Physicochemical Properties and Phenolic Contents of Fresh and Concentrated Juice of Four Pomegranate Cultivars in Iraq

Azhin Bakhtyar Mahmood Abdulrahman, Huda Jamal Mhamad, Sonia Sardar Talb and Ali Muhi Aldeen Omar Aljabary

1College of Agricultural Engineering Science, University of Sulaimani, Iraq.
2Technical College of Applied Sciences, Sulaimani Polytechnic University, Iraq.
3Email: azhin.mahmood@univsul.edu.iq
4Email: huda.jamal@spu.edu.iq

Abstract

In this study, four pomegranate cultivars were selected in Halabja City. Their physical properties such as peel, arils, juice, seed, and juice concentrate percentage, chemical properties, and some phenolic and sugars compounds of the juices and juices concentrate was compared among all cultivars. Of all four cultivars (Wonderful, Swra hanar, Salakhani, and Kaua hanar), Wonderful and Salakhani presented the highest pH values in juice and juice concentrate and they obtained a significant percentage of juice concentrate, total sugars, total anthocyanin, total phenols, and ascorbic acid. Other cultivars presented also individual properties such as high phenolic compounds were studied and interesting juice concentrate percentage content (Swra hanar cultivar) and the highest arils percentage and high amounts of fructose, sucrose, glucose, and ascorbic acid in juice and juice concentrate content (Kaua hanar cultivar) and highest juice percentage (Wonderful cultivar). Thus, this work will help pomegranate producers in selecting the extreme appropriate cultivar depending on its final utilize, especially being convenient for fresh consumption or juice concentrate.

Keywords: Pomegranate, Cultivars, Phenolic compounds, Ascorbic acid, Pomegranate juice.

1. Introduction

Pomegranate (Punica granatum L.) is contained polysaccharides and phenolics, flavonoids, proanthocyanidin compounds, also, it is a source of several minerals especially phosphorus, calcium, magnesium, potassium, and sodium [1], they also reported that the seed of the pomegranate contains protein, vitamins, sugars, isoflavones, pectin, the phytoestrogens, coumestrol and the sex steroid, estrone, crude fibers, polyphenols.

Recently, the cultivation of pomegranate and production in Halabja city has grown significantly. This increment comes back to the success of their cultivation due to the proper climate for pomegranate cultivation and the increasing requirement for the pomegranate fruit due to the useful health characteristic of its phenolic compounds, involving flavonoids (anthocyanins), phenolic acids, hydrolyzable tannins (gallotannins and ellagitannins) and condensed tannins (proanthocyanidins) [2,3].

In the study conducted by [4], shown that some flavonoids may have possible impacts on minimizing the incidences of cancer diseases, hyperlipidemia, cardiovascular, and other chronic diseases. In higher plants, the extremely popular anthocyanidins are pelargonidin, delphinidin, petunidin, malvidin, peonidin, and cyanidin. The three non-methylated glycosides of anthocyanidins (pelargonidin, delphinidin, and cyanidin) are high abundant in nature. The phenolic compounds involve phenolic acids: fundamentally, hydroxybenzoic acids (like ellagic acid and gallic acid) [5], hydroxycinnamic acids (like chlorogenic acid and caffeic acid) [6]. In relation to pomegranate has a high amount of 3-glucosides and 3, 5-diglucosides of pelargonidin, cyanidin, and delphinidin [7,8]. The chemical composition and anthocyanin content may differ among fruits of the same type because of various internal and external factors, as agronomic and genetic factors, temperature, light intensity, storage conditions, and processing method [9,10]. In this situation, the physical and chemical properties affected by the genotype (anthocyanin composition, phenolic content and antioxidant activity) of eight pomegranates that studied by [11]. The pomegranate juice concentration is big processing in fruit operation that plays a critical role in determining the quality of the matured products in terms of color, flavor, aroma, and nutritional characteristics [12]. Evaporation is a major technique used to concentrate different beverages that safely change the nutritional and sensorial properties of last products especially because of its destructive thermal impacts [13].

