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Website: http://www.aun.edu.eg/faculty_agriculture/arabic *E-mail: ajas@aun.edu.eg*

Physico-Chemical and Antioxidant Contents During Developmental Stages in Three Pomegranates Cultivars under Assiut Condition

Mohamed, A.K.A.; R. A. Ibrahim; *Maha M. Abdel-Salam and A.M.M. Abd-El- Ghany
Pomology Department, Assiut University, Assiut, Egypt, Box 71526
*Email: Maha.hussien@agr.au.edu.eg

Abstract:

The experiment included three Egyptian pomegranate cultivars namely as Manfalouty, Hejazy and Nab-El-Gamal. The study aimed to assess some physical and chemical characteristics in the fruits and estimate their content of some anti-oxidants at different stages of development.

The study revealed that there were significant differences between the studied cultivars in most traits. The average weight and fruit dimension (length and diameter) significantly increased and reached their maximum values at 165 days after full bloom (maturity stage). Total soluble solids (TSS) and sugars increased while the acidity gradually decreased until they reached the optimum level in maturity. Vitamin C concentration increased progressively until the fruits reached their maturity. The total phenolics content (T.P.C) measured in the fruit peel and arils started high, and then there was a gradual decline until they minimized at fruit maturity. Total anthocyanin content of pomegranate arils and peel began low for the three cultivars and gradually increased till the end of fruit development. Hydrolysable tannin content (as mg tannic acid/ gm of dry weight basis) in peel and lit. of juice began high and rapidly decreased reaching its lowest level at fruit maturity. The differences were significant between the studied cultivars in both seasons for most abovementioned attributes.

Key words: Pomegranates**,** Antioxidant**,** Anthocyanin**,** Soluble solids

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Introduction:

The pomegranate (*Punica granatum* L.) belongs to the family Punicaceae which includes one genus and two species. The pomegranate originates from Persia and has been cultivated over the whole Mediterranean region and the Cancasus since ancient times. It is widely cultivated throughout Egypt, Algeria, Armenia, Iran, India, Tunisia, Turkey and tropical Africa and was introduced into Latin America and California by Spanish settlers in 1769. Pomegranate aril juice provides about 16% of an adults daily vitamin C and is a good source of vitamin B5 (Panthothenic acid), potassium and antioxidant polyphenols (Fuhrman and Aviram, 2007).

In Egypt, Pomegranate is one of the most important fruit trees cultivated in warm regions such as Assiut province (375 km south of Cairo) where the climate is characterized by long hot summer and low air humidity. Such weather is ideal for the growth and fruiting of this crop. The most important cultivar is Manflaouty which characterized by a good acidic taste and attractive color. Another cultivar called Hejazy is not widely cultivated but it is very promising. It is characterized by medium size fruit with ruby red color and less susceptible to crack. The 3rd cultivar is Nab-El-Gamal that produces pink fruits with low acidic taste.

In recent years, pomegranate is increasingly recognized as attractive fruit trees that produce valued health beneficial ingredients. The high beneficial effects of pomegranates are due to the antioxidants such as polyphenols where the most abundant one in juice are the hydrolyzable tannins called punicalagins which have free-radical scavenging properties. The pomegranate juice has been found effective in reducing heart disease risk factors. Tannins have been identified as the primary components responsible for the reduction of oxidative stress which lead to the risk factors. Pomegranate has been shown to reduce systolic blood pressure. Pomegranate seed oil was effective against proliferation of breast cancer cells *in vitro*. The juice may also have antiviral and antibacterial effects against dental plaque (Fuhrman and Aviran, 2007). (Hayrapetyan *et al*., 2012) reported that Pomegranate peel is used as preservative of meat products whereas (Negi *et al.* 2003) reported it as a bio preservative in food applications and nutraceuticals. Also, peel and whey powder have antioxidant properties against oxidative stress (Ashoush *et al*., 2013). Other researchers have reported that juice has anticancer activities (Lanskyand Newman 2007). In the same way, juice was found to has pharmacological and toxicologicalproperties, anti-oxidant, anti-inflammatory, anticancer and anti-angiogenesis activities (Rahimi *et al*. 2012). Another researcher (Tehranifar *et al*. 2011) has reported antifungaland antioxidant activity of peel and seed; they also have antidiabetic actions (Banihani *et al.* 2013). Also, (Dey *et al*. 2012) reported a greater antibacterial activity of pericarp than juice extract.Finally, fruit and peel extract are able to treat a wide number of health disorders such as inflammation, diabetes, diarrhea, dysentery, dental plaque and combating intestinal infections and

malarial parasites (Ismail *et al,*. 2012).

The aim of the current study was to assess some physical and chemical characteristics in the fruits of three pomegranate cultivars and estimate their content of some antioxidants at different stages of fruit development. As well as opening the way for future efforts to improve the content of antioxidants of such cultivars where they are the most important components in the pomegranate fruits.

Materials and Methods:

The experiment was executed at the experimental orchard; the laboratory of fruit crops department and the central laboratory of plant physiology of the Faculty of Agriculture Assiut University throughout two successive seasons of 2012 and 2013. The experiment included three pomegranate cultivars named as Manfalouty, Hejazy and Nab-El-Gamal. Ten trees from each cultivar were chosen and each tree was represented as a replicate.

The flowering period in pomegranate extends from early April until early July (Mohamed, 2004 and El-Sese, 1988a and b). Accordingly, fifty hermaphrodite flowers from each tree were labeled at the period of full bloom at first week of May during both experimental seasons.

