equivalent (Table 2). Total phenolic contents of NST and NPT fruit extracts were in the range of 9.28-11.98 and 12.12-14.66 mg/100g dry matter, respectively. The highest TPC was observed in the extract of LITTH-786 from NST and LITTH-786 from NPT whereas, the lowest was for LITTH-788 from NST and LITTH-788 from NPT. Generally the significantly ($p \leq 0.05$) higher TPC was found in NPT as compared to NST. TFC of the NST and NPT fruit extracts tomatoes were measured in terms of catechin equivalent (Table 2). TFC of NST fruits extracts were less than NPT with the range of 2.9-3.77 and 3.15-4.83 mg/100g dry material, respectively. Some reports available in literature confirmed the high TPC and TFC in various genotypes of tomatoes and our results are comparable with those reports [28, 29, 30].

Free-radical-scavenging activity, as measured in the DPPH radial-scavenging assay, increased with an increase of extract concentrations and extract concentrations providing 50% scavenging (IC_{50}) are shown in Table 2. NPT and NST fruits extract exhibited significantly different radical-scavenging activity. NPT fruits extracts showed better DPPH radical-scavenging activity with the IC50values of 22.56-40.23 µg/mL, whereas NST fruit extract showed lesser activity with the IC50 values of 29.49-48.37µg/mL. The significant differences ($p \leq 0.05$) in DPPH radical-scavenging of different tomato genotypes were observed and data showed parthenocarpy has improved the DPPH radical-scavenging activity that could be attributed due to their better TPC and TFC.

3.4 *Vitamin C and Sugar Contents.* Vitamin C concentration in NST and NPT fruits extract is shown in Table 2. Genotypes of NST showed high vitamin C concentration (0.41-0.45 g/kg) followed by NPT fruits with concentration of (0.33-0.37 g/kg). Results are comparable with the

findings of Abdullah et al., who reported the presence of vitamin c and mineral in the fresh tomatoes [28].

The sugars contents found in the NPT and NPT fruit extracts in the present study are shown in Table 2. Sugar contents of NPT fruits had higher levels of glucose (24.71-26.67 g/kg fw), fructose (17.41-23.34 g/kg fw), and sucrose (3.89-6.87 g/kg fw) than NST fruits having glucose (20.19-25.43 g/kg fw), fructose (15.36-20.26 g/kg fw), and sucrose (0.41-0.45 g/kg fw). These sugars are the major source of energy for metabolism in living organism [29]. Parthenocarpic tomatoes had better nutritional values in terms of carbohydrate/sugar than normal seeded tomato fruits. The present results were comparable to previously reported data on tomato puree [30].

3.5 *HPLC Estimation of Phenolics and Flavonoids.* The amounts (mg/100 g of dry material) of eight detectable phenolic acids in the MeOH extracts are reported in Table3.Gallic acid(1), chlorogenic acid(2), *p*-hydroxy benzoic acid(3), caffeic acids(4), vanillic acid(5), *p*-coumeric acid(6), sinapic acid (7)and the ferulic acid(8), were the major phenolic acid detected (Figure 3). Catechin(9), quercetin (10)and kaempferol(11)were the major flavonoids detected in NST and NPT fruit extracts (Figure 3). Overall chlorogenic acid was found to be the major phenolic acid in the MeOH extract of NST genotypes ranged between 1116.67-1163.1 mg/100 g of dry plant material) followed by gallic acid (603.9-677.7 mg/100 g of dry plant material), *p*-coumeric acid (50.06-56.5 mg/100 g of dry plant material), *p*-hydroxy benzoic acid (15.5-21.2 mg/100 g of dry plant material), ferulic acid (6.09-9.9 mg/100 g of dry plant material), caffeic acid (2.4-3.2 mg/100 g of dry plant material) and vanillic acid (1.1-1.7 mg/100 g of dry plant material), whereas quercetin was separated as the major flavonoid with the concentration range of122.01-149.5 mg/100 g of dry plant material followed by catechin (54.55-84.3 mg/100 g of dry plant material) and kaempferol (13.3-19.7 mg/100 g of dry plant material) (Figure 2).

