British Journal of Applied Science & Technology
4(22): 3263-3280, 2014

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Nutritional Status, Fruit Quality and Volatile Compounds in Eight Egyptian Pomegranate Cultivars

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Authors' contributions

This work was carried out in collaboration between all authors (Reference collection, analysis and writing). Author HAH Put the idea of research, collect samples from the field and performed analyses of macro and micro-elements. Author GEI performed volatile compounds and produced a draft of the manuscript. Author OMH performed fruit quality assessments, the statistical analysis and checked the data for validity. Also, review and send of the manuscript to the magazine and repairs. All authors read and approved the final manuscript.

Original Research Article

Received 15th March 2014
Accepted 29th April 2014
Published 13th June 2014

ABSTRACT

Fruits of 8 Egyptian pomegranate cultivars grown in Upper Egypt, namely Asuity, Asuity beshoka, Asuity morkub, Manfalouty, Nab El-Gamal, Melasy, Sukkary and Maghal were compared for their nutritional status, fruit quality and volatile compounds. Obtained results showed that Asuity cv. had pronounced concentrations of P, Ca, Fe and Mn in peels. Besides its significant progress concentrations of Fe and Mn in leaves as well as recorded the highest significant concentration of K in grains than other cultivars. Meanwhile, Manfalouty cv. had significant progress concentrations of P and K in leaves. Moreover Maghal cv. superiority concentrations of N, K and Mn in peel as well as Ca concentration in grain than other cultivars. Concerning fruit quality, the total soluble solids values varied from 14.6 to 16.3%, pH from 2.8 to 4.0, total acidity from 0.8 to 4.0% and total anthocyanins contents from 4.7 to 42.3 mg/100 ml. The highest value of total

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anthocyanin contents was recorded in Asuity beshoka while the minimum values in Sukkary cultivar. In pomegranate juice, 14 volatile compounds were fractioned and identified, including 6 monoterpene; 3 monoterpenoids, 3 aldehydes, 1 esters and 1 alcohols. Also, Hexanal, α-pinene, β-pinene, γ-Terpinene and limonene were recorded as important odour contributors found in the headspace gas of pomegranate juice.
In conclusion, local pomegranate fruits grown in Upper Egypt are rich in its nutrient contents for both arils and peel besides important amounts of juice, sugars, total soluble solids, vitamin C and antioxidants as well as higher concentrations of volatile compounds in their headspace.

Keywords: Pomegranate cultivars; Upper Egypt; nutrition status; fruit quality; volatile compounds.

1. INTRODUCTION

Pomegranate (*Punica granatum* L.) is considered one of the most important deciduous shrubs grown successfully in Egypt, not only for local consumption but also for exportation. It requires a long hot summer and a little chilly winter for fruit to mature. It is also drought and salinity tolerance [1]. Recently pomegranate cultivation has been expanded in several countries, especially those with a Mediterranean-like climate, where fruit of excellent quality can be obtained. The growing interest of this fruit not only for its pleasant to eat, but also considered it as a functional product of great benefit in the human diet, as it contains several substance groups that are useful in disease prevention [2], high antioxidant activity and several medical benefits [3]. It follows an increasing demand for industrial processing to make juice, jams, syrup, sauce, flavouring, colouring agents and nutraceuticals,… etc., in addition to the growing demand for fresh consumption. The aril as edible part of pomegranate fruits contains great amounts of organic acids, sugars, minerals, vitamins, anthocyanin and polyphenols [4]. Fruit chemical properties such as pH, total soluble solids, total acidity, maturity index, vitamin C, total anthocyanin and total sugars may provide important information to the consumer in terms of recognizing a more nutritional fruit [5]. Also, total soluble solids, total sugars, ascorbic acid and anthocyanin contents parameters play a major role in crop due to their essentiality in fruit quality [6]. Anthocyanins are a member of phenolic compounds that contributes to the red, blue, or purple color of many fruits, including pomegranate juice and they are well-known for their antioxidant activity [7]. Locally pomegranates *Cvs*. are concentrated in Upper Egypt especially Asuit Governorate in a long time ago because of the expansion in land reclamation using new introduced varieties, to overcome the increasing amount of export. Where, the total production exceeded 51.3,000 tons in 2009 [8].

The reduction in volatile concentration compounds of fruit juice is considered the main problems for pomegranate quality that leading to low intensities of both odour and aroma. For this reason, only a few papers describing the volatile aroma composition of pomegranate juices are found in scientific literatures. For instance, [9] studied the possibility of using the pervaporation process to recover pomegranate aroma compounds and identified only nine compounds in pomegranate juices from Iran. The only common volatile compound found in the previously published manuscript was 1-hexanol. In fact, it is a necessary step to get essential and useful information for fresh market and processing industry, as well as for cultivars classification. [10] assessed volatiles in juice berries and identified ten volatiles coming from pomegranate. Of these compounds, hexanol was only found in the present study. This information proves how difficult is working with pomegranate volatiles.

So, in the current study, we evaluated shrub nutrition status, fruit quality assessments and its volatile components of eight local pomegranates *Cvs.* grown in Upper Egypt.