Five fruits from each tree were periodically sampled at six growth stages e.g 90, 105, 120, 135, 150 and 165 days after full bloom beginning from the 1st week of August till 15th of October at 15 days intervals. The samples were picked and transferred directly to the laboratory to determine their physical traits including average fruit length and diameter (cm) average fruitweight (g), average fruit peel and arils weight (g) in addition to chemical traits and antioxidant contents. The determined chemical traits were:

Total soluble solids (T.S.S.) using the hand refractometer (ATAGO N-IE). Titratible acidity was estimated by titration of NaOH at 0.1N using phenolphthalene as an indicator. The NaOH was adjusted by using a known volume of oxalic acid 0.1M according to A.O.A.C. (1984). The titratible acidity was expressed as citric acid. The measured TSS and acidity were used to calculate TSS/acid ratio. Reducing and total sugars were determined according to Lane and Eynon method as outlined in A.O.A.C (1984).

Antioxidant contents were determined by the following components:

1 - **Vitamin C (Ascorbic acid) content**

It was determined by the method described by Ruck (1963).

Vitamin C (%) was calculated according to the following equation:

$$\text{Vit.C}(\%) = \frac{\text{Dye volume used in titration} \times \text{dye molarity}}{\text{Sample volume}} \times 100$$

2 - Total phenolic content (T.P.C.) of peel and arils:

Peel and arils extracts were prepared as by the procedure that described by Rababah *et al*. (2005). Then the total phenolic contents in the extracts were determined according to the method described by Singleton and Rossi (1965). The results were calculated as Gallic acid equivalent (GAE) (mg/100g of dry weight basis)

3 - Total anthocyanin content (T.A.C.) of peel and arils:

The plant extracts were prepared by the procedure described by (Fuleki and Francis 1968). The anthocyanin content was expressed as mg of cyaniding-3-glucoside (C.3.G) equivalent per 100 gm of dry sample weight.

The anthocyanin content (AC) was calculated according to (Rabino and Mancinelli, 1986) equation:

$$A.C. = \frac{\text{Absorbance x } 449.2\text{x Dilution factor}}{29600\text{x sample weight}}$$

Where: 29600 = molar extinction coefficient.

449.2 = molecular weight of C.3.G.

Dilution factor = final volume / initial volume.

4 - Hydrolyzable tannin content (H.T.C) of peel and arils:

Methanolic extract were prepared from peel and juice extracts according to the method described by El-falleh *et al*. (2009) and (2011). H.T.C was determined by the modified method of Cam and Hisil (2010). The final results were expressed as mg tannic acid equivalent (TAE) per 100 g. of dry weight of peel and mg/ L of juice.

Statistical analysis:

Data were analyzed as a factorial experiment (6x3). The analysis of variance (ANOVA) was applied according to Snedecor and Cochran (1989). Means were compared using the L.S.D. values at 5% level of the probability.

Results:

1- Physical properties:

Table (1) shows the fruit growth stages of three pomegranate cultivars. There was a progressive increase in fruit weight. Generally, the average fruit weight in the first season at any measurement period was less than the second season due to the heavier bearing in the first season of study than the second one (data not shown).

On the other hand, Hejazy cultivar recorded the lowest average fruit weight during the two seasons (229.3 and 329.9g, respectively). In the first season of study there were significant differences between the studied cultivars. However, in the second season the significant differences were found between Hejazy and the other two cultivars. The peel weight in the second season recorded much higher peel weight comparing to the first season. The average peel weight was 68.4; 66.2 and 62.9g during the first season while it was 142.8; 152.5 and 147.0g during the second season for Nab-El-Gamal; Manfalouty and Hejazy cultivars; respectively. The significant differences were found between Nab El-Gamal and Hejazy in the first season and between Manfalouty and Nab El-Gamal during the second season. Concerning the arils weight, there were significant differences during the two seasons except of Manfalouty and Nab-El-Gamal in the first season.

Fruit dimension (length and diameter) increased steadily till 120 DAFB and then they slowly increased till the fruits reached the maturity (Table 2).

2- Chemical properties:

Table (3) showed that Manfalouty cultivar had the highest TSS content (15.8 and 16.4% in the two seasons, respectively) comparing to the other two cultivars. The percent-

age of TSS during the first season in pomegranate fruits was low in the first stage and it gradually increased until the maximum when the fruits reached the maturity (105 DAFB). In the second season, the percentage of TSS has been gradually increased with some dips during fruit growth stages and then reached the highest value at maturity or just before it. However, Nab-EL-Gamal cultivar contained the highest percentage of TSS at maturity (17.7% in both seasons).

The acidity (Table 3) in Nab-EL-Gamal was high at 90 DAFB and then it gradually decreased until it reached the lowest level at maturity. For Manfalouty and Hejazy, it began high and then it gradually decreased until it reached the lowest level at 135 DAFB and then it increased again or remains constant until the fruits reached their maturity.

Concerning TSS/acid ratio (Table 3), Nab-EL-Gamal cultivar recorded the highest ratio during the two seasons. In this cultivar, this ratio was low at 90 DAFB during the two seasons and then it began to gradual increase and reached the highest level at maturity while in Manfalouty and Hejazy it began low; increased and fell again until maturity.

Concerning the sugar contents, Table (4) showed that both total and reducing sugars increased rapidly reaching the highest percentage during maturation. The percentage of total sugars at maturation was 15.6, 13.9 and 14.3% and 15.7, 14.9 and 14.7 during both seasons of study for Nab-El-Gamal, Manfalouty and Hejazy cultivars, respectively.

Reducing sugars reached 14.1, 12.5 and 13.2% in the first season and 14.4, 14.1 and 13.6% in the second one, for same cultivars, respectively. The data revealed that the reducing sugars which are mainly consist of glucose and fructose is the predominant sugars in pomegranate juice while Non-reducing sugars were found in minor level.