Similarly caffeic acid was found to be major phenolic acid in methanolic extract of NPT genotypes (1999.2-2200.6 mg/100 g of dry plant material) followed by *p*-coumeric acid (1795.2-1971.6 mg/100 g of dry plant material), gallic acid (240.2-272.3 mg/100 g of dry plant material),

sinapic acid (226.8-254.5 mg/100 g of dry plant material), ferulic acid (151.5167.4 mg/100 g of dry plant material), *p*-hydroxy benzoic acid (109.9-117.4 mg/100 g of dry plant material), vanillic acid (101.3-113.2 mg/100 g of dry plant material) and chlorogenic acid (69.9-81.1 mg/100 g of dry plant material)(Fig. 3). The highest amount of flavonoid was kaempferol (311.1-320.4 mg/100 g of dry plant material) followed by catechin (266.3-297.7 mg/100 g of dry plant material) and quercetin (264.7-305.8 mg/100 g of dry plant material)(Fig. 3). All individual phenolic acids identified were at the higher level in extract NPT fruits extracts than NST fruits extracts. Significant ($p \leq 0.05$) variations were observed in the contents of phenolic acids and flavonoids among different genotypes of the fruits. Our findings regarding phenolic profile and flavonoids are in agreement with the findings of Silva et al. [32] who reported the presence of gallic acid, chlorogenic acid, caffeic acid, ferulic acid, rutin and quercetin in tomatoes extracts.

4 Conclusions

This is the first study revealing the comparison of physical parameters, nutritional composition, antioxidant activity, vitamin C, sugar contents, phenolics, and flavonoids profiles of NPT and NST genotype of tomatoes. Parthenocarpy appears to be an important trait for improving the yield, quality and processing traits of vegetable crops. Parthenocarpy could not only increase the production and nutritional quality of tomato fruits but also did increase the sugar contents and decreased vitamin C, which increased the shelf-life of fruits. Parthenocarpic tomato also showed high antioxidant activity due to the presence of high amounts of phenolics and flavonoids contents. The current findings could potentially assist the food technologists and nutritionalprofessionals in recommending the use of parthenocarpic tomato fruits in human diets directly or as additives in food products due to its high sugar content, phenolics and flavonoids.

Data Availability

The supporting data for findings of the present study are included in the article.

Conflicts of interest

The authors declare no conflicts of interest.

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TABLE 1:Physical parameters and proximate composition of NST and NPT