2. MATERIALS AND METHODS

The study was performed during 2011 and 2012 seasons in a private orchard at El-Badary Centre, Assiut Governorate, Egypt on eight pomegranate *Cvs*. (*Punica granatum* L.) namely Asuity, Asuity beshoka, Asuity morkub, Manfalouty, Nab El-Gamal, Melasy, Sukkary and Maghal. Shrubs were uniform in vigour with nearly 15-years old spaced 4 x 3 m apart chosen randomly as 3 replicates (tree/replicate) and arranged in a randomized block design. Fertilization was used as follows: 30 m^3/fed of farmyard manure during December - January. NPK rates were 250 kg N/fed, as ammonium nitrate (33.5% N), 66 kg P_2O_5 /fed, as superphosphate (15.5%) and 100 kg K_2O/Fed as potassium sulfate (48%) per year were applied as split fertilizer and distributed around the tree. The trees were grown in sandy clay soil under the flow surface irrigation system. Soil texture was a sandy clay with 1.34 % organic, 5.7% $CaCO_3$, 2.7 P, 7.6 K, 400 Ca, 29 Mg, 10.2 Na%, 3.7 Zn, 4.6 Mn, 3.4 Fe and 0.2 Cu ppm.

2.1 The Following Measurements were carried out

2.1.1 Leaf nutrient concentration

The leaf samples 4 to 7 months old young shoots were collected randomly around the Shrub from the fully mature leaves of spring flush. The leaves were washed, dried at 70ºC till constant weight, grind and digested to determine the macro-nutrients (N, P, K, Ca, Mg and Na%) and micro-nutrient (Zn, Mn, Fe and Cu ppm) concentrations according to [11]. Where, Mineral analyses were done in fruit peel and grains.

2.2 Fruit Samples

Uniform ripe pomegranate fruits were free from physiological and pathological disorders [12] were harvested in late summer and fall for both seasons and transported to the research Lab. of the National Research Center, Cairo, Egypt for measurements and analyses.

2.3 Fruit Quality Assessments

2.3.1 Physical characters

Fifteen fruits of each cultivar were individually analyzed for physical characteristics and averaged for each replicate. The length (L) (cm) and diameter (D) (cm) of the fruit were measured with a digital vernier caliper. The measurement of fruit length was made on the polar axis, i.e. between the apex and the end of the stem. The maximum width of the fruit, as measured in the direction perpendicular to the polar axis, is defined as the diameter. Fruit weight (g), grain weight (g) and peel weight (g) and grain/peel ratio was estimated.

2.4 Juice Extraction

Ripe fruits were cut-up, the outer skin that encloses hundreds of fleshy sacs removed, juice localized in the sacs extracted by a domestic blender juice and the resulting juice filtered through chess cloth. Juice volume (cm^3) was estimated and chemical properties determined.

2.5 Chemical Characters

- Total soluble solids percentage: Was determined using hand Carl Zeis refractometer.
- pH juice: was measured using a digital pH meter.
- Total acidity %: Was estimated as citric acid according to [13].
- Maturity index (MI): Was calculated as a ratio of Total soluble solids/ Total acidity.
- Vitamin C (mg/100ml juice): Was measured by titration with 2-6 dichlorophenol indophenols blue dye, as described by [13].
- Total Sugars (g/100g FW): Was determined using the phenol and sulphoric acid by method described by [14].
- Total anthocyanin (mg/100ml juice): Anthocyanin pigments undergo reversible structural transformations with a change in pH manifested by strikingly different absorbance spectra [15]. The coloured oxonium form predominates at pH 1.0 (25 mM with potassium chloride buffer) and the colourless form at pH 4.5 (0.4 M with sodium acetate buffer). The samples were diluted by potassium chloride buffer until the absorbance of the sample at a 510 nm wavelength was within the linear range of the spectrophotometer. This dilution factor was used later to dilute the sample with the sodium acetate buffer. At two wavelengths of 510 and 700 nm, readings were performed after 15 min. of incubation, four times per sample diluted in the two different buffers. The absorbance was then calculated according to the following equation: $A= (A_{510}- A_{700})\ pH_{1.0} - (A_{510}- A_{700})\ pH_{4.5}$

Results were expressed as mg cyaniding-3-glucoside /100 ml of juice [16].

2.6 Volatiles Composition

2.6.1 Extraction of volatile compounds from pomegranate fruit *Cvs.*

The aroma volatiles in headspace of juice were isolated using a dynamic headspace system. The samples were purged for ~ 3 h. with nitrogen gas (grade of N_2 > 99.99 %) at a flow rate 100 ml/min. The headspace volatiles were swept into cold traps containing diethyl ether and pentane (1:1, v/v) and hold at –10ºC. Solvents containing the volatiles were dried over anhydrous sodium sulfate for 1h and evaporated under reduced pressure to obtain juice volatiles according to [17].

2.7 Gas Chromatography (GC) Analysis

It was performed using Perkin Elmer Auto system equipped with flame ionization detector (FID) and a fused silica capillary column DB-5 (60 m X 0.32 mm *i.d*). The oven temperature was maintained initially at 50ºC for 10 min, then programmed from 50 to 180ºC at a rate of 3ºC/min. Helium was used at a flow rate 1.0 ml/min as carrier gas. The injector and detector temperatures were 220 and 250ºC, respectively. The retention indices (Kovats index) of the separated volatile components were calculated with hydro-carbons (C_6-C_{22}) as references [18].