3- Antioxidant contents:

Table (5) showed that in the first season and for all tested cultivars vitamin C (ascorbic acid) concentration increased progressively until the fruits reached their maturity. In the second season, the Vit. C of Manfalouty and Hejazy began more higher at the beginning of estimation, increased at the middle of season and declined again at the maturity while of Nab-EL-Gamal it began low and increased until fruit maturation. There were insignificant differences between the studied cultivars in the second season, however, in the first season the differences were found between Hegazi and the other two cultivars. It was also observed that, vitamin C content was higher during the second season comparing to the first one.

T.P.C., T.A.C. and H.T.C. were determined in fruit peel and arils. Generally, the total phenolics content (Table 5) measured in the peel was higher than that found in the juice. The peel T.P.C. began high and gradually decreased reached the lowest level at maturity. The differences between cultivars were significant in both seasons.

The changes of total phenolics in the juice (Table 5) were differed among the cultivars. There were high

significant differences between the three cultivars in this respect. During the two seasons they started high, and then there was a gradual decline until they reached the lowest level at fruit maturity. Our data (Table 5) also indicated that Hejazi pomegranate cultivar demonstrated the highest T.P.C in the juice followed by Manfalouty and then Nab-El-Gamal.

The changes of total anthocyanin content (T.A.C.) in the peel and juice of the three studied pomegranate cultivars are presented in Table (6). During both seasons of study there was a gradual increase of T.A.C. in fruit peel upon fruit maturity where reached its maximum value. Hejazy cultivar had the highest level of T.A.C. with a significant difference between it and the two cultivars in the first season and between it and Nab-El-Gamal in the second season. Additionally, Hejazy cultivar recorded the highest T.A.C. at fruit maturity (0.85 and 0.82 mg for both seasons, respectively).

Total anthocyanin content of pomegranate juice began low for the three cultivars and gradually increased till the end of fruit growth. Manfalouty and Hejazy juice contained more T.A.C. than that found in Nab-El-Gamal. The differences were significant between the both cultivars and Nab-El-Gamal.

Hydrolysable tannin content measured as mg tannic acid/100 gm of dry weight basis in peel and juice are presented in Table (6). The peel contains very higher H.T.C. than that in the juice. In both seasons, H.T.C. in the peel began high and rapidly decreased reaching its lowest level at fruit maturity. The differences were significant between the studied cultivars in both seasons.

On the other hand, lower H.T.C. was found in the juice comparing with peel. Similarly to the peel trend, H.T.C. declined rapidly upon fruit maturity where it reached the lowest values. There were no significant differences between Manfalouty and Hejazy however, the significant was found between them and Nab-El-Gamal cultivar.

Discussion:

The growth of pomegranate fruit follows the single sigmoid curve (Gozlekci and Kaynak, 2000). The increase of fruit size and weight could be attributed to the increase in aril size and its juice content as well as the peel growth during different growth stages (Mirdehghan and Rahemi, 2007). As well as, the increase during initial stages of fruit growth was due to cell divisions and that depends on the prevailing weather conditions and on the cultivar (Shulman *et al*. 1984b). Our observations indicated that the increase in fruit size and weight also depended on the state of bearing during the season where the present study showed that the yield weight was moderate in the second season comparing with the first one (heavy crop).

The results of current study showed a significant increase in the fruit weight as well as peel and arils weight during different growth stages reaching the highest value at fruit maturity. The results indicated that the highest rate increase in the fruit weight during the first season recorded at 105 DAFB while in the second season the largest rate increase occurred in the fourth period

(135 DAFB). The increment percentage at 105 DAFB for the first season was 130.0%, while it was 32.3% during the same stage in the second season. The increment percentage of fruit weight at 135 DAFB in the second season reached 42.5% while such percentage was 10.6 for the same stage in the first season. The fruit size, arils and peel weight exhibit the same direction of the fruit weight. This was consistent with what found by Kumar and Purohit (1989) that the growth of pomegranate fruit doesn't take constant rate during the fruit growth but there are stages of rapid growth punctuated by slow growth stages. Al-Mainam and Ahmed (2002) found that there was a significant increase in the fruit and arils weight from unripe through half mature along with mature fruits. (Gozlekci and Kaynak, 2000) found that after the first two weeks of a rapid increase in fruit size the growth will be slow until the arrival of harvest and they explained that by the higher temperatures during the summer months. Our study indicated that both fruit diameter and length increased during the initial stages of development and then the rate of size growth slowly increased. (Fawole and Opara, 2013a) on Ruby and Bhagwa cultivars and (Fawole and Opara, 2013b) on Ruby cultivar grown in South Africa found that the fruit weight increases with maturity in both cultivars and seasons. They also found that the fruit weight significantly increased between the first and second measurement (54 and 82 days from full bloom) followed by a rapid increase at the 3rd stage (110 days) along with the 4th stage (140 days from full bloom) before hitting the maximum weight at the 5th stage.

The physical fruit characteristics were greatly differed among different pomegranate cultivars (Drogoudi *et al*. 2005; Akbarpour *et al*. 2009; Tehranifar *et al*. 2010; Zaouay *et al*. 2012). They may also differ for the same cultivar which grown in the different regions. In a study made by Gadze *et al*. (2011) on Glavas pomegranate cultivar cultivated in 9 different regions found that the average fruit and arils weight greatly differed depending on the area. On the other hand, Wetzstein *et al*. (2011) found that the average fruit weight in Wonderfull cultivar was 345 gm and the granules weight was 174 gm represented 50.4% of fruit weight and also found that the larger fruits contain the large number of granules. The later does not agree with our results where the percentage of arils weight represented about 60-70% of total fruit weight depending on the season and bearing density.