Tomato variety	Physical parameters and proximate analysis												
	Genotype	Fruit shape	Fruit weight (g)	Fruit length (mm)	Fruit width (mm)	Number of seeds per fruit	Shelf life (days) at 34 ^{0}C	Moisture (g/100g dry weight)	Ash (g/100g dry weight)	Crude fat (g/100g dry weight)	Crude fibre (g/100g dry weight)	Total Carbohydrate (g/100g dry weight)	Crude protein (g/100g dry weight)
Normal seeded tomato	LITTH-778	Elongated	124.3±3.12^{b}	75.22±2.77^{b}	62.86±1.24^{b}	29±0.2^{b}	10±0.34^{k}	92.53±4.3^{c}	0.71±0.03^{ef}	0.32±0.01^{d}	0.83±0.07^{e}	1.33±0.15^{c}	2.65±0.19^{fg}
	LITTH-784	Elongate	119.6±2.28^{c}	74.95±2.54^{c}	59.33±1.76^{c}	27±0.4^{d}	12±0.36^{i}	94.72±4.5^{a}	0.64±0.20^{f}	0.30±0.01^{d}	0.51±0.05^{f}	1.29±0.12^{c}	1.72±0.12^{g}
	LITTH-786	Elongated	109.8±2.09^{e}	73.83±2.49^{d}	53.83±1.59^{d}	28±0.9^{c}	13±0.47^{f}	90.99±4.3^{d}	0.70±0.01^{ef}	0.27±0.01^{d}	0.90±0.06^{e}	1.13±0.12^{c}	3.75±0.29^{g}
	LITTH-788	Elongated	111.4±1.17^{d}	71.85±2.39^{e}	51.85±1.39^{e}	32±0.3^{a}	11±0.35^{j}	92.41±4.3^{c}	0.79±0.02^{e}	0.29±0.03^{d}	0.86±0.07^{e}	1.15±0.13^{c}	2.77±0.18^{ef}
	LITTH-790	Elongated	127.8±4.09^{a}	75.95±2.29^{a}	64.74±1.13^{a}	25±0.2^{f}	14±0.37^{d}	94.16±4.4^{b}	0.59±0.01^{f}	0.28±0.01^{d}	0.49±0.06^{f}	1.18±0.12^{c}	1.69±0.16^{g}
Parthenocarpic tomato	LITTH-778	Rounded	26.2±0.21^{f}	33.02±0.15^{g}	31.91±0.39^{g}	Absent	15±0.45^{c}	82.11±4.2^{h}	1.87±0.19^{a}	0.62±0.04^{bc}	1.54±0.17^{a}	3.93±0.29^{a}	5.44±0.62^{b}
	LITTH-784	Rounded	22.7±0.53^{h}	29.99±0.29^{h}	30.82±0.34^{h}	Absent	13±0.35^{f}	84.98±4.0^{g}	1.19±0.10^{c}	0.63±0.03^{bc}	1.13±0.15^{cd}	3.86±0.29^{a}	4.21±0.50^{c}
	LITTH-786	Rounded	18.5±0.32^{j}	28.73±0.23^{i}	29.63±0.28^{i}	Absent	18±0.60^{a}	81.67±4.1^{i}	2.06±0.15^{b}	0.67±0.03^{ab}	1.27±0.16^{bc}	3.10±0.25^{b}	6.90±0.69^{a}
	LITTH-788	Rounded	20.3±0.21^{i}	27.85±0.19^{j}	29.17±0.25^{j}	Absent	14±0.37^{d}	85.36±4.3^{f}	1.24±0.11^{c}	0.69±0.03^{d}	0.98±0.14^{d}	3.89±0.29^{a}	3.57±0.52^{c}
	LITTH-790	Rounded	24.8±0.24^{g}	34.11±0.50^{f}	33.65±0.48^{f}	Absent	17±0.50^{b}	86.80±4.3^{e}	0.92±0.09^{d}	0.61±0.03^{c}	1.43±0.17^{ab}	3.76±0.28^{b}	2.25±0.46^{d}

Values are mean ± SD in triplicate determinations. Different letters in superscript represent significant ($p \leq 0.05$) difference among selected fruit varieties.

