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Fruit Biochemical and Nutritional Properties of Some Asian and European Pears (*Pyrus* spp.) Grown under Tehran Environmental Conditions

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ABSTRACT

Pear is one of the most important pome fruits in the world fruit market with a high nutritional value. This study was performed to determine the phenolic compounds and some chemical properties of the fruit flesh and peel of 12 Asian and European pears. Chlorogenic acid and rutin were found as the important phenolic compounds in the fruit peel, which were measured using HPLC. Results showed fruit Titratable Acidity (TA, 0.17-0.53%), Total Soluble Solids (TSS, 13.33-17.33 °Brix), firmness (1.7-2.75, kg cm^{-2}), and color parameters. The highest L* value was observed in KS7 (40.55), while the lowest was in KS12 (14.26) and KS13 (14.78). Additionally, the study assessed the nutrient and total phenol content of fruit samples. The `Shahmiveh' cultivar displayed the highest total phenol content (638 mg 100 g^{-1} FW), while the KS7 cultivar had the lowest (420 mg 100 g^{-1} FW). Potassium was the most abundant nutrient (1.16 mg 100 g^{-1} DW), followed by nitrogen and calcium contents. As the total phenol increased, so did the amount of rutin. Principal Components Analysis (PCA) of all data showed that the European and Asian pears studied cultivars and genotypes were different in terms of most of the studied biochemical traits, and significant relationships were observed between some traits. Besides, the obtained results help in the selection of the best pear cultivars or genotypes in terms of the highest phenolic content and nutrients, both for fresh consumption and in the juice industry.

Keywords: Rutin, Chlorogenic acid, Pear macronutrients, Pear micronutrients, Total phenol **.**

INTRODUCTIN

Pyrus (*Pyrus* spp.) is the second most important crop following apple in the *Rosaceae* family and can be divided into two major groups of Asian and European type pears (Arzani, 2019; Wang and Arzani, 2019). European species (*Pyrus. communis* L.) have more than 5000 cultivars (Kadkhodaei *et al*., 2021; Monte-Corvo *et al*., 2001). Asian pears (*Pyrus pyrifolia*) are mainly cultivated in countries such as Korea, China, and Japan in East Asia. They have been cultivated in various parts of Asia for over 3,000 years. Currently, this species is grown commercially in more than 50 countries under temperate climate regions. At least 22 early Pyrus species have been identified, all of which are native to Asia, Europe, and the mountainous regions of North America (Bell *et al.,* 1996). This crop is cultivated mainly due to its commercial value and desirable fruit taste (Arzani, 2002; Wang and Arzani, 2019; Arzani, 2019; Arzani, 2021).

Today, plants can be used to prevent and treat diseases (Jimenez-Garcia *et al*., 2021; Fattahi *et al*., 2021). Pears contain phenolic substances and have antioxidant and antimicrobial properties (Jennings *et al*.,

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2017; Tiwari *et al*., 2023). Antioxidant supplements can be mentioned as an important non-pharmacological strategy against oxidative stress (Mota *et al*., 2022). A self-incompatible, high heterogeneity and allelic diversity have been reported in this genus (Monte-Corvo *et al*., 2001). In recent decades, numerous studies have been devoted to assessing the genetic diversity in various *Pyrus* species including morphological, biochemical, and DNA markers among European, Asian, and other species. Polyphenols are secondary metabolites (de Paulo Farias *et al*., 2020). Plant secondary metabolites are a group of chemicals that play a major role in plant growth and survival (Singh *et al*., 2021; Fattahi *et al*., 2021). Polyphenols are compounds that occur naturally in fruits and vegetables and are important because of their healing properties and application in technology (de Araújo *et al*., 2021), and as such, they have received much attention in recent years (de Paulo Farias *et al*., 2020). Consumption of plants helps the supply of macro- and micro-nutrient elements and reduces the incidence of functional disorders in the body and human health (Li *et al*., 2017). The role of nutrients in improving the quality of fruit and its other effects- in particular, respiratory failure- causes delay in ripening, increased fruit firmness, and improved fruit storage. Meanwhile, over-consumption of nutrients also impedes the production of quality fruit. Besides, nutrient imbalances cause numerous disorders that affect the quality and performance of pears (Dar *et al*., 2015; Wang and Arzani, 2019; Arzani, 2019).