Total soluble solids, acidity and TSS/acid ratio are the most important fruit quality for juicy fruits, e.g. citrus, grapes and pomegranate. These attributes especially TSS/acid ratio has define the appropriate time for harvesting and it called maturity index. TSS mainly consist of sugars while the main organic acids in pomegranate juice are citric and malic; however, citric acid is much higher than malic (Tezcan *et al*., 2009). The current study revealed that the percentage of TSS in pomegranate fruits was low in the first stage and it gradually increased until the maximum when the fruits reached the maturity while the acidity was

high and then it gradually decreased until it reached the lowest level at maturity. Our results came on line with that reported by the other investigators, e.g., Gozlekci and Kaynak (2000); Al-Maiman and Ahmed (2002); Kulkarni and Aradhya (2005); Shwartz *et al*. (2009); Borocho- Neori *et al*. (2009); Gozlekci *et al*. (2011); Fawole and Opara (2013a&b) and Nuncio- Jáuregui *et al*. (2014). They found that soluble solids content began low and steadily increased during fruit development, however, the titratable acidity decreased with the advancing maturity.

Total soluble solids in fruits are around 15 to 17 for most pomegranate cultivars while acidity ranged from 0.3 to 3.0 for most cultivars (Drogoudi *et al*. (2005); Ozgen *et al*. (2008); Akbarpour *et al*. (2009); Tehranifar *et al*. (2010); Mena *et al*. (2011); Gadze *et al*. (2011); Caliskan and Bayazit (2012) and Zaouay *et al*. (2012).The variation between these attributes could originate from the cultivar and agro-climatic as well as the environmental conditions Akbarpour *et al*. (2009).

The present study revealed that total, reducing and non-reducing sugars increased progressively from the 1st stage until the fruit reached its maturity where they reached their maximum percentage. This result became on line with that reported by Al-Maiman and Ahmed (2002) on Taifi pomegranate cultivar that the total and reducing sugars reached maximum level when the fruit attained ripeness and that ripe fruit had more reducing sugars than unripe one. Shwartz *et al*. (2009) studied the chemical changes of Wonderful and Rosh-Hapered cultivars and found that the sugar content in the juice increased in both cultivars. Sugar concentrations of Ruby pomegranate cultivar increased considerably during fruit maturation (Fawole and Opera, 2013a). Similar results were found by Shwartz *et al*. (2009) and Kulkarni and Aradhya (2005).

The prevalent sugars in pomegranate fruits are fructose and glucose while sucrose is found in a minute amounts. Ozgen *et al*. (2008); Orak (2009), Tezcan *et al*. (2009), Mena *et al*. (2011), Caliskam and Bayazit (2012), Fawole and Opera (2013a) and Nuncio- Jáuregui *et al*. (2014) found that glucose and fructose are the major components and the amount of sucrose was almost negligible.

The present study determined some antioxidant compounds in the fruit peel and aril juice. Recently, antioxidant components of pomegranate have a great important. Pomegranate is a potent antioxidant, superior to red wine and equal to or better than green tea (Jadon *et al*., 2012). The antioxidants components were found at any part of pomegranate trees, e.g. fruit peel, seeds, flower and leaves (El-Falleh *et al*., 2012). Wang *et al*. (2013) noted that, pomegranate leave are rich sources of phenolic compounds. Zhang *et al*. (2010) found that all bioactive compounds of pomegranate leaves increased during leaf growth and development. Zhang *et al*. (2011) extracted the anthocyanins from pomegranate flowers and found that the purified anthocyanins showed strong antioxidant and radical scavenging activities. The antioxidants could also extracted

from marc or bag gases after juice processing (Qu *et al*., 2010;Viuda-Mortos *et al*., 2011) or from wine lees after juice fermentation and centrifugation or from ground seeds (Jing *et al*., 2012) or dried seeds (Schuber *et al*., 1999).

Drogoudi *et al*. (2005) determined the antioxidant activity of 20 pomegranate accessions and found that the total phenolics in juice varied between 22.5 and 69.7 mg/100 ml, anthocyanins between 42.7 and 72.4 mmol/100 ml and ascorbic acid between 1.3 and 5.2 mg/100 ml. Ozgen *et al*. (2008) found a considerable variation in antioxidant properties of pomegranate cultivars grown in Turkey. The amount of total phenolics in juice varied between 1245 and 2076 mg gallic acid/L, anthocyanin between 6.12 and 219 mg cyaniding-3-glucoside/L and vit. C between 0.014 and 0.069 g/100 ml. Akbarpour *et al*. (2009) also found a considerable variation of some pomegranate cultivars. The total phenolics of pomegranate juice were found to be 3.246 µg/L and total anthocyanin 492.9 mg/L. In a study on six commercial pomegranate juices collected from local markets in Turkey, Tezcan *et al*. (2009) found that the total phenolics ranged from 2602 to 10086 mg/L. Tehranifar *et al*. (2010) study twenty pomegranate cultivars grown in Iran and found a significant variations between them where the total phenolics values ranged from 297.79 to 985.32 (mg/100 g^{-1}), total anthocyanins from 5.56 to 30.11 (mg/100 g^{-1}) and ascorbic acid from 9.91 to 20.92 (mg/100 g^{-1}). Mena *et al*. (2011) studied 15 pomegranate cultivars and found that the phenolic compound (Ellagic acid) was varied significantly from 3 to 160 mg/L^{-1}, vitamin C from 80 to 200 mg/L^{-1} and total anthocyanins from 30 to 1080 mg/L^{-1}. Tabaraki *et al*. (2012) found that the TPC in pomegranate peel varied from 5506.42 to 8923.24 mg/gallic acid equivalent/100 g of dry weight. A study on 76 pomegranate accessions. Caliskan and Bayazit (2012) found that the TA ranged from 1.1 to 63.3 mg/100 g and TP ranged from 108.0 to 944.9 mg/100 g. Zaouay *et al*. (2012) studied 13 pomegranate cultivars grown in southern Tunisia and found that the amount of total phenolics ranged from 133.93 to 350.06 g/100 ml of juice and the total content of anthocyanin varied rom 50.5 to 490.4 mg/L^{-1}. Hmid *et al*. (2013) found that the TP of 18 pomegranate cultivars varied from 1385 to 9476 mg/L of juice, TA varied from 64.16 to 188.7mg/L. Sentandreu *et al*. (2013) found a total of 151 phenolics in pomegranate juice.