2.8 Gas Chromatographic-mass Spectrometric (GC-MS) Analysis

Isolation, identification, and quantification of the volatile compounds were performed using a gas chromatograph (Hewllet-Packard (5890)/mass spectrometry Hewllet-Packard-MS (5970) and operated with the MS Workstation software. The GC-MS system was equipped with DB-5 column (Varian, Inc. Walnut Creek, CA; 60 m X0.25 mm X 1.0 mm film thickness). Column temperature began at 50ºC and held for 10 min, increased 3ºC per minute to 180ºC, and finally increased 10ºC per minute to 230ºC and kept at this temperature for 10 min. The constant column flow was 1 ml min^{-}1, using helium as carrier gas.

The isolated peaks were identified by comparison of mass spectra of the target compounds with those of the National Institute of Standards and Technology (NIST) library and verified by the retention indices of pure standard compounds identified by matching with data from the library of mass spectra and compared with those of authentic compounds and published data [19].

2.9 Statistical Analysis

The results were submitted to analysis of variance according to [20]. Differences among treatment means were determined as using the LSD test at a significance level of 0.05 according to [21].

3. RESULTS AND DISCUSSION

3.1 Nutritional Status of Pomegranate Cultivars

3.1.1 Macro-nutrients

Results presented in (Table 1) showed that leaves of tested pomegranate cultivars were significantly differed in their macro-nutrient values *i.e*. N, P, K, Ca and Mg concentrations.

Table 1. Macro-nutrients concentration (% dry matter) in leaves of eight local pomegranate cultivars grown in Upper Egypt (Means of the two seasons)

Cultivars	Leaves				
	N	P	K	Ca	Mg
Asuity	2.06 c	0.15 b	1.83 f	3.10 b	0.87 c
Asuity beshoka	2.47 d	0.12 a	1.75 e	4.15 g	0.96 e
Asuity morkub	1.95 b	0.12 a	1.53 b	3.05 a	1.31 g
Manfalouty	2.72 e	0.16 c	1.90 g	3.60 e	0.96 e
Nab El-Gamal	2.06 c	0.15 b	1.55 c	3.20 c	0.85 a
Melasy	1.85 a	0.16 c	1.57 d	3.60 e	0.92 d
Sukkary	3.06 g	0.12 a	1.50 a	3.85 f	0.86 b
Maghal	2.87 f	0.15 b	1.50 a	3.50 d	0.98 f

Values with the same letter within the same column were not statistically different (Duncan Multiple at P ≤ 0.05)

3.1.1.1 Leaf N concentration

It ranged from 1.85 - 3.06%. The highest significant values in leaves N concentration were obtained from Sukkary, Maghal, Manfalouty and Asuity beshoka *Cvs*. which recorded (3.06, 2.88, 2.72 and 2.47% respectively) as compared than other cultivars. The lowest statistical values in leaves N concentration were recorded by Melasy (1.85%) and Asuity morkub (1.95%).

3.1.1.2 Leaf P concentration

It ranged from 0.12 – 0.16%. Manfalouty and Melasy *Cvs*. recorded dominated values of P leaf concentration (0.16 %) but without significant differ between them. The lowest statistical obtain by Asuity beshoka, Asuity morkub and Sukkary (0.12%) with not significant among them.

3.1.1.3 Leaf K concentration

It ranged from 1.50 – 1.90%. It is clear that the cultivars of Manfalouty (1.90%), Asuity (1.83 %), Asuity beshoka (1.75%) and Melasy (1.57%) were highly significant increased in leaf K concentration than other ones. Meanwhile the *Cvs*. of Sukkary (1.50%) and Maghal (1.50%) induced lowest significant decreased in leaf K concentration, with no differ among them.

3.1.1.4 Leaf ca concentration

It ranged from 3.05 – 4.15%. It can be noticed that Asuity beshoka (4.15%) and Sukkary (3.85%) *Cvs.* had pronounced values of leaf Ca concentration with high significant differ between them. Whereas Asuity morkub cv. (3.05%) had the lowest statistical values in leaf Ca concentration than other *Cvs*.

3.1.1.5 Leaf Mg concentration

It ranged from 0.85 – 1.31%. Where, Asuity morkub and Maghal Cvs. induced the highest significant concentration in this character (1.31 and 0.98%, respectively). But the lowest one (0.85%) was recorded by Nab El-Gamal cultivar.

Data in Table 2 revealed that different cultivars had increased macro-nutrients concentration (%) in fruits (peel and grain) of the eight cultivars.

3.1.1.6 Fruit N concentration

It ranged between 1.44 – 2.79% in peel and between 1.90 – 3.43% in grains. The *Cvs.* of Maghal, Melasy, Asuity morkub and Asuity beshoka progressed in peel and Manfalouty, Nab El-Gamal, Asuity beshoka and Sukkary *Cvs*. in grains in this respect than other ones. While the Asuity cv. in peel and Melasy cv. in grain induced the lowest significant values in this character.

3.1.1.7 Fruit P concentration

It ranged from 0.06 to 0.14% in peel and from 0.11 to 0.28% in grains. Where Asuity, Sukkary and Asuity beshoka *Cvs*. in peel also Nab EL-Gamal, Asuity and Asuity morkub *Cvs*. in grain were pronounced in this respect. However the cultivars Asuity morkub & Manfalouty in peel and Asuity beshoka in grains had statistical decreased in this respect.