406 TABLE 2: Antioxidant activity, vitamin c and sugar profile

Tomato variety	Antioxidant activity, vitamin C and sugar profile								
	Genotype	%age yield	TPC (mg/100g dry plant material)	TFC (mg/100g dry plant material)	DPPH Radical Scavenging (IC50 µg/mL)	Glucose (g/kg dry plant material)	Fructose (g/kg dry plant material)	Sucrose (g/kg dry plant material)	Vitamin C (g/kg) (Fresh weight)
Normal seeded tomato	LITTH-778	42.76±2.13^{d}	10.11±.41^{fg}	3.26±0.16^{de}	37.51±1.87^{bcd}	25.43±1.27^{ab}	17.37±0.86^{de}	4.32±0.21^{de}	0.42±2.13^{a}
	LITTH-784	42.52±2.12^{d}	11.34±0.42^{def}	3.53±0.18^{ef}	29.49±1.47^{e}	22.72±1.13^{bc}	16.46±0.82^{de}	5.30±2.65^{c}	0.44±2.24^{a}
	LITTH-786	47.89±2.39^{bcd}	11.98±0.40^{de}	3.77±0.15^{cd}	46.65±2.33^{a}	20.19±1.00^{c}	19.89±0.99^{bc}	4.26±2.13^{e}	0.41±2.09^{ab}
	LITTH-788	42.51±2.12^{d}	9.28±0.37^{g}	3.01±0.15^{f}	33.94±1.69^{d}	24.61±1.23^{ab}	15.36±0.70^{e}	5.29±0.26^{c}	0.43±2.20^{a}
	LITTH-790	49.33±2.46^{ab}	10.74±0.38^{ef}	2.9±0.18^{f}	48.37±2.41^{a}	25.18±1.25^{ab}	20.26±1.01^{b}	3.25±0.16^{f}	0.45±2.27^{a}
	BHT				9.82±0.49^{g}				
Parthenocarpic tomato	LITTH-778	44.16±2.20^{cd}	12.61±0.63^{cd}	4.19±0.21^{bc}	35.18±1.76^{cd}	26.22±1.31^{a}	18.22±0.91^{bcd}	4.91±0.24^{c}	0.35±1.77^{c}
	LITTH-784	49.22±2.46^{abc}	13.89±0.69^{bc}	4.83±0.24^{a}	22.56±1.13^{f}	24.71±1.23^{ab}	17.88±0.89^{cd}	6.87±0.34^{a}	0.34±1.74^{c}
	LITTH-786	52.37±2.61^{ab}	16.34±0.81^{a}	4.26±0.21^{b}	38.82±1.94^{bc}	23.90±1.19^{ab}	20.00±.001^{bc}	4.86±0.24^{cd}	0.37±1.89^{bc}
	LITTH-788	49.69±2.48^{ab}	12.12±0.60^{de}	3.15±0.15^{ef}	33.72±1.68^{de}	25.99±1.29^{a}	17.41±0.87^{de}	6.00±0.30^{b}	0.35±1.78^{c}
	LITTH-790	53.53±2.67^{a}	14.66±0.73^{b}	3.88±0.19^{bcd}	40.23±2.01^{b}	26.67±1.33^{a}	23.34±1.16^{a}	3.89±0.19^{e}	0.33±1.69^{c}
	BHT				9.82±0.49^{g}				

407 Values are mean ± SD in triplicate determinations. Different letters in superscript represent significant ($p \leq 0.05$) difference among selected fruit
408 varieties.
409
410 TPC: Total phenolic content measured as mg/g of dry plant material, as compared as gallic acid equivalent
411 TFC: Total flavonoids content measured as mg/g of dry plant material, as compared as catechin equivalent
412 IC_{50}: DPPH radical scavenging activity in term of IC_{50}

TABLE 3: Contents of individual phenolic acids and flavonoids identified from the methanolic extracts of tomato fruits by HPLC