On the other hand, Zhuang *et al*. (2011) on green and red peel pomegranate cultivars grown in China found that the juice of the red color cultivar had the highest TA (mg/L) while the sweet green color cultivar had the highest TP (mg/L), however, the sour green color cultivar gave the least values of both attributes.

Investigators (Riccei *et al*., 2006; Li *et al*., 2006; El-Falleh *et al*., 2011; Anoosh *et al*., 2012 and Mirdehghan and Rahem, 2007) found that the antioxidants content were higher in fruit peel than juice.

The antioxidant activity in pomegranate cultivars during fruit development was extensively studied. The researches mostly reported that

there are a gradual increase of anthocyanins and reduction in phenolics, tannins and ascorbic acid contents.

For instance, Kulkarni *et al*. (2005) found a continuous increase in anthocyanin accompanied by a significant reduction in phenolics and ascorbic acid. Mirdehghan and Rahemi (2007) on MalasYazdi pomegranate cultivar found that the amount of total phenolics increased at the early stage of growth but thereafter decreased during maturation. Shwartz *et al*. (2009) studied the changes in antioxidants of wonderful and Rosh-Hapered pomegranate cultivars. They found that the levels of total phenolics and hydrolysable tannins in the peel were reduced while the anthocyanin level increased. However, in the juice the total phenolics decreased in Rosh-Hapered but such reduction was not observed for wonderful. The anthocyanin increased in wonderful and did not changed in Rosh-Hapered. The levels of Ascorbic acid increased in both cultivars. Fawole and Opera (2013a) on Ruby and (2013b) on Bhagwa pomegranate cultivars found that the total phenolic content was highest at the early immature stage then it significantly decreased until the full ripe stage. The anthocyanin and ascorbic acid contents increased with advancing maturity. Nuncio-Jáuregui *et al*. (2014) found that the total phenolic content significantly decreased as the ripening stage progressed.Borochov-Neori *et al*. (2009) also found that arils of fruit ripening later in the season contained more soluble phenolics and exhibited a higher antioxidant activity. These results consistent with findings of the current study.

Conclusion:

The experiment involved three Egyptian pomegranate cultivars named as Manfalouty, Hejazy and Nab-El-Gamal. The study revealed that there were significant differences between the studied cultivars in most traits. These cultivars have a special importance in their areas either for domestic consumption or to meet the growing demands of export. Great interest is growing now in Egypt towards pomegranate export mainly to Arabian Gulf countries, Russia and some European countries. Finally, it is important, therefore, to direct the research effort towards the pomegranate cultivars and try to improve their characteristics such as antioxidant compounds.

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Table (1): Average fruit weight (g), peel weight (g), arils weight (g), fruit length (cm) during developmenatl stages of Nab-El-Gamal, Manfalouty and Hejazy pomegranate cultivars in 2012 and 2013 seasons.

year	DAFB	Fruit weight (g)				Peel weight (g)				Arils weight (g)			
		N	M	H	X□	N	M	H	X□	N	M	H	X□
2012	90	96.2	78.0	79.5	84.6	18.7	18.5	24.7	20.6	77.5	59.5	54.8	63.9
	105	206.9	194.5	182.5	194.6	44.1	40.2	44.1	42.8	162.8	154.3	138.4	151.8
	120	276.4	261.5	253.8	263.9	59.9	66.1	59. 6	63.0	216.5	195.4	194.2	202.0
	135	305.9	300.4	269.7	292.0	83.3	80.1	70.2	77.9	222.6	220.3	199.5	214.1
	150	324.9	324.3	284.5	311.2	92.8	94.8	84.9	90.8	232.1	229.5	199.6	220.4
	165	349.9	328.4	305.8	328.0	111.5	97.6	93.9	101.0	238.4	230.8	211.9	227.0
	X□	260.0	247.9	229.3		68.4	66.2	62.9		191.7	181.6	166.4	
2013	90	154.3	178.2	155.3	162.6	71.2	105.0	72.4	82.9	83.1	82.2	82.9	82.7
	105	218.2	231.8	195.3	215.1	85.5	106.2	91.4	94.4	132.7	125.6	103.9	120.7
	120	298.2	291.5	287.7	292.5	112.4	123.4	124.1	120.0	185.8	168.1	163.6	172.5
	135	424.2	404.3	421.5	416.7	186.6	186.5	191.1	188.9	237.6	217.8	230.4	228.6
	150	462.2	453.1	432.5	449.3	198.2	194.1	199.2	197.2	264.0	259.0	233.3	252.1
	165	484.3	488.7	487.2	486.7	203.0	199.6	203.7	202.1	281.3	289.1	283.5	284.6
	X□	340.2	341.3	329.9		142.8	152.5	147.0		197.4	190.3	182.9	