In Iraqi Kurdistan especially in the Halabja city, the concentrate of pomegranate juice is extremely produced and used especially with salad and most foods, Also [14], reported that arils of Salakhani pomegranate are the edible part represented...
about 50-65% and juice about 49-54% of the total fruit weight and its sour-sweet taste and juicy thus can be utilized as juice and its concentrate, which is the most common cultivar cultivated in Halabja city. There are many cultivars had been cultivated in Halabja city for a long time, there are no or little studies performed on physicochemical properties of these cultivated cultivars, thus we were preferred this study for showing their physicochemical properties.

Therefore, the goal of this research is to study the differences between juices and juice concentrate for four popular cultivars of pomegranate in Halabja (Wonderful, Swra hanar, Salakhani, and Kaua hanar) in chemical characteristics, in addition to a comparison between these cultivars in some physicochemical characteristics.

2. Material and Methods

Preparation of pomegranate juice Approximately, 10 Kg of fruit from each cultivar (Wonderful, Swra hanar, Salakhani, and Kaua hanar) pomegranates were harvested on November 2020 at the full ripening stage in the different private orchard in Halabja and immediately fruits transported to the lab. The fruits were peeled carefully with a severe knife, and then to gain the fresh pomegranate juice the arils were extracted manually according to the procedure reported by [15], and placed in a stainless steel container. The juice was mechanically extracted from arils. And then, immediately the juices were stored in the dark place at 4°C until utilized.

2.1. Processing of pomegranate juice concentrate

The juice was heated in a large open bowl on a low heat cooker for 24-25 hours to allow the moisture to evaporate more rapidly. During boiling the syrup must be stirred continuously to prevent burning, the total soluble solid of concentrated juice was checked using Hand Refractometer (Atago - Japan) continuously until reached 73-75 °Brix.

2.2. Physical parameters for the four cultivars

Fruit peel % and fruit arils % were measured based on the total weight of fruit, but fruit juice %, fruit seed %, and juice concentrate % were measured based on the total weight of arils for each cultivar.

2.3. Chemical parameters in fresh and concentrate juices for the four cultivars

A total soluble solid (TSS) (*Brix) was measured using Hand Refractometer (Atago - Japan). For titratable acidity (TA) % samples (fresh fruit juice and juice concentrate) were titrated with (0.1N)NaOH using phenolphthalein as indicator and the acidity was determined as citric acid content followed by the method of. The glucose, fructose, and sucrose concentration were determined using a spectrophotometer (Spectrophotometer UV/Visible – Shimadzu - Japan) according to the procedure reported by (Steegmans et al. 2004.). The pH was measured using a pH meter (Eu tech – Singapore). The total solid (TS%) and the moisture (%) were determined in fresh fruit juice and juice concentrate by drying 5 g at 100°C until constant weight [16].

2.4. Extraction of phenolic compounds

The following steps were conducted based on [17]. This is for the extraction of phenolic compounds in fresh pomegranate juice and juice concentration as follows: Specimens were taken 4 mL of juice for each cultivar and mixed by using an electric mixer. Then (50 mL of ethyl alcohol (70%) was added to the mixture and left at room temperature for two days. And filtration has been done by using Ederol filter paper (medium pore filtering). The extract was concentrated to adequate volume in order to get rid of alcohol by using an air conditioner. In much as the volume of petroleum ether (50-60°C boiling point) is added to the product. The mixture was shaken gently, placed in the separating funnel, and left for some time to separate clearly into two layers. The bottom aqueous was removed, and the upper clear aqueous (extracts of phenolic compounds) were left then transferred to clean vials extracts of phenolic compounds were concentrated approximately into a half volume by exposing to dry air.

Determination of the quantification of the phenolic compounds carried out by using an HPLC (Shimadzu, Japan) using a Supelcosilmt Column C-18 separator a column with dimensions of 250 x 4.6 mm, the mobile phase consisting of Acetonitrile + Acetic acid 1% (40: 60 V/V) Flow rate: 1 mL.min⁻¹, and sample volume 20 μL at a flow rate of 0.8 mL.min⁻¹, and the quantification was done based on the Retention Time and the area of the curve in each of the samples and the standard solution, and the wavelength of 280 nm was used to estimate the phenolic compounds (CiFeie acid, Ellagic acid, Gallic Acid, Choestine acid, and Para Hydroxybenzoic acid) at room temperature.
2.5. Statistical analysis

Data from the analyses of pomegranate fresh juice and juice concentrate were examined first by one way (ANOVA) analysis of variance for mean comparison. Finally, to the comparison among the means used Duncan’s Multiple Range Test. Significance was defined at p ≤0.05. XLSTAT Pro 7.5.2 software was used for statistical analyses.