Tomato variety	Phenolics and Flavonoids											
	Genotype	Gallic acid	Chlorogenic acid	p-hydroxy benzoic acid	Caffeic acid	Vanillic acid	p-Coumeric acid	Sinapic acid	Ferulic acid	Catechin	Quercetin	Kaempferol
Normal seeded tomato	LITTH-778	615.6±30.8^{d}	1128.9±45.2^{d}	17.2±1.0^{f}	-	1.3±0.06^{ef}	57.92±1.7^{fg}	-	7.2±0.4^{fg}	54.92±1.6^{i}	133.4±6.7^{g}	14.5±0.7^{fg}
	LITTH-784	637.2±38.2^{b}	1145.7±68.7^{b}	19.6±1.2^{c}	2.4±0.1^{f}	1.4±0.05^{ef}	58.26±0.4^{f}	2.6±0.1^{e}	9.6±0.5^{de}	76.95±2.3^{g}	-	15.2±0.6^{ef}
	LITTH-786	677.7 ± 25.8^{a}	1163.1 ± 4.7^{a}	21.2 ±0.8^{d}	-	1.7 ± 0.08^{e}	56.5 ± 3.2^{g}	-	9.9±0.5^{d}	84.3 ± 4.9^{f}	125.7± 7.1^{h}	16.6 ± 0.9^{e}
	LITTH-788	603.9±24.2^{e}	1116.6±33.5^{e}	15.5±0.8^{g}	-	1.1±0.04^{ef}	54.33±1.5^{h}	1.7±0.1^{e}	6.09±0.3^{g}	66.32±2.6^{h}	149.5±8.9^{f}	13.3±0.4^{g}
	LITTH-790	626.5±8.8^{c}	1137.3±45.5^{c}	18.9±0.6^{e}	3.2±0.1^{f}	1.4±0.03^{ef}	50.06±2.5^{i}	-	8.2±0.4^{ef}	54.55±1.6^{i}	122.01±4.8^{i}	19.7±0.9^{d}
Parthenocarpic tomato	LITTH-778	242.3±9.7^{i}	73.9±4.4^{h}	109.9±6.6^{c}	1956.8±97.8^{e}	-	1821.4±91.1^{d}	-	167.4±8.4^{a}	297.7±14.8^{a}	280.3±11.2^{c}	315.8±12.5^{b}
	LITTH-784	265.4±10.6^{g}	76.8±4.6^{g}	113.1±4.5^{b}	2109.5±84.3^{c}	109.46±6.6^{b}	1900.1±76.0^{b}	245.1±14.7^{b}	156.2±10.9^{b}	278.5±11.1^{d}	305.8±15.2^{a}	-
	LITTH-786	272.5 ± 19.4^{f}	81.1± 5.2^{f}	117.4 ± 8.1^{a}	2200.6±152.4^{a}	113.2 ± 7.7^{a}	1971.6±98.3^{a}	254.5±17.3^{a}	151.5 ± 10.2^{c}	284.7 ± 19.0^{c}	281.9 ± 19.3^{b}	320.4±22.4^{a}
	LITTH-788	240.2±7.2^{j}	69.9±2.8^{i}	-	1999.2±79.8^{d}	101.3±5.1^{d}	1795.2±71.8^{e}	226.8±11.3^{d}	157.3±6.3^{b}	266.3±13.3^{e}	264.7±10.6^{e}	311.1±15.6^{c}
	LITTH-790	249.9±9.9^{h}	75.5±3.0^{g}	110.5±5.5^{c}	2178.4±108.9^{b}	104.9±5.2^{c}	1834.5±91.5^{c}	239.3±9.6^{c}	-	288.6±11.5^{b}	274.9±13.7^{d}	319.3±19.2^{a}

NA= not identified Values are mean ± SD of triplicate determinations. Different letters in superscript represent significant ($p \leq 0.05$) difference among selected fruit varieties