N = Nab-El-Gamal, M= Manfalouty, H= He jazy, X□ = Mean

year	L.S.D (0.05)	Fruit weight	Peel weight	Arils weight
2012	Cultivar	11.1	4.0	10.8
	Days after full bloom	16.5	5.7	14.3
	Cultivar x Days after full bloom	27.3	9.8	25.1
2013	Cultivar	9.9	5.9	6.1
	Days after full bloom	10.2	8.3	8.6
	Cultivar x Days after full bloom	19.4	14.5	15.1

Table (2): Average fruit length (cm) and diameter (cm) of Nab-El-Gamal, Manfalouty and Hejazypomegranate cultivars during 2012 and 2013 seasons.

year	DAFB	fruit length (cm)				fruit diameter (cm)			
		N	M	H	X□	N	M	H	X□
2012	90	4.9	4.9	5.0	4.9	6.0	5.6	5.6	5.7
	105	6.9	7.0	6.9	6.9	7.6	7.8	7.3	7.6
	120	7.6	7.7	7.5	7.6	8.6	8.6	8.2	8.5
	135	7.6	7.8	7.7	7.7	8.9	8.7	8.5	8.7
	150	7.9	7.9	7.8	7.9	8.9	9.0	8.6	8.8
	165	8.2	8.0	7.9	8.0	9.2	9.1	8.7	9.0
	X□	7.2	7.2	7.1		8.2	8.1	7.8	
2013	90	6.2	6.1	6.4	6.2	7.0	6.9	6.9	6.9
	105	6.9	7.0	6.9	6.9	7.5	7.6	7.3	7.5
	120	7.5	7.6	7.7	7.9	8.5	8.4	8.4	8.4
	135	8.5	8.3	8.4	8.4	9.4	9.1	9.3	9.3
	150	8.6	8.7	8.5	8.6	9.7	9.6	9.6	9.6
	165	8.7	9.0	8.9	8.9	9.8	9.8	9.9	9.8
	X□	6.2	6.1	6.4		8.7	8.6	8.6	

N = Nab-El-Gamal, M= Manfalouty, H= Hejazy

year	L.S.D(0.05)	Fruit length	Fruit diameter
2012	Cultivar	N.S	0.2
	Days after full bloom	0.2	0.2
	Cultivar x Days after full bloom	0.3	0.4
2013	Cultivar	N.S	0.1
	Days after full bloom	0.2	0.1
	Cultivar x Days after full bloom	0.3	0.2

Table (3): Changes in total soluble solids (%), total acidity (%) and TSS/acid ratio of Nab-El-Gamal, Manfalouty and Hejazy pomegranate cultivars during 2012 and 2013 seasons.

year	DAFB	Total soluble solids				Total acidity%				TSS/acid ratio			
		N	M	H	X□	N	M	H	X□	N	M	H	X□
2012	90	13.4	13.8	13.8	13.7	2.6	2.8	2.6	2.7	5.2	4.9	5.3	5.1
	105	14.1	15.0	15.6	14.9	1.9	2.6	1.9	2.1	7.4	5.8	8.2	7.1
	120	14.3	15.6	16.0	15.3	1.0	1.1	0.8	1.0	14.3	14.2	20.0	16.2
	135	14.2	16.2	15.2	15.2	0.8	0.7	0.7	0.7	17.8	23.1	21.7	20.9
	150	15.3	17.6	16.5	16.5	0.8	1.3	1.3	1.1	19.1	13.5	12.7	15.1
	165	17.7	16.5	16.2	16.8	0.7	1.1	1.2	1.0	25.3	15.0	13.5	17.9
	X□	14.8	15.8	15.6		1.3	1.6	1.4		14.9	12.8	13.6	
2013	90	13. 8	15.2	14.3	14.4	1. 8	2.5	2.4	2.2	7.7	6.1	6.0	6.6
	105	13.4	14.7	14.7	14.3	1.4	1.8	1.6	1.6	9.6	8.2	9.2	9.0
	120	16.1	17.2	16.7	16.7	1.0	1.6	1.3	1.3	16.1	10.8	12.8	13.2
	135	16.5	17.1	17.4	17.0	0.8	1.1	1.0	1.0	20.6	15.5	17.4	17.8
	150	15. 8	17.6	16.7	17.2	0.8	1.0	0.9	0.9	19.8	17.6	18.6	18.7
	165	17.7	16.5	16.7	17.0	0.7	1.0	1.0	0.9	25.3	16.5	16.7	19.5
	X□	15.6	16.4	16.1		1.1	1.5	1.4		16.5	12.5	13.5	

N = Nab-El-Gamal, M= Manfalouty, H= Hejazy, X□ = Mean

year	L.S.D (0.05)	Total soluble solids	Total acidity%	TSS/acid ratio
2012	Cultivar	0.3	0.1	1.3
	Days after full bloom	0.6	0.1	1.6
	Cultivar x Days after full bloom	0.9	0.2	1.9
2013	Cultivar	0.3	0.1	1.0
	Days after full bloom	0.3	0.1	1.1
	Cultivar x Days after full bloom	0.6	0.2	2.1

Table (4): Changes in total (%), reducing (%) and non-reducing sugars (%) of Nab-El-Gamal, Manfalouty and Hejazy pomegranate cultivars during 2012 and 2013 seasons.