3. Results and Discussion

3.1. Physical properties

Regarding with, the physical properties of all Pomegranate cultivars were studied. The obtained results in (figure 1) appeared the significant differences among them. It is evident from the results that the peel percentage ranged from 34.29 to 51.48% for Wonderful and Swra hanar cultivars respectively. On the other hand, arils percentage found ranging between 43.74-60.16% for Salakhani and Kawa hanar cultivars respectively. Regarding Salakhani cultivar, our

![Figure 1](https://example.com/figure1.png)

**Figure 1.** Physical parameters of four pomegranate cultivars cultivated in Halabja.

Although, the highest juice percentage in arils was obtained in Wonderful (73.25%), which is significantly superior to other cultivars. While the lowest juice percentage in arils was obtained in Kawa hanar (62.57%). The perfectly opposite happened regarding seed percentage in arils, the highest seed percentage was obtained in Kawa hanar (33.17%), which is significantly superior on other cultivars. While the lowest seed percentage was obtained in Wonderful (19.96%). In the contrary to our result in other studies of various pomegranate, cultivars found that Wonderful cultivar content of the arils percentage was 49.49% and seed percentage 10.65% [18]. In addition, Swra hanar gives the maximum juice concentrate percentage (21.84%), but the minimum percentage (19.67%) was recorded in Kawa hanar. These differences among the cultivars in physical properties maybe related to the genotype of the cultivar and ecotype conditions or agricultural service processes. Postharvest and environmental factors, processing methods, and cultivar type have been found among the agents influencing the formation of pomegranates juice [19-21].

3.2. Chemical properties

Total soluble solids content in pomegranate fresh juice and juice concentrate, are presented in Table (1). The TSS values ranged from 16.167 (Salakhani) to 17.467 °Brix (Wonderful) in fresh juice, from 73 (Swra hanar) to 75 °Brix (Wonderful, Salakhani) in juice concentrate. The Wonderful cultivar obtained the maximum values in fresh juice and juice concentrate. Concerning titratable acidity (TA), a significant difference was observed among cultivars in fresh juice and juice concentrate. The highest values of TA were recorded (2.836% and 11.630%) in fresh juice and juice concentrate of Kawa hanar cultivar respectively, which is significantly superior on other cultivars. The Wonderful and Salakhani cultivars were recorded the lowest values of fresh juice and juice concentrate (Table 1). Our result is similar to those found by [22], in their study of various pomegranate cultivars that Wonderful cultivar juice content of the TSS was 18.04 °Brix and TA 1.92%. As reported
by [23], the Salakhani cultivar juice content of the TSS was 16.5 °Brix and TA 0.68%. [24], reported that the lowest °Brix of pomegranate juice should be 14.0 °Brix marks the percentage of the soluble solids in fruit juice and may be influenced by many agents: growth year, growing region, cultivar, and maturity degree of the fruit.

Data in the same Table appeared significant difference among cultivars in pH in fresh juice and juice concentrate. The pH ranged from 3.320 to 4.027% in fresh juice, while in juice concentrate ranged from 2.703 to 3.727%. The highest values were recorded in fresh juice of Salakhani cultivars and in juice concentrate of Wonderful cultivar.

### Table 1. Chemical properties in juice and juice concentrate of four pomegranate cultivars.

| Pomegranate | Cultivars          | T.S (%T.A.) | pH   | T.S (%) | Moisture (%) |
|-------------|--------------------|-------------|------|---------|--------------|
| Juice       | Wonderful          | 17.467a     | 1.088a| 4.017a  | 17.731a      | 82.269a      |
|             | Swara hanar        | 17.167a     | 1.835b| 3.577b  | 17.439a      | 82.561a      |
|             | Salakhani          | 16.167b     | 1.054b| 4.027a  | 17.273b      | 82.763a      |
|             | Kawa hanar         | 17.2a       | 2.836c| 3.320c  | 17.302ab     | 82.698a      |
| Juice       | Wonderful          | 75a         | 3.393  | 3.727c  | 77.072a      | 22.928b      |
|             | Swara hanar        | 73a         | 7.380b | 3.350b  | 75.181b      | 24.819b      |
| concentrate | Salakhani          | 75a         | 4.351c| 3.593b  | 77.156b      | 22.844b      |
|             | Kawa hanar         | 74a         | 11.630a| 2.703a  | 75.850a      | 24.150b      |

Different letters on the means in the same column of juice or juice concentrate are statistically different (p < 0.05).