Phenolic compounds are chemicals found in most plant tissues of fruits and vegetables. Also, chlorogenic acid (5-Ocaffeoylquinic acid) is a secondary metabolite of phenolic acids and is found in many plants and has an obese anti-obesity mechanism (He *et al*., 2021). Chlorogenic Acid (CGA) is a natural product that has medicinal properties such as anti-cancer, light protection, antioxidant, anti-inflammatory, hypoglycemic, and hypoglycemic effects. After absorption, CGA is further metabolized into sulfate metabolites, glucuronic acid, and glycosides (Sanchez *et al*., 2017; Nwafor *et al*., 2022). Rutin is an important flavonoid also known as vitamin P and quercetin-3-o-rotinoside, and has a protective role against liver and gastrointestinal problems (Hosseinzadeh and Nassiri-Asl, 2014), with anti-inflammatory, anti-tumor, antioxidant, and neuro-protective effects (Muvhulawa *et al*., 2022; Song *et al*., 2014). Recently, eight phenolic compounds have been identified in the fruit peel of Asian pear (Lee *et al*., 2011). Pear fruit peel has far higher and more varied phenolic contents than its flesh (Chen *et al*., 2006). In addition, it is highly recommended that natural products are eaten with their peels, because if they reduce oxidation, they will be useful for well-being and disease reduction (Nazir *et al*., 2020). Previous studies on pears have shown that they contain minerals (Brunetto *et al*., 2015; Ozturk *et al*., 2009), and pear fruit is rich in macro- and micro-nutrients (Nazir *et al*., 2020). Mineral nutrients play an important role in plant growth and metabolic functions and are heavily involved in maintaining the health and proper functioning of an organism (Tewari *et al*., 2021). There are human, plant, and animal diseases associated with micronutrient deficiencies. Also, efforts should be made to produce aggregating microelements of genotypes with an overexpression approach (bio-genetic enhancement) (Izydorczyk *et al*., 2021). \`Shahmiveh' and \`Sebri' are native commercial European pears cultivars in Iran. Additionally, A95 promising chance seedling genotype showed superiority in some qualitative fruit characteristics (Wang and Arzani, 2019; Kadkhodaei *et al*., 2021; Yadegari and Arzani, 2023).

The objective of this research was to explore the phenolic and biochemical compounds of \`Shahmiveh', \`Sebri' and A95 promising genotype compared with some commercial Asian pear cultivars that are grown under Tehran (Iran) environmental conditions.

MATERIALS AND METHODS

In this experiment, 9 Asian pear cultivars including KS6, KS7, KS8, KS9, KS10, KS11, KS12, KS13, and KS14 (Arzani, 2002), as well as 3 European pear cultivars, `Shahmiveh', `Sebri', and A95 promising genotypes (Najafzadeh, 2015; Wang and Arzani, 2019), were used. Trees were planted under Tehran environmental conditions at Tarbiat Modares University (TMU) Asian Pear Collection Orchard, with latitude: 35° 41' 39.80" N and longitude: 51° 25' 17.44" E. Besides, fruits were harvested at the commercial maturity harvest index (Arzani, 2019) mainly based on the fruit background color, flesh firmness, and Total Soluble Solids (TSS) for further assessments.

Determination of Total Phenolic Content

Fruit samples (fruit with the peel) were freeze-dried for 48 hours and then powdered. For the extraction of phenolic compounds, 2 g. of powdered pulp was used according to the method described by Lister *et al.* (1994) with slight modification. Then, 5 mL of extraction solvent consisting of 85% methanol and 15% acetic acid was added. The samples were placed at 4 °C for 24 h and centrifuged at 10,000 rpm for 10 min. About 1 mL of the supernatant of each sample was filtered using a 0.45 µm syringe filter.