year	DAFB	Total sugars%				Reducing sugars%				Non-reducing sugars%			
		N	M	H	X□	N	M	H	X□	N	M	H	X□
2012	90	11.1	11.1	11.3	11.2	10.2	10.5	10.8	10.5	0.9	0.6	0.5	0.7
	105	12.2	12.7	13.0	12.6	10.9	11.8	12.3	11.7	1.3	0.9	0.7	1.0
	120	12.2	13.0	14.6	13.3	10.9	12.1	13.8	12.3	1.3	0.9	0.8	1.0
	135	12.7	14.2	13.3	13.4	11.5	13.0	12.4	12.3	1.2	1.2	0.9	1.1
	150	13.0	15.0	13.9	14.0	11.6	13.7	12.9	12.7	1.4	1.3	1.0	1.2
	165	15.6	13.9	14.3	14.6	14.1	12.5	13.2	13.3	1.5	1.4	1.1	1.3
	X□	12.8	13.3	13.4		11.5	12.3	12.6		1.3	1.1	0.8	
2013	90	11.1	13.0	12.7	12.3	10.6	12.3	12.2	11.7	0.5	0.7	0.5	0.6
	105	10.8	12.7	12.4	12.0	10.1	11.8	11.8	11.2	0.7	0.9	0.6	0.7
	120	14.7	15.2	14.6	14.8	13.8	14.3	13.8	14.0	0.9	0.9	0.8	0.9
	135	14.4	14.9	15.6	15.0	13.6	14.3	14.9	14.3	0.8	0.6	0.7	0.7
	150	13.8	15.3	14.7	14.6	12.7	14.6	13.8	13.7	1.1	0.7	0.9	0.9
	165	15.7	14.9	14.7	15.1	14.4	14.1	13.6	14.0	1.3	0.8	1.1	1.1
	X□	13.4	14.3	14.1		12.5	13.6	13.4		0.9	0.8	0.8	

N = Nab-El-Gamal, M= Manfalouty, H= Hejazy

year	L.S.D(0.05)	Total sugars%	Reducing sugars%	Non-reducing sugars%
2012	Cultivar	0.4	0.3	0.4
	Days after full bloom	0.6	0.5	0.6
	Cultivar x Days after full bloom	1.1	0.9	1.1
2013	Cultivar	0.3	0.2	0.4
	Days after full bloom	0.4	0.4	0.5
	Cultivar x Days after full bloom	0.7	0.6	0.9

Table (5): Changes in vitamin C of juice (%), total phenolics content (T.P.C of peel and arils) (mg Gallic acid equivalents/100 gm of dry weight basis) of Nab-El-Gamal, Manfalouty and Hejazy pomegranate cultivars during 2012 and 2013 seasons.

year	DAFB	Vitamin C of juice%				Total phenolics content of peel(mg/100gm)				Total phenolics content of arils(mg/100g)			
		N	M	H	X□	N	M	H	X□	N	M	H	X□
2012	90	0.9	0.6	0.5	0.7	4924.8	4701.4	4948.1	4858.1	1997.5	3332.8	3061.7	2797.3
	105	1.3	0.9	0.7	1.0	4441.1	4675.3	4373.1	4496.5	1773.4	1924.9	2750.8	2149.7
	120	1.3	0.9	0.8	1.0	4171.4	4625.3	4228.2	4341.6	1042.8	1914.1	1663.0	1534.0
	135	1.2	1.2	0.9	1.1	4055.8	4283.4	4109.5	4149.6	988.6	1022.5	1552.8	1188.0
	150	1.4	1.3	1.0	1.2	4022.1	4114.0	3942.8	4026.3	957.2	893.2	1275.1	1041.8
	165	1.5	1.4	1.1	1.3	3639.4	4100.2	2310.1	3349.9	896.4	759.0	1216.2	957.2
	X□	1.3	1.1	0.8		4209.1	4416.6	3985.3		1276.0	1641.1	1919.9	
2013	90	0.8	1.7	1.4	1.3	5141.4	4707.8	4852.8	4900.7	1970.3	3413.8	3215.1	2866.4
	105	0.9	1.6	1.3	1.3	4675.4	4664.5	4756.2	4698.7	1719.2	1903.0	2498.4	2040.2
	120	2.1	2.3	2.1	2.2	4220.3	4600.9	4661.4	4494.2	1037.8	1440.9	1647.0	1375.2
	135	2.1	2.6	3.0	2.6	4054.1	4228.1	4367.3	4216.5	982.0	982.4	1277.5	1080.6
	150	3.1	2.0	2.5	2.5	3670.1	4124.2	4267.8	4020.7	938.2	825.6	1187.0	983.6
	165	3.6	1.3	1.3	2.1	3578.0	3938.8	2298.1	3271.6	933.0	740.4	1100.6	924.7
	X□	2.1	1.9	1.9		4223.2	4377.3	4200.6		1263.4	1551.0	1820.9	

N = Nab-El-Gamal, M= Manfalouty, H= Hejazy, X□ = Mean

year	L.S.D(0.05)	vitamin C of juice%	total phenolics content of peel(mg/100gm)	Phenolics contentof arils(mg/100gm)
2012	Cultivar	0.2	105.1	50.2
	Days after full bloom	0.1	116.2	76.0
	Cultivar x Days after full bloom	0.3	221.4	123.0
2013	Cultivar	0.2	115.3	141.6
	Days after full bloom	0.3	128.9	196.1
	Cultivar x Days after full bloom	0.5	241.8	349.6

Table (6): Changes in total anthocyanin content (T.A.C) arils (mg cyaniding -3-glucoside equivalents/100 gm of dry weight basis) and hydrolysable tannin content (H.T.C)(mg tannic acid equivalents/gm of dry weight basis) of peel and of Nab-El-Gamal, Manfalouty and Hejazy pomegranate cultivars during 2012 and 2013 seasons.