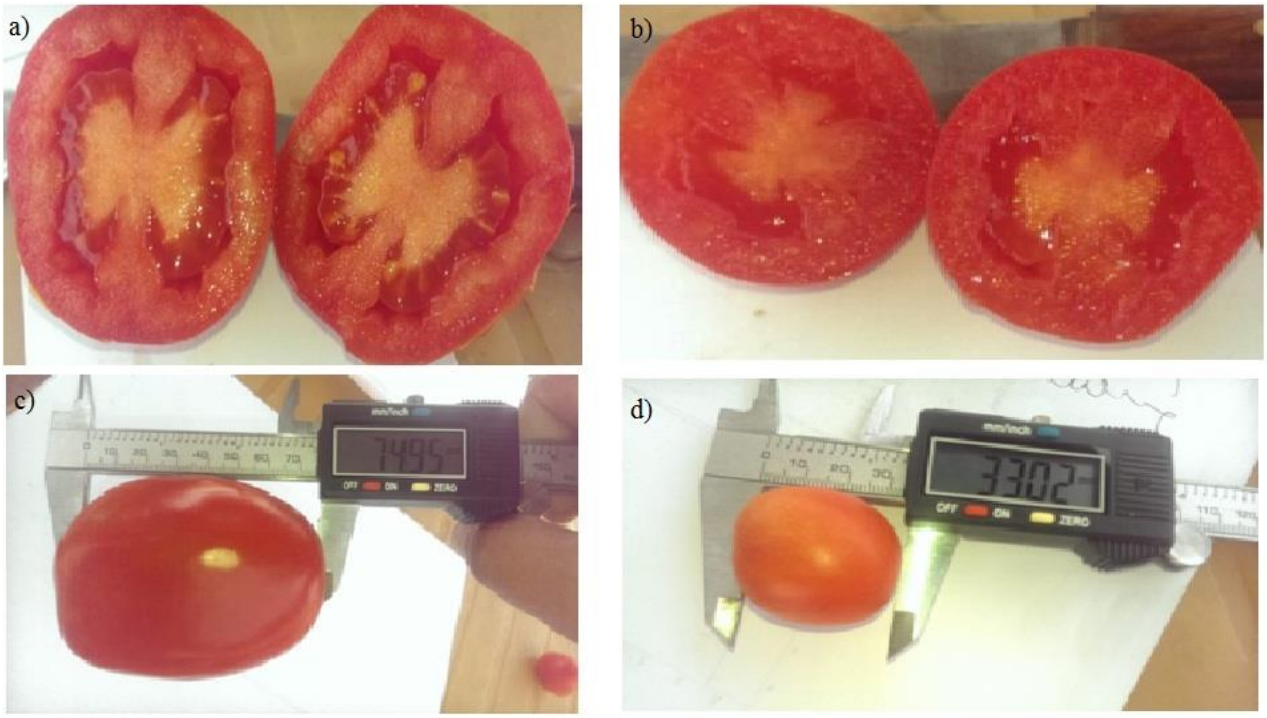

FIGURE 1:Normal seeded and parthenocarpic tomatoes

a) Cross section of normal seeded tomato b) Cross section of parthenocarpic tomato c) Length of normal seeded tomato d) Length of parthenocarpic tomato