3.1.1.8 Fruit K concentration

It ranged from 1.90 – 3.75% in peel and from 2.45 – 4.15% in grains. Maghal and Asuity *Cvs.* significantly recorded the highest significant increase in peel and grains K concentration consecutively as compared with other cultivars. But, Asuity beshoka cv. had the lowest ones in the fruit (peel and grain).

3.1.1.9 Fruit Ca concentration

It ranged between 1.10 to 2.25% in peel and between 1.25 to 1.65% in grains. Asuity cv. in peel and Sukkary and Maghal *Cvs.* in grains had the highest fruit Ca concentration than other *Cvs.* while Maghal and Asuity morkub *Cvs.* in both peel & grain recorded the lowest, in this respect.

3.1.1.10 Fruit Mg concentration

It ranged from 0.22 to 0.27% in peel and from 0.16 to 0.31% in grains. It is clear that Maghal cv. superiority in this respect while Nab El-Gamal cv. had the lowest ones in both peel and grains.

Generally the highest concentration N and P were recorded with grains followed in descending order by leaves and peel. While the increment concentrations K were obtained by grain, peel and leaves respectively. But Ca and Mg the highest concentration recoded with leaves, grain and peel consecutively.

3.1.2 Micro-nutrients

Data in (Table 3) recorded significant differences in micro-nutrient concentrations (ppm) among leaves, peels and grains of the tested *Cvs*. such as Fe, Mn and Zn.

3.1.2.1 Fe concentration

It ranged from 234 to 319 ppm in leaves, from 80 to 150 ppm in peels and from 89 to 125 in grains. Asuity cv. had superiority in this character in both leaves and peel but Nab El-Gamal cv. in grains. The lowest Fe concentration was obtained by Manfalouty and Sukkary *Cvs*. in leaves, Nab El-Gamal and Melasy *Cvs*. in peel and grains consecutively.

3.1.2.2 Mn concentration

It ranged from 33 to 78 ppm in leaves, from 5 to 12 ppm in peels and from 9 to 14 in grains. The highest significant Mn concentration which recorded with Asuity beshoka cv. in grains but the same result in leaves and peel in this respect. The *Cvs.* Melasy, Asuity beshoka and Nab El-Gamal had the lowest statistical Mn concentration in leaves, peel and grains respectively.

3.1.2.3 Zn concentration

It ranged from 26 to 44 ppm in leaves, from 11 to 19 ppm in peels and from 12 to 36 in grains. Where Asuity morkub, Melasy and Manfalouty and Sukkary *Cvs*. were superior to other *Cvs.* in this character and registered the highest statistical values in leaves, peel and grains consecutively. The lowest Zn concentrations were recorded by the *Cvs*. Asuity and Manfalouty in leaves, Asuity morkub in peel and Melasy in grains.

In general, micro-nutrient concentrations in different parts of tested *Cvs*. can be arranged as follows the highest concentration Fe was recorded with leaves followed in descending order by peel and grains. While the increment concentrations Mn was obtained by leaves, grain and peel respectively. But Zn the highest concentration recoded with leaves, grain and peel consecutively. In addition, the trend was varied according to cultivars.

Our results are in contrast with those researchers by [22] who found that the range of variation of K in pomegranate fruits of ten varieties grown in Iran was 80.0–160.6mg/100g. Also concentrations of Ca and Mg ranged from 13.05 to 30.60 and 2.75–5.20mg/100g, respectively. In addition, [23] revealed that the mean values of the mineral content of pomegranate fruit cultivars in Tunisia are about 10.44mg/100 ml for P and 218.2mg/100 g for K. The mineral concentrations were generally lower than those reported in the previous results. But our results are in harmony with the results reported by [24] and [25]. In the literature, they recorded that the differences in mineral composition of leaves and fruits of pomegranates depending on cultivar, growing region, climate, maturity stage, harvest practices and storage conditions lead to difference in cultivars ability to absorb element from the soil.

3.2 Fruit Quality Assessments

3.2.1 Physical characteristics

Physical characters were differed in tested pomegranate cultivars as shown in (Table 4).

3.2.1.1 Fruit weight

It ranged between 198.1 and 313.9 g. The heaviest fruits were significantly obtained from Nab El-Gamal (313.9 g). The next Manfalouty, Asuity morkub, Maghal and Melasy *Cvs*. which recorded 284.5, 275.0, 246.5 and 222.0 g respectively, followed by Asuity (211.4 g) and Asuity beshoka (204.3 g) *Cvs*. The lower value was obtained from Sukkary cv. (198.1 g).

3.2.1.2 Grain weight

It ranged between 132.5 and 211.0 g where Nab El-Gamal, Manfalouty and Sukkary *Cvs*. were superior to other *Cvs.* in this character and registered the highest statistical values as sequence descending (211.0, 193.8 and 171.5 g). Asuity morkub (160.6 g) and Maghal (159.9 g) *Cvs.* came next. The lowest grain weights were recorded in descending order by the *Cvs*. Asuity beshoka (135.6 g), Melasy (134.4 g) and Asuity (132.5 g).

3.2.1.3 Peel weight

Obtained data illustrated that mean values of peel weight ranged from 18.0 to 114.3 g. Asuity morkub (114.3 g) and Nab El-Gamal (101.3 g) *Cvs.* had the highest significant values than other *Cvs.* while Maghal (18.0 g) and Sukkary (34.4 g) *Cvs.* recorded the lowest, in this respect.