The total phenol content of the extracts was measured by the Folin-ciocalteu method. The absorbance was measured using a spectrophotometer at 765 nm. Total phenol contents were expressed in terms of a milligram of gallic acid content per 100 g fruit fresh weight.

Determination of the Phenolic Content and Components

A water liquid chromatography apparatus consisting of a separations module: Waters 2695 (USA) and a PDA Detector water 996 (USA) was used for the HPLC analysis. Data acquisition and integration were performed via Millennium32 software. The injection was performed by an auto-sampler injector equipped with chromatographic assay performed on a 15 cm×4.6 mm with pre-column, Eurospher 100-5 C18 analytical column provided by waters (Sunfire) reversed-phase matrix (3.5 µm) (waters). The elution was carried out in a gradient system with methanol as the organic phase and distilled water with a flow rate of 1 mL min^{-1}. Peaks were monitored at 195-400 nm wavelength. The injection volume was 20 µL and the temperature was maintained at 25°C.

Fruit Sample Preparation for TSS, TA, pH, Firmness, and Color

To determine Total Soluble Solids (TSS), a few drops of fruit flesh extract were poured onto the refractometer. For this purpose, Japan's portable refractometer Model 9703 was used (Bexiga *et al*., 2017). For Titratable Acidity (TA) and pH of the fruit extract, 10 g of smashed fruit flesh was used, with the addition of about 30 mL of distilled water. The extract was centrifuged at 50°C for 30 minutes at 4000 rpm. To determine the TA with 0.1 normal solutions, it was titrated to reach pH 8.3 (pH meter Consort- model C860), after which the acidity was calculated based on a milligram of malic acid per 100 g of fruit tissue. To measure the flesh firmness of the fruit tissue, after removing a thin layer of fruit peel, an 8 mm diameter probe by penetrometer (Wagner) was used and fruit firmness was measured in kg cm^{-2}. The pear fruit peel color was measured via the Lutron RGB-1002 color analyzer and converted to L* (Lightness), a* (green to red), and, b* (blue to yellow).

Extraction to Measure Nutrients

Initially, the fruit samples (fruit with the peel) were washed with tap water, followed by 0.1 M hydrochloric acid (HCl), then, rinsed again with distilled water. The sample was dried in an oven at 70°C and powdered. The 0.5 mm sieve mesh was used for collecting the clean powdered samples. Extraction steps were performed as follows: Briefly, 2 g of the dried sample was heated in an oven at 550°C for 4 hours. The ash was slightly moistened with distilled water, and 10 mL of 2 M HCl was added. The final extract was delivered in a volume of 100 mL (Waling *et al*., 1989). Distillation and sample titration were used to measure the percentage of plant nitrogen (Waling *et al*., 1989). Phosphorus was measured using a colorimetric (Vanadate-Molybdate) method. The absorbance was measured via a spectrophotometer at 470 nm (Chapman and Pratt, 1962). Potassium and sodium were measured by atomic emission spectrometry.

The absorbance was read by a flame photometer with 766.5 nm for K and 589 nm for N (Waling *et al*., 1989) The Azomethine colorimetric method was employed to measure the amount of boron, and the spectrophotometer device was used at 430 nm. An atomic absorption device was utilized to measure the percentage of magnesium (285.2 nm) and calcium (422.7 nm) in the plant (Waling *et al*., 1989). Measurement of microminerals (iron-manganese-zinc and copper) was performed by Atomic Absorption Spectrometry (AAS) method. Measurement of the resulting extraction was carried out by dry burning and use of HCl. The absorption rate of Fe, Mg, Zn, and Cu was measured at 248.3, 289.5, 213.9, and 324.7 nm, respectively (Elmer and Conn, 1982).