The results from the current investigation showed significantly the difference among cultivars in TS in fresh juice and juice concentrated (Table 1). The highest values of TS in fresh juice for Wonderful cultivar were recorded (17.731%) also juice concentrate of Salakhani cultivar were (77.16%). The lowest values of Salakhani cultivar in fresh juice and juice concentrated of Swra hanar cultivar were recorded. Regarding the moisture content in fresh juice and juice concentrated, data presented in (Table 1) showed the non-significant difference among cultivars in fresh juice of this parameter, while the highest value was recorded in Swra hanar cultivar, which is significantly superior to other cultivars in moisture content for juice concentrate.

In general, the alterations in chemical properties through thermal processing appears in (Table 1) excess in total acidity, TS and increase in moisture and pH over primary of fresh juice utilized values for making concentrate might be due to the water vaporization during the juice concentrate process which led to a decline in the moisture content in the ultimate product, thus increased these chemical compounds as a result of juice concentrate.

### Table 2. Phenolic compounds in juice and juice concentrate of four pomegranate cultivars.

| Cultivars | Caffeic acid (mg/100ml) | Choestine acid (mg/100ml) | Gallic acid (mg/100ml) | Ellagic acid (mg/100ml) | Para Hydroxybenzoic acid (mg/100ml) |
|-----------|-------------------------|---------------------------|------------------------|------------------------|------------------------------------|
|           | Juice                   | Concentrate               | Juice                  | Concentrate             | Juice                              | Concentrate                      |
| A         | 0.32^a                  | 0.15^a                    | 0.025^b                | 0.031^b                | 23.37^c                           | 24.1^c                         | 0.017^b                           | 0.020^b                           | 0.032^a                           | 0.031^a                           |
| B         | 0.56^ab                 | 0.62^a                    | 0.053^c                | 0.051^c                | 27.40^d                           | 26.2^d                         | 0.030^c                           | 0.030^c                           | 0.043^c                           | 0.040^c                           |
| C         | 0.18^c                  | 0.25^b                    | 0.023^d                | 0.014^e                | 23.23^f                           | 23.1^f                         | 0.017^g                           | 0.030^g                           | 0.020^g                           | 0.021^h                           |
| D         | 0.76^d                  | 0.02^d                    | 0.023^b                | 0.013^c                | 24.77^g                           | 18.9^d                         | 0.040^b                           | 0.013^c                           | 0.025^bc                          | 0.013^e                           |

^A= Wonderful, B= Swra hanar, C= Salakhani, D= Kawa hanar.

The different letters on the means in the same column with are statistically different (p < 0.05).

Some phenolic compounds were specified and quantified in pomegranate juice and juice concentrate using the HPLC. These phenolic compounds include gallic acid, caffeic acid, ellagic acid, and para hydroxybenzoic acids. Table (2) gives the single phenolic compound concentrations identified in the pomegranate juice and juice concentrate of studied cultivars. In this study the results shows that the concentration of the phenolic component in pomegranate juice and juice the concentrate has significant differences among cultivars: the highest values of Choestine acid 0.053, 0.051 mg/100 mL, gallic acid 27.40, 26.2 mg/100 mL and para hydroxybenzoic acid 0.32 mg/100 mL in pomegranate juice and juice concentrate respectively of Swra hanar cultivar, whilst the highest values of caffeic acid 0.76 mg/100 mL and ellagic acid 0.040 mg/100 mL in pomegranate juice of Kawa hanar and caffeic acid 0.62 mg/100 mL and ellagic acid 0.030 mg/100 mL in pomegranate juice concentrate of Swra hanar. Generally, in pomegranate juice, the phenolic compounds are more than juice concentrated (Table 2). Our study appeared that phenolic components concentrations vary according to the cultivars in pomegranate juice and juice concentrate. [25], they reported that the concentration of the phenolic component in pomegranate pulp content differs according to ecotypes. On the other hand, some studies showed that the chemical composition and anthocyanin content may differ among fruits of the same type because of various agronomic and genetic factors, environment, and processing method [26,27]. The physicochemical properties affected by the genotype (anthocyanin composition, and phenolic content ) of some pomegranate cultivars that mentioned by [28].