3.2.1.4 Grain/peel ratio

Its values ranged between 1.7 and 3.2%. Where, Sukkary, Maghal, Manfalouty, Nab El-Gamal and Asuity beshoka Cvs. induced the highest significant ratio in this character (3.2, 2.4, 2.2, 2.0 and 2.0%, respectively). But the lowest one (1.7%) was recorded by Melasy cultivar.

3.2.1.5 Fruit length

Data showed that means of the two seasons for fruit length ranged between 5.6 and 9.5 cm. Nab El-Gamal, Manfalouty and Asuity morkub *Cvs*. significantly recorded the tallest as compared with other cultivars. But, Maghal, Asuity and Asuity beshoka *Cvs*. had the shortest ones.

3.2.1.6 Fruit diameter

It ranged between 4.8 and 9.3 cm for the means of both seasons. Manfalouty, Asuity morkub and Nab El-Gamal *Cvs*. recorded the highest values, while Maghal cv. gave the lowest fruit diameter.

3.2.1.7 Juice volume

It ranged from 94.3 to 176.7 cm^3. The increments in juice volume were recorded in descending order by the *Cvs*. of Maghal (176.7 cm^3), Nab El-Gamal (176.7 cm^3), Melasy (133.3 cm^3), Manfalouty (123.3 cm^3), Asuity morkub (121.6 cm^3) and Asuity beshoka (114.3 cm^3).The lowest values were significantly recorded by Asuity cv. (94.3 cm^3) and Sukkary cv. (96.7 cm^3).

These results are in harmony with those obtained by [22] who found that the medium size of ripe pomegranate fruits in ten varieties grown in Iran ranged (250 – 300 g). Also, [26] reported that the highest fruit weight (171 g); largest fruit size (7.34 cm long, 7.47 cm in diameter) with aril weight (102 g). In addition, these results are in agreement with those of [27]. [28] found that percentages of juice content in Spanish and Indian varieties ranging from 44.96 to 68.55. In other study, [29] revealed that Nab El-Gamal from Upper Egypt and Sukkary Red from North Sinai *Cvs*. had highest amount of juice (75.00- 67.33 ml/100 g seeds) compared with other *Cvs*. (46.67 ml/100g). The differences in our results comparing with previous reports either by increase or decrease may be due to the difference in growing region, climate and tested cultivars.

3.3 Chemical Characteristics

Chemical characters were differed in juice of tested pomegranate *Cvs.* (Table 5).

3.3.1 pH values

Obtained results clearly showed that pH ranged from 2.8 to 4.0. The highest significant values were recorded with Sukkary cv. (4.0), followed in descending order by Nab El-Gamal cv. (3.9), Manfalouty cv. (3.7) and Asuity cv. (3.0). The lowest values were recorded by Asuity beshoka cv. (2.8) and Maghal cv. (2.9). These results are in agreement with those obtained by [30], [4] and [29] who found that pH in the studied *Cvs*. ranged between 4.5 in Sukkary red cv. (from North Sinai) to 3.1 in Asuity cv. (from Upper Egypt). However, the pH values obtained in the current study are greater than those reported by [31] on Turkey pomegranate *Cvs*.

3.3.2 Total soluble solids (TSS %)

It ranged from 14.6 to 16.3%. The highest significant values were obtained by *Cvs*. Maghal and Manfalouty which recorded 16.3 and 16.1%, respectively. While, Asuity beshoka cv.

recorded the lowest one (14.6%). In this respect, present results are in agreement with those obtained by [22] who mentioned that TSS content ranged between (11.0 - 16.5 °Brix) in Iran *Cvs*. Similarly, [28] reported that TSS% of Turkey *Cvs*. ranged between 12.36 and 16.32%. Also, [29] found that both sour and sweet *Cvs*. from Siwa Oasis recorded the highest TSS% (20.33 and 18.67 °Brix) while, Asuity Maragab cv. from Upper Egypt had the lowest TSS % (12.40 °Brix).

3.3.3 Total acidity (TA %)

It ranged from 0.8 to 4.0% where the lowest significant TA % was recorded with Nab El-Gamal cv. fruits (0.8%), followed in ascending order by Sukkary cv. (0.9%), Manfalouty cv. (0.9%) and Asuity morkub cv. (1.2%). Contrarily, the highest value was recorded by Asuity beshoka cv. (4.0%). The current results are in agree with those obtained by [29] who revealed that fruit acidity in Upper Egypt *Cvs*. recorded the highest values (2.75- 2.81%) whereas, fruit acidity of Siwa Oasis and North Sinai *Cvs*. showed the lowest values (0.30%). Similar results were also reported by [22] who recorded significant differences in total acidity of ten varieties grown in Iran. Its mean values were varied from (4.0 g/L to 24.5 g/L) expressed as citric acid. While, [28] reported that acidity in Spanish variety ranged from (1.004 to 0.268%).

3.3.3 Maturity Index (MI)

TSS/TA as MI ranged from 3.6 to 18.7. The highest values were recorded by Nab El-Gamal cv. (18.7), followed in descending order by Manfalouty (17.5), Sukkary (16.7), Asuity morkub (13.2), Maghal (12.0) and Asuity *Cvs*. (11.0). The reduction in MI was significantly obtained by either Asuity beshoka (3.6) or Melasy *Cvs*. (9.5). MI is responsible for the taste and flavor of pomegranate, which some author used for classifying the pomegranate *Cvs*. [32]; [28] and [31].