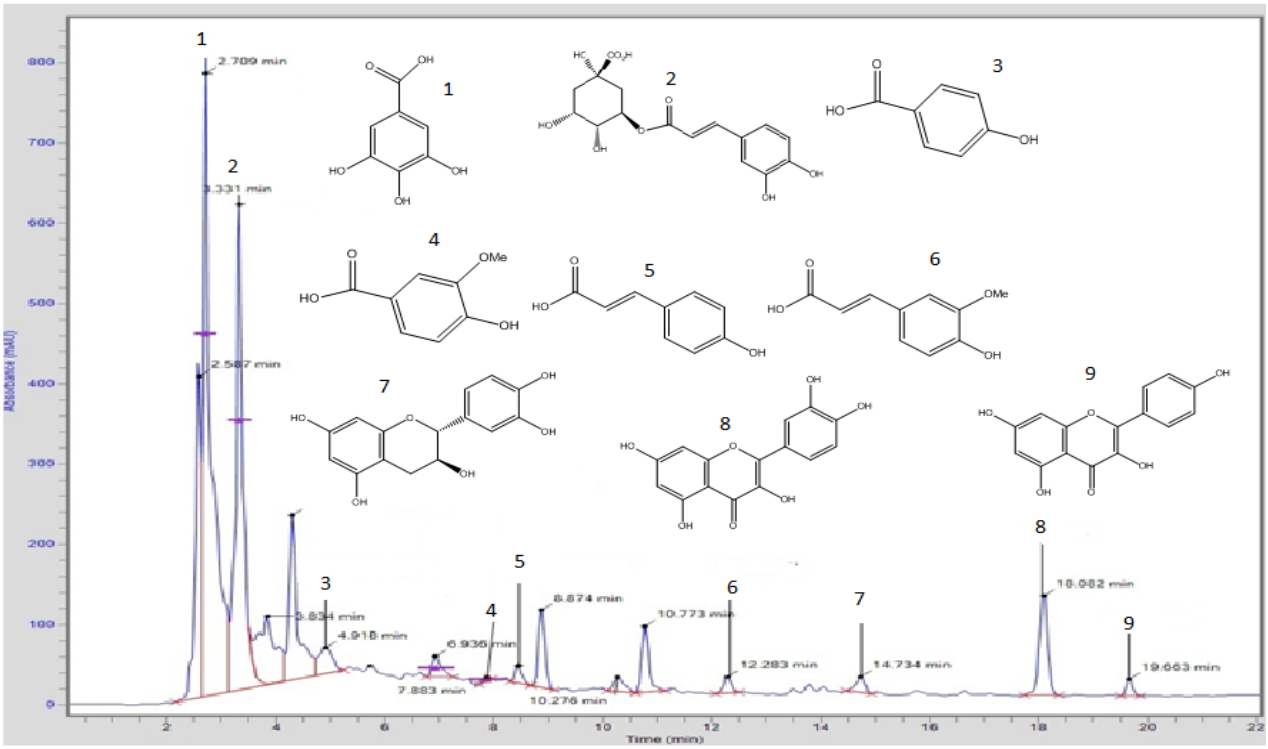

FIGURE 2: Typical chromatogram of phenolic acid and flavonoids of normal seeded tomatoes (1) gallic acid, (2) chlorogenic acid, (3) *p*-hydroxy benzoic acid, (4) vanillic acid, (5) *p*-coumeric acid, (6) ferulic acid, (7) catechin, (8) quercetin, (9) kaempferol

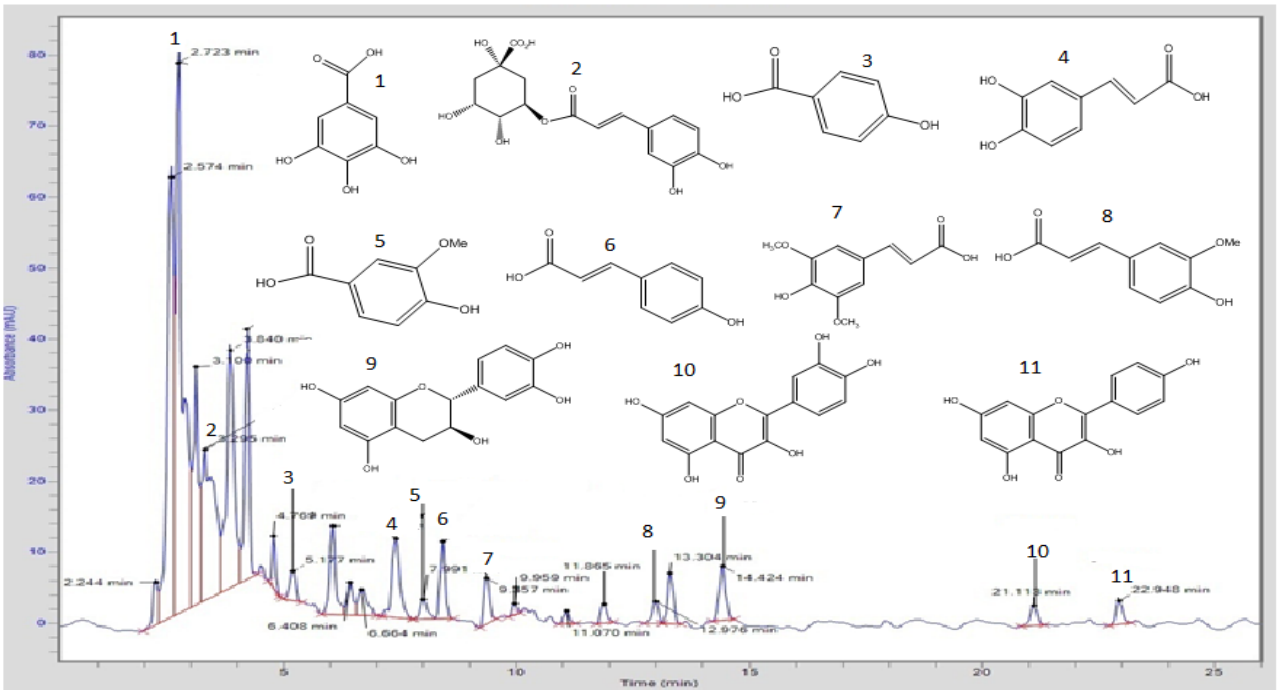

FIGURE 3:Typical chromatogram of phenolic acid and flavonoids of parthenocarpic tomatoes (1) gallic acid, (2) chlorogenic acid, (3) *p*-hydroxy benzoic acid, (4) caffeic acid, (5) vanillic acid, (6) *p*-coumeric acid, (7) sinapic acid, (8) ferulic acid, (9) catechin, (10) quercetin, (11) kaempferol