Total sugars content in the juice of the four cultivars in the current study ranged between 4.47 and 7.52 % for the Kawa hanar and Salakhani cultivars, respectively, whilst in concentrated juice ranged between 3.80 and 8.69 % for the Kawa hanar and Wonderful cultivars, respectively (Table 3). As for the cultivars, we found that the highest amount of fructose sugar was in Wonderful and Kawa hanar in juice and juice concentrate, which significantly superior on the other cultivars. As well, these cultivars (Wonderful and Kawa hanar) obtain the highest amount of glucose sugar significantly superior on the other cultivars in juice, while no significant differences in juice concentrate was found among the cultivars. On the other hand, all cultivars...
significantly superior on Wonderful cultivar in sucrose sugar content in juice, while non-significant differences were found in juice concentrate.

Table 3. Total Sugars, Fructose, Glucose and Sucrose in juice and juice concentrate of four pomegranate cultivars.

| Cultivars  | Total Sugars (%) | Fructose (mg/100ml) | Glucose (mg/100ml) | Sucre (mg/100ml) |
|-----------|------------------|---------------------|--------------------|-----------------|
| Juide      | Concentrate      | Juide               | Concentrate        | Concentrate     |
| Wonderful  | 5.31 c           | 8.69 a              | 0.16 a             | 0.16 ab         | 0.021 a         | 0.014 a         | 0.050 b         | 0.07 a          |
| Swra hanar | 5.51 b           | 4.61 c              | 0.14 b             | 0.15 b          | 0.019b          | 0.018 a         | 0.073 a         | 0.07 a          |
| Salakhani  | 7.52 a           | 7.29 b              | 0.12 c             | 0.13 c          | 0.016 c         | 0.016 a         | 0.073a          | 0.06 a          |
| Kawa hanar | 4.47 d           | 3.80 d              | 0.16 a             | 0.17 a          | 0.02 ab         | 0.02 a          | 0.077a          | 0.07 a          |

The different letters on the means in the same column with are statistically different (p < 0.05).

Table 4. Total Anthocyanin, Total Phenol and Ascorbic acid in juice and juice concentrate of four pomegranate cultivars.

| Cultivars  | Total Anthocyanin (mg/100ml) | Total Phenol (mg/100ml) | Ascorbic acid (mg/100ml) |
|-----------|-------------------------------|-------------------------|--------------------------|
| Juice     | Concentrate                   | Juice                   | Concentrate              |
| Wonderful | 19.503 b                      | 14.713 b                | 485.866 b                | 48 a            | 52 a           |
| Swra hanar| 15.397 c                      | 13.344 c                | 427.699 c                | 42 a            | 45 c           |
| Salakhani | 21.556 a                      | 20.872 a                | 389.719 d                | 35 a            | 47 b           |
| Kawa hanar| 15.055 c                      | 7.870 d                 | 550.876 a                | 44 a            | 48 b           |

The different letters on the means in the same column with are statistically different (p < 0.05).

The Data in (Table 4) show that total anthocyanin content in the juice of the four cultivars in the current study ranged from 15.055 to 21.556 mg/100ml for the Kawa hanar and Salakhani cultivars, respectively, whilst in concentrated juice ranged from 7.870 and 20.872 mg/100ml for the Kawa hanar and Salakhani cultivars, respectively. Regarding total phenol content in the juice of the four cultivars in the current study ranged from 280.228 and 353.108 mg/100ml for the Kawa hanar and Wonderful cultivars, respectively, whilst in concentrated juice ranged from 389.719 and 550.876 mg/100ml for the Salakhani and Kawa hanar cultivars, respectively (Table 3).