3.3.4 Vitamin C

It ranged from 8.5 to 19.0 mg/100 ml. The increments in its content was recorded in descending order by Maghal, Manfalouty, Asuity morkub, Asuity, Nab El-Gamal and Sukkary *Cvs*. (19.0, 18.2, 16.3, 13.4, 11.9 and 10.7 mg/100 ml, respectively). The lowest values were significantly recorded by the Melasy and Asuity beshoka *Cvs*. (8.5 and 9.9 mg/100 ml, consecutively). The previous results are in agreement with those obtained by [29] who determined ascorbic acid contents in different pomegranate *Cvs*. and found that Sukkary red cv. Grown in North Sinai recorded higher ascorbic acid (9.48 mg/100 ml, while both of Nab El Gamal and Manfalouty *Cvs*. showed the lowest values, in this respect. [22] recorded significant differences in ascorbic acid values (0.13 - 0.28 mg/100g) of ten *Cvs*. grown in Iran. But, our results recorded the highest values, in this respect.

3.3.5 Total anthocyanin

Its values ranged from 4.7 to 42.3 mg/100ml juice. Asuity beshoka, Asuity morkub and Maghal *Cvs*. recorded significant increase in anthocyanin contents which recorded 42.3, 34.7 and 30.8 mg/100ml, consecutively. While, Nab El-Gamal, Asuity and Manfalouty *Cvs*. recorded moderate values which induced 22.7, 21.7 and19.5 mg/100ml, respectively. Moreover, Sukkary and Melasy *Cvs*. reflected the lowest anthocyanin values (4.7 and 8.6 mg/100ml), consecutively. The previous results are in harmony with those obtained by [29] who found that both Wardy and Asuity Abo Shoka *Cvs*. grown in Upper Egypt displayed high amounts (1.37 mg/ml), while variability among other *Cvs*. ranged from (0.04 - 0.8 mg/ml), but sour cv. grown in Siwa Oasis it recorded the lowest value (0.045 mg/ml). In their study, [31] indicated that levels of total anthocyanin varied between 8.1 and 36.9 mg/100ml juice among different pomegranate *Cvs*. grown in Turkey.

3.3.6 Total sugars

Its mean values ranged from 17.5 to 62.3 g/100g fresh weight (FW). Maghal, Sukkary, Melasy, Asuity morkub and Asuity beshoka *Cvs*. recorded the highest significant values (62.3, 40.2, 39.1, 37.8 and 31.3 g/100g), respectively as compared with other *Cvs*. While, Manfalouty, Nab El-Gamal and Asuity *Cvs*. reflected lower sugars values (17.5, 18.5 and 24.1 g/100g), consecutively. The above results are in agreement with [22] who found that total sugar content ranged between (7.20 - 12.36 g/100g) in pomegranate *Cvs*. grown in Iran. But our results recorded the highest values in this respect.

3.4 Volatiles Composition

A total of 14 compounds were isolated from pomegranate *Cvs.* juices. Several identified volatiles were present and compared as relative area percentage (Table 6). The volatile fractions of pomegranate juices consist mostly of aldehydes, monoterpene, monoterpenoids, alcohols and esters. Compounds were grouped as follows: (a) aldehydes –hexanal, nonanal and decanal; (b) monoterpenes – α-pinene, β-pinene, β-myrcene, *P*-cymene limonene and γ -terpinene; (c) monoterpenoids – fenchone, camphor, and α-terpineol; (d) alcohols – 1-hexanol; (e) Esters-Hexyl acetate.

In general, aldehydes were the predominant group in the headspace of pomegranate juices, followed by monoterpenes. Aldehydes can be related to green, grassy, and herbaceous notes, while monoterpenes can be related to pine and citrus notes; it is possible that the different predominance of chemical groups have some influence on consumers' preference for pomegranate juices. Finally, alcohols also played an important role in the volatile profile of several pomegranate cultivars, for instance Asuity, Asuity beshoka, Sukkary and Maghal *Cvs*.

Fatty and amino acids are the precursors of a great number of volatile aldehydes, and part of these aldehydes can be enzymatically reduced to the corresponding alcohols [33]. Aldehydes seem to contribute to the juices' general aroma with green-leafy (hexanal), fatty (heptanal, octanal) or soapy-fruity (nonanal) aromas, while alcohols provided wine-like, (Z-3-hexen-1-ol) or oily and sweet (2-ethyl-1-hexanol) notes [34]. [35] found a positive and negative correlations among consumer liking and the presence of monoterpenes (for example *α*- terpineol and *α*-pinene) and aldehydes (for example *cis*-3-hexenal and hexanal), respectively.