year	DAFB	T.A.C of peel (mg/100gm)				T.A.C of arils (mg/100gm)				H.T.C of peel (mg/g)				H.T.C of arils (mg/g)			
		N	M	H	X□	N	M	H	X□	N	M	H	X□	N	M	H	X□
2012	90	0.08	0.07	0.06	0.07	0.02	0.08	0.04	0.05	199.5	185.5	203.2	196.1	4.4	6.3	6.8	5.8
	105	0.16	0.15	0.14	0.15	0.06	0.12	0.13	0.10	175.4	166.0	179.9	173.8	3.6	5.8	5.7	5.0
	120	0.28	0.29	0.27	0.28	0.08	0.22	0.25	0.18	161.5	158.4	165.0	161.6	3.1	4.9	5.0	4.3
	135	0.39	0.40	0.47	0.42	0.10	0.39	0.41	0.30	148.3	148.9	148.7	148.6	2.7	4.5	4.3	3.8
	150	0.47	0.46	0.62	0.52	0.13	0.47	0.49	0.36	138.9	137.4	146.6	141.0	2.3	3.9	3.6	3.3
	165	0.57	0.60	0.85	0.67	0.20	0.65	0.59	0.48	125.5	130.2	131.8	129.2	1.7	2.9	2.7	2.4
	X□	0.33	0.33	0.40		0.10	0.32	0.32		158.2	154.4	162.5		3.0	4.7	4.7	
2013	90	0.06	0.10	0.05	0.07	0.03	0.06	0.03	0.04	201.1	180.7	201.3	194.4	4.1	5.9	6.6	5.5
	105	0.15	0.15	0.13	0.14	0.08	0.12	0.13	0.11	173.7	173.5	173.3	173.5	3.3	5.0	5.5	4.6
	120	0.27	0.29	0.29	0.28	0.10	0.22	0.22	0.18	158.1	155.3	164.0	159.1	2.9	4.4	4.0	3.8
	135	0.42	0.46	0.46	0.45	0.10	0.36	0.42	0.30	150.3	147.2	152.2	149.9	2.3	3.6	3.3	3.1
	150	0.51	0.56	0.58	0.55	0.13	0.48	0.47	0.36	136.5	131.1	142.5	136.7	1.9	2.6	2.7	2.4
	165	0.62	0.66	0.82	0.70	0.18	0.61	0.59	0.48	121.9	117.1	125.2	121.4	1.3	2.0	2.1	1.8
	X□	0.34	0.37	0.39		0.10	0.31	0.31		156.9	150.8	159.8		2.6	3.9	4.0	

N = Nab-El-Gamal, M= Manfalouty, H= Hejazy, X□ = Mean

year	L.S.D(0.05)	T.A.C of peel (mg/100gm)	T.A.C of arils (mg/100gm)	H.T.C of peel (mg/g)	H.T.C of arils (mg/g)
2012	Cultivar	0.02	0.01	1.6	0.1
	Days after full bloom	0.03	0.01	2.3	0.1
	Cultivar x Days after full bloom	0.04	0.02	3.9	0.2
2013	Cultivar	0.04	0.01	1.9	0.1
	Days after full bloom	0.05	0.01	2.6	0.1
	Cultivar x Days after full bloom	0.09	0.02	4.6	0.2

الصفات الطبيعية والكيماوية ومضادات الأكسدة في ثمار الرمان

أيمن كمال أحمد محمد ، رشاد عبد الوهاب إبراهيم ، مها محمد عبد السلام و أحمد محمد عبد الغني
قسم الفاكهة – كلية الزراعة – جامعة اسيوط

الملخص:

وشملت التجربة دراسة ثلاثة أصناف من الرمان (المنفلوطى، حجازي، ناب الجمل) تهدف هذه الدراسة إلى تقييم بعض الخصائص الطبيعية والكيميائية في الثمار وتقدير محتواها من المواد المضادة للاكسدة في بعض مراحل النمو المختلفة. وكشفت الدراسة عن وجود فروق معنوية بين الأصناف الثلاثة في معظم الصفات. كما أظهرت البيانات أن متوسط الوزن (الثمار؛ القشرة وزن الحبوب) وأبعاد الثمرة (الطول والقطر) وزاد زيادة معنوية وصلت القيم إلى الحد الأقصى في ١٦٥ يوما من الإزهار الكامل (المرحلة النضج). ارتفعت المواد الصلبة الذائبة الكلية (TSS) والسكريات بينما انخفض الحموضة تدريجيا حتى وصلت إلى المستوى الأمثل للنضج. من ناحية أخرى؛ زيادة تركيز فيتامين C (حمض الاسكوربيك) تدريجيا حتى وصلت الثمارإلي نضجها. إرتفاع محتوى الفينولات الكلية (TPC) المقدرة في قشرة الثمار والحبوب وبعد ذلك اصبح هناك انخفاض تدريجي حتى وصلت إلى أقل مستوى لها عند نضج الثمار. المحتوى الكلي الأنثوسيانين (TAC) في حبوب الرمان والقشرة بدأ بالأنخفاض في مراحل النمو الأولي للأصناف الثلاثة ويزداد تدريجيا حتى مرحلة النضج. محتوى التانين (Hydrolysable HTC) المقاس علي أساس (حمض التانيك مل / جم من الوزن الجاف) في قشر وعصير، كانت عالية في بداية مراحل النمو وبسرعة انخفض حتي وصلت إلى أقل مستوى لها عند نضج الثمار. كانت الفروق كبيرة بين الأصناف الثلاثة في كلا الموسمين بالنسبة لمعظم الصفات التي تمت دراستها.