Concerning the ascorbic acid content in the juice and its concentrate, the results in Table 4 showed that generally the amount of ascorbic acid is higher in the juice concentrate than the juice. The highest value was found in the Wonderful in juice and juice concentrate, which is significantly superior to the other cultivars in juice concentrate. Our values of Vitamin C in Wonderful cultivar juice were generally higher than reported by [29], that Wonderful 1,2 cultivars content 39.3–25.6 mg AA/100 mL juice respectively.

Probably, there is a collection of conditions that impacts the content of the chemical compound in fresh juice and juice concentrate such as climate conditions, species, the cultivar, processing method, etc. The present study was the first one studied the comparison among pomegranate juice and juice concentrate on some chemical compounds content of some of the cultivars cultivated in Halabja. The variability in the total phenolic compounds values may be caused by reactions taking place during juice manufacture (i.e., hydroxylation, methylation, isoprenylation, dimerization, and/or glycosylation) [30]. The bright red color of pomegranate arils and juice is due to anthocyanins or its constancy through manufacturing. Delphinidin derivative of anthocyanin give purple and blue color whilst pelargonidin is given orangish red colors and are existing in minimal amounts [31]. Generally, pomegranate juices vary of the anthocyanin content of between 10 to 700 mg./L relying on the cultivar [32]. Thus recommended of the nutritionists keeping of these components through the processing of fruit juice because they have beneficial preventive impacts for human health [33].

The reduced of phenols content is polyphenol oxidase enzyme responsibility [26] thus due to water evaporation during processing, bioactive compounds decrease, reduced polyphenol oxidase activity and polyphenols concentration as noticed in pomegranate juice by [35], in pomegranate juice concentrate.

Conclusion

The current work demonstrated that novel research work demonstrated that various pomegranate juice and juice concentrate offered differently physicochemical properties, which are great factors important to characterize pomegranate cultivars regarding their future utilize. Wonderful and Salakhani presented the highest pH values in juice and juice concentrate, which means they are sweeter than other cultivars and they gave a good percentage of juice concentrate, total sugars, total anthocyanin, total phenol, and ascorbic acid, being convenient for fresh consumption and juice concentrate. Since these compounds have high potential as an antioxidant, suggesting health benefits for the consumers. On the other hand, Swra
hanar cultivar given distinguishing characteristics than the other cultivars because its juice and juice concentrate showed the highest values of phenolic compounds were studied and interesting juice concentrate percentage. Even though the lowest juice and juice concentrate percentage present of Kaua hanar Even though the lowest juice and juice concentrate percentage present in Kaua hanar, this cultivar should have high amounts of fructose, sucrose, glucose, and ascorbic acid in juice and juice concentrate content.

Acknowledgements

We thank Dr. Muhammad Saeed Rashid (Sulaimani Polytechnic University, Technical College of Applied Sciences) for his linguistic assistance during the revision of this manuscript.

References

[1] Akhtar, S., Ali, J., Javed, B. and Khan, F.A., 2013. Studies on the preparation and storage stability of pomegranate juice based drink. *Middle-East Journal of Scientific Research,* 16(2), pp.191-195.

[2] Al-Jabary, A. M. 2007. Effect of GA3 and some Nutrients of Pomegranate Fruit (*Punica granatum* L.) Splitting and Storability CV. (Salakhani). M. Sc. Thesis, Univ, of sulaimani. Department of Horticulture.

[3] Al-Jabbari, K. H. Pakyürük, M., and Yaviç, A. 2019. Identification of morphological and pomological characteristics of Iraq pomegranate (*Punica granatum* L.) variety Salakhani and comparing with variety Zivzik. *International Journal of Secondary Metabolite.* 6(3): 270-282.

[4] Amakura, Y., Okada, M., Tsuji, S. and Tonogai, Y., 2000. High-performance liquid chromatographic determination with photodiode array detection of ellagic acid in fresh and processed fruits. *Journal of Chromatography A,* 896(1-2), pp.87-93.

[5] Dhumal, S.S., Karale, A.R., More, T.A., Nimbalkar, C.A., Chavan, U.D. and Jadhav, S.B., 2013. September. Preparation of pomegranate juice concentrate by various heating methods and appraisal of its physicochemical characteristics. *In III International Symposium on Pomegranate and Minor Mediterranean Fruits* 1089 (pp. 473-484).