Table 2. Macro-nutrients concentration (% dry matter) in fruits (peel and grain) of eight local pomegranate cultivars grown in Upper Egypt (Means of the two seasons)

Cultivars	Fruits									
	Peel					Grain				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Asuity	1.44 a	0.14 f	2.15 b	2.25 f	0.25 c	2.42 b	0.24 g	4.15 h	1.60 d	0.22 d
Asuity beshoka	1.96 e	0.10 d	1.90 a	1.70 e	0.27 e	3.33 f	0.11 a	3.45 e	1.60 d	0.31 g
Asuity morkub	2.07 f	0.06 a	2.55 c	1.70 e	0.23 b	2.67 d	0.22 f	2.45 a	1.25 a	0.21 c
Manfalouty	1.83 c	0.06 a	3.50 f	1.55 d	0.23 b	3.43 h	0.15 d	3.50 f	1.50 c	0.29 f
Nab El-Gamal	1.86 d	0.08 b	2.60 d	1.35 c	0.22 a	3.36 g	0.28 h	3.10 d	1.45 b	0.16 a
Melasy	2.41 g	0.10 d	3.15 e	1.35 c	0.22 a	2.57 c	0.14 c	3.60 g	1.45 b	0.21 c
Sukkary	1.63 b	0.11 e	3.50 f	1.25 b	0.22 a	2.79 e	0.13 b	3.05 c	1.65e	0.20 b
Maghal	2.79 h	0.09 c	3.75 g	1.10 a	0.26 d	1.90 a	0.16 e	2.80 b	1.65 e	0.26 e

Values with the same letter within the same column were not statistically different (Duncan Multiple at P≤0.05)

Table 3. Micro-nutrients concentration (ppm dry matter) in leaves and fruits (peel and grain) of eight local Pomegranate cultivars grown in Upper Egypt (Means of the two seasons)

Cultivars	Leaves			Fruit peels			Fruit grains		
	Fe	Mn	Zn	Fe	Mn	Zn	Fe	Mn	Zn
Asuity	319 f	78 f	26 a	150 g	12 d	15 d	105 c	10 b	23 e
Asuity beshoka	305 e	54 c	28 c	122 e	5 a	13 c	105 c	14 e	16 b
Asuity morkub	298 d	59 d	44 f	150 g	11 c	11 a	91 b	10 b	27 g
Manfalouty	234 a	53 c	26 a	87 b	10 b	12 b	115 d	13 d	36 h
Nab El-Gamal	247 b	49 b	28 c	80 a	11 c	13 c	125 e	9 a	26 f
Melasy	274 c	61 e	29 d	138 f	10 b	19 f	89 a	10 b	12 a
Sukkary	234 a	54 c	33 e	97 d	10 b	16 e	90 b	11 c	17 c
Maghal	245 b	33 a	27 b	90 c	12 d	12 b	104 c	11 c	21 d

Values with the same letter within the same column were not statistically different (Duncan Multiple at P≤0.05)

Table 4. Physical characteristics of eight local pomegranate cultivar fruits grown in Upper Egypt (Means of the two seasons)

Cultivars	Fruit weight (g)	Grain weight (g)	Peel weight (g)	Grain/ Peel ratio	Fruit length (L) "cm"	Fruit diameter (D) "cm"	Juice volume (cm^3)
Asuity	211.4 a	132.5 a	79.1 ab	1.8 ab	7.0 b	8.0 c	94.3 a
Asuity beshoka	204.3 a	135.6 a	68.7 ab	2.0 abc	7.0 b	8.1 c	114.3 ad
Asuity morkub	275.0 bc	160.7 ab	114.3 d	1.7 ab	9.0 d	9.3 e	121.6 b
Manfalouty	284.5 bc	193.8 bc	90.8 bc	2.2 bc	9.0 d	9.3 e	123.3 b
Nab El-Gamal	313.9 c	211.0 c	101.3 cd	2.0 abc	9.5 e	9.2 e	176.7 c
Melasy	222.0 a	134.4 a	71.3 ab	1.7 ab	8.3 c	8.5 d	133.3 b
Sukkary	198.1a	171.5 abc	34.4 a	3.2 c	7.2 b	7.7 b	96.7 b
Maghal	246.4 ab	159.9 a	18.0 a	2.4 c	5.6 a	4.8 a	176.7 d

Values with the same letter within the same column were not statistically different (Duncan Multiple at $P \leq 0.05$)

Table 5. Chemical characteristics of eight local pomegranate cultivar fruits grown in Upper Egypt (Means of the two seasons)

Cultivars	pH	TSS %	TA %	MI (TSS/TA)	V.C (mg/100ml)	Total anthocyanin (mg/100ml)	Total sugars (g/100g FW)
Asuity	3.0 c	15.1 ab	1.4 bc	11.0 bc	13.4 e	21.7 d	24.1 c
Asuity beshoka	2.8 a	14.6 a	4.0 d	3.6 a	9.9 b	42.3 h	31.3 d
Asuity morkub	2.9 b	15.2 ab	1.2 b	3.2 d	16.3 f	34.7 g	37.8 e
Manfalouty	3.7 d	16.1 ab	0.9 a	17.5 e	18.2 g	19.5 c	17.5 a
Nab El-Gamal	3.9 e	15.5 ab	0.8 a	18.7 e	11.9 d	22.7 e	18.5 b
Melasy	2.9 b	14.9 ab	1.6 c	9.5 b	8.5 a	8.6 b	39.1 f
Sukkary	4.0 f	14.7 ab	0.9 a	16.7 e	10.7 c	4.7 a	40.2 g
Maghal	2.9 b	16.3 b	1.4 bc	12.0 cd	19.0 h	30.8 f	62.3 h

Where: TSS: Total Soluble Solids, TA: Total Acidity, MI: Maturity Index

Values with the same letter within the same column were not statistically different (Duncan Multiple at $P \leq 0.05$)

Table 6. Volatile compounds in juice of eight local pomegranate cultivars grown in Upper Egypt (extracted using headspace)