[6] Hasan AM, Al-Falahy THR and Al-Taey. DKA. 2020. the effect of cutting diameter and storage method on the rooting and growth of pomegranate cuttings (salimi and rawa cultivars). *Int. J. Agricult. Stat. Sci.,* 16 Supplement 1: 1457-1463.

[7] Elalleh, W., Tilii, N., Nasri, N., Yahia, Y., Hannachi, H., Chaïra, N., Ying, M. and Ferchichi, A., 2011. Antioxidant capacities of phenolic compounds and tocopherols from Tunisian pomegranate (*Punica granatum*) fruits. *Journal of food science,* 76(5), pp.C707-C713.

[8] Fernandes, L., Pereira, J.A.C., Lópex-Cortés, I., Salazar, D.M. and Ramalhosa, E.C., 2015. Physicochemical changes and antioxidant activity of juice, skin, pellicle and seed of pomegranate (cv. Mollar de Elche) at different stages of ripening. *Food technology and biotechnology,* 53(4), pp.397-406.

[9] Fernandes, L., Pereira, J.A., Lópex-Cortés, I., Salazar, D.M., González-Álvarez, J. and Ramalhosa, E., 2017. Physicochemical composition and antioxidant activity of several pomegranate (*Punica granatum L.*) cultivars grown in Spain. *European Food Research and Technology,* 243(10), pp.1799-1814.

[10] Gómez-Caravaca, A.M., Verardo, V., Toselli, M., Segura-Carretero, A., Fernández-Gutiérrez, A. and Caboni, M.F., 2013. Determination of the major phenolic compounds in pomegranate juices by HPLC–DAD–ESI-MS. *Journal of agricultural and food chemistry,* 61(22), pp.5328-5337.

[11] Fischer, U.A., Jakusch, A.V., Carle, R. and Kammerer, D.R., 2013. Influence of origin source, different fruit tissue and juice extraction methods on anthocyanin, phenolic acid, hydrolysable tannin and isolaricresinol contents of pomegranate (*Punica granatum* L.) fruits and juices. *European Food Research and Technology,* 237(2), pp.209-221.

[12] Herborne, J.B., 1973. Phytochemical methods. *A guide to modern techniques of plant analysis,* pp.5-11.

[13] Hasnaoui, N., Jbir, Y., Mars, M., Trifi, M., Kamal-Eldin, A., Melgarejo, P. and Hernandez, F., 2011. Organic acids, sugars, and anthocyanins contents in juices of Tunisian pomegranate fruits. *International Journal of Food Properties,* 14(4), pp.741-757.

[14] Orak, H.H., 2009. Evaluation of antioxidant activity, colour and some nutritional characteristics of pomegranate (*Punica granatum* L.) juice and its sour concentrate processed by conventional evaporation. *International Journal of food sciences and nutrition,* 60(1), pp.1-11.

[15] Ismail, F.A., Abdelatif, S.H., El-Mohsen, N.R.A. and Zaki, S.A., 2014. The physico-chemical properties of pomegranate juice (*Punica granatum L.*) extracted from two Egyptian varieties. *World Journal of Dairy & Food Sciences,* 9(1), pp.29-35.

[16] Jalal, H., Pal, M.A., Ahmad, S.R., Rather, M., Andrali, M. and Hamdani, S., 2018. Physico-chemical and functional properties of pomegranate peel and seed powder. *J. Pharm. Innov,* 7, pp.1127-1131.

[17] Khajehi, F., Niakousari, M., Eskandari, M.H and Sarshar, M., 2015. Production of pomegranate juice concentrate by complete block cryoconcentration process. *Journal of Food Process Engineering,* 38(3), pp.488-498.

[18] Li, X., Wasila, H., Liu, L., Yuan, T., Gao, Z., Zhao, B. and Ahmad, I., 2015. Physicochemical characteristics, polyphenol compositions and antioxidant potential of pomegranate juices from 10 Chinese cultivars and the environmental factors analysis. *Food chemistry,* 175, pp.575-584.

[19] Martínez, J.J., Hernández, F., Abdelmajid, H., Legua, P., Martínez, R., El Amine, A. and Melgarejo, P., 2012. Physico-chemical characterization of six pomegranate cultivars from Morocco: processing and fresh market aptitudes. *Sciencia Horticulturae,* 140, pp.100-106.

[20] Maskan, M., 2006. Production of pomegranate (*Punica granatum L.*) juice concentrate by various heating methods: colour degradation and kinetics. *Journal of Food Engineering,* 72(3), pp.218-224.
[21] Mena, P., Garcia-Viguera, C., Navarro-Rico, J., Moreno, D.A., Bartual, J., Saura, D. and Martí, N., 2011. Phytochemical characterisation for industrial use of pomegranate (*Punica granatum L.*) cultivars grown in Spain. Journal of the Science of Food and Agriculture, 91(10), pp.1893-1906.

[22] Miguel, G., Dandlen, S., Antunes, D., Neves, A. and Martins, D., 2004. The effect of two methods of pomegranate (*Punica granatum L.*) juice extraction on quality during storage at 4 C. Journal of Biomedicine and Biotechnology, 2004(5), p.332.

[23] Mphahlele, R.R., Caleb, O.J., Fawole, O.A. and Opara, U.L., 2016. Effects of different maturity stages and growing locations on changes in chemical, biochemical and aroma volatile composition of ‘Wonderful’ pomegranate juice. Journal of the Science of Food and Agriculture, 96(3), pp.1002-1009.

[24] Nuncio-Jáuregui, N., Cano-Lamadrid, M., Hernández, F., Carbonell-Barrachina, Á.A. and Calín-Sánchez, Á., 2015. Comparison of fresh and commercial pomegranate juices from Mollar de Elche cultivar grown under conventional or organic farming practices. Beverages, 1(2), pp.34-44.

[25] Özkan, M. (2002) Degradation of anthocyanins in sour cherry and pomegranate juices by hydrogen peroxide in the presence of added ascorbic acid, Food Chem 78(4), pp.499–504.

[26] Pérez-Vicente, A., Serrano, P., Abellán, P. and García-Viguera, C., 2004. Influence of packaging material on pomegranate juice colour and bioactive compounds, during storage. Journal of the Science of Food and Agriculture, 84(7), pp.639-644.

[27] Radunić, M., Špika, M.J., Ban, S.G., Gadže, J., Díaz-Pérez, J.C. and MacLean, D., 2015. Physical and chemical properties of pomegranate fruit accessions from Croatia. Food chemistry, 177, pp.53-60.

[28] Rajasekar, D., Akoh, C.C., Martino, K.G. and MacLean, D.D., 2012. Physico-chemical characteristics of juice extracted by blender and mechanical press from pomegranate cultivars grown in Georgia. Food Chemistry, 133(4), pp.1383-1393.

[29] Rice-Evans, C., Miller, N. and Paganga, G., 1997. Antioxidant properties of phenolic compounds. Trends in plant science, 2(4), pp.152-159.

[30] Saenz, C. Seguel, J. Gorena, T. and Sepulveda, E. 2010. Effect of the concentration temperature on some bioactives compounds and rheological properties of pomegranate juices. In: International Conference Food Innovation, Uni. Politecnica De Valencia. Food Innova. p1-4.

[31] Steegmans, M., Iliensa, S. and Hoebregs, H., 2004. Enzymatic, spectrophotometric determination of glucose, fructose, sucrose, and inulin/oligofructose in foods. Journal of AOAC International, 87(5), pp.1200-1207.

[32] Türkmen, İ. and Ekşi, A., 2011. Brix degree and sorbitol/xylitol level of authentic pomegranate (*Punica granatum*) juice. Food chemistry, 127(3), pp.1404-1407.

[33] Vardín, H. and Fenercioğlu, H., 2003. Study on the development of pomegranate juice processing technology: clarification of pomegranate juice. Food/Nahrung, 47(5), pp.300-303.

[34] Yılmaz, Y., Çelik, I. and Isik, F., 2007. Mineral composition and total phenolic content of pomegranate molasses. Journal of Food Agriculture and Environment, 5(3/4), p.102.

[35] Zaouay, F., Mena, P., García-Viguera, C. and Mars, M., 2012. Antioxidant activity and physico-chemical properties of Tunisian grown pomegranate (*Punica granatum L.*) cultivars. Industrial Crops and Products, 40, pp.81-89.