Volatile compounds	KI[a]	Cultivars								
		Asuity	Asuity beshoka	Asuity morkub	Manfalouty	Nab El-Gamal	Melasy	Sukkary	Maghal	Sensory descriptors[c]
Aldehydes										
Hexanal	792	26.49[b]	14.14	6.57	8.55	7.24	8.09	9.15	10.81	Fatty, green, grassy, powerful
Nonanal	1102	2.29	3.49	18.76	0.98	2.92	4.82	1.69	8.79	Floral, citrus, orange, rose, fatty
Decanal	1202	1.61	6.12	13.18	0.22	7.36	12.54	6.12	9.37	Waxy, floral, citrus
Monoterpene										
α-Pinene	861	5.02	4.48	6.73	5.52	8.63	7.57	6.38	7.93	harp, pine
β –Pinene	932	7.17	3.26	0.82	0.23	1.82	1.62	0.33	5.62	Woody, pine
B-Myrecene	986	5.08	7.92	1.28	15.23	0.69	0.73	4.25	3.25	Sweet, balsamic, plastic
P-cymene	1025	5.07	6.62	13.76	6.84	0.46	5.37	7.85	6.79	Weak, citrus odor
Limonene	1030	8.31	8.74	1.46	3.21	10.25	7.33	9.56	6.45	Mild, citrus, sweet, orange, lemon
γ -Terpinene	1058	14.27	3.07	4.16	0.16	5.34	6.84	6.82	4.62	Herbaceous, citrus
Monoterpenoids										
Fenchone	1083	3.72	2.16	5.08	2.46	11.61	5.69	4.53	5.28	Sweet, vanilla
Camphor	1141	4.81	2.03	10.79	3.47	7.72	2.33	2.34	8.19	Aromatic, woody, medicinal
α-Terpineol	1189	2.70	2.45	4.52	1.92	4.55	7.52	4.65	6.58	Lilac
Alcohols										
1-Hexanol	853	2.87	4.93	0.47	0.14	0.53	0.56	4.62	1.51	Mint, grass
Esters										
Hexyl acetate	1009	0.06	5.29	0.40	12.64	1.31	8.77	6.31	4.67	Apple, cherry, floral, pear

a: KI: Kovat Indices, b: values are expressed as relative area percentage, c: SAFC (2008)

Therefore, breeding and agricultural practices must try to increase monoterpene concentrations and decrease the nondesired aldehydes contents. Also, they mentioned that, consumers mainly like the sweetness, but unfortunately this sensory attribute is not directly correlated with the phenolic compound contents (they usually have bitter taste) and thus their antioxidant capacity and beneficial health effects. It is difficult to talk about the biosynthetic routes of these compounds, because the volatile composition of pomegranates was only studied at one specific time, *i.e.* commercial maturity. However, further studies are being conducted to follow the synthesis of the compounds identified in this experiment throughout the pomegranate fruit development on the tree. Some compounds found in the volatile profiles of pomegranate juices can be formed during juice processing. For instance, [36] reported the formation of *α*-terpineol and terpinen-4-ol, and simultaneous decreases in *δ*-limonene and linalool in mandarin juices. [37,35] reported respectively 21 and 18 different aromatic compounds in Spanish pomegranates. Fourteen volatile compounds were found in the juices extracted from Egyptian cultivars in the present study, including in the same main chemical families than the previously mentioned authors. The major difference between the Spanish cultivars and the Egyptian cultivar grown in the Egypt was the presence of different ketons and linear hydrocarbons compounds. Hexanal, E-2- hexenal, Z-3-hexenol and limonene were the main compounds reported by [37] in Spanish cultivars using HS-SPME. Although two aldehydes and one alcohol were predominant compounds in Spanish samples, terpene derivatives (α-pinene, β-pinene, γ terpinene limonene) were the main volatile compounds in all studied samples in the present research (Egyptian *Cvs.*). Since the pomegranate trees were grown on the same farm and under the same agronomic conditions (weather, fertilization… *etc.*) and the harvest time was identical to all samples under study, the experimental differences in volatile composition were basically due to the pomegranate cultivars. According to the literature, a compound contributes positively to the global odour of a food if the logarithm of the odour units (concentration/odour threshold) is positive. Only 3-carene and α-terpineol were present in high enough concentrations to contribute positively to the aroma of pomegranate juice in a sweet cultivar [35].

4. CONCLUSION

In conclusion, nutrition status, fruit quality assessments and volatile compounds were evaluated in eight local pomegranate cultivars grown in Upper Egypt. Our results were compared with those found in other studies to reveal that local pomegranate fruit contains high nutrient amounts in both arils and peel with important amounts of juice, sugars, total soluble solids, vitamin C and antioxidant i.e., anthocyanins besides higher concentrations of volatile compounds in their headspace including 14 compounds were isolated and identified as follows: 3 aldehydes (for example hexanal) 6 monoterpenes (*α*-pinene), 3monoterpenoids (fenchone), 1alcohols (1-hexanol) and 1esters (hexayl acetate) that plays a valuable role in human's daily diet. Therefore, pomegranate cultivars under study have more using for fresh consumption and industrial processing to obtain fruit juice, jams…. etc. and to face the need of local and foreign markets. Further studies are needed to evaluate both other local and foreign cultivars to select the better ones that produce high production and quality for such region and optimal use under Egypt conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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