Statistical Analysis

The obtained data were initially checked for normality and analyzed using SAS (Ver. 9.3, SAS Institute, Cary, NC). The results were statistically evaluated by Analysis Of Variance (ANOVA) and expressed as mean±Standard Error (SE). Biochemical data for Principal Component Analysis (PCA) and cluster analysis were used. PCA and cluster analysis were performed using Minitab software (Ver. 17). For the Heat map, R 3.5.3 software was used.

RESULTS AND DISCUSSION

Total Phenol

The highest total phenol amount was observed in the `Shahmiveh' cultivar and the lowest in KS7 which were 638.01 and 420.02 (mg 100 g^{-1} FW), respectively. Based on the results, the total phenol amount in different cultivars and the studied genotype showed significant differences (Table 1). The differences in the phenolic composition of different cultivars confirm the genetic role in the synthesis of phenolic compounds since the amount of polyphenols was affected by genotype, rootstock, and climatic conditions (Lin and Harnly, 2008; Mainla *et al*., 2011; Maleki Asayesh *et al*., 2023). Phenolic compounds may impair callus formation by affecting cell division, development, and differentiation (Bennett and Wallsgrove, 1994). The total phenolic compound in the fruit tissue of the KS13 was higher than KS6 and KS9 Asian pear cultivars (Maghdori *et al*., 2015). In another study performed on several Australian pear cultivars, the highest amount of total phenol was observed in `Beurre Bosc' (3.14 ± 0.02 a mg GAE $g^{-1}$) and the lowest in `Winter Nelis' European pear (1.89 ± 0.03 a mg GAE g^{-1}) (Wang *et al*., 2021).

Phenolic Compounds

The minimum amount of chlorogenic acid was observed in `Sebri' and KS8, which were 3.48 and 3.55 (mg g^{-1} FW), respectively, while it's maximum was obtained in KS14 and was 9.48 (mg g^{-1} FW).

Table 1. Total Phenole, Chlorogenic acid, Rutin, TSS, TA, and TSS/TA of pear cultivars.[a]

Cultivar	Total Phenol (mg 100 g^{-1} FW)	Chlorogenic acid (mg g^{-1} FW)	Rutin (mg g^{-1} FW)	TSS ºBrix	TA (%)	**TSS/TA**
KS6	466.93±9.19efg	7.8±0.0274b	0.08±0.000cde	14.67±0.033cde	0.24±0.003g	60.33±2.166b
KS7	420.02±14.6g	5.56±0.140gh	0.05±0.001fg	14.33±0.033de	0.38±0.015bc	37.82±1.478f
KS8	586.68±32.6ab	3.55±0.177i	0.04±0.000g	17.33±0.033a	0.32±0.011def	54.25±1.212bc
KS9	450.92±3.45fg	7.67±0.328bc	0.04±0.000g	16±0.577ab	0.33±0.003de	48.96±1.360cd
KS10	443.75±16.1fg	7.2±0.208cd	0.07±0.000def	13.67±0.333e	0.23±0.003g	58.57±1.260b
KS11	489.55±7.42def	7.71±0.158bc	0.11±0.006c	13.34±0.333e	0.29±0.005f	46.01±1.441de
KS12	487.35±7.82def	6.54±0.144ef	0.10±0.008cd	15.33±0.333bcd	0.33±0.005de	46.5±1.275cde
KS13	560.75±7.05bc	6.89±0.058de	0.06±0.002efg	14.66±0.333cde	0.17±0.006h	84.95±4.681a
KS14	473.55±8.88efg	9.46±0.088a	0.06±0.003efg	13.33±0.333e	0.33±0.012de	41.43±2.638def
A95	520.46±11.6cd	5.03±0.088h	0.66±0.003a	16.67±0.333ab	0.41±0.008b	40.39±1.618ef
Shahmiveh	638.01±18.2a	5.99±0.106fg	0.47±0.020b	16.33±0.333ab	0.35±0.003de	45.79±0.802de
Sebri	530.40±1.91cd	3.48±0.061i	0.06±0.008efg	15.33±0.333bcd	0.53±0.012a	29.32±0.774g

[a] Values represent the mean±Standard Errors (SE). Different letters in the same column indicate significant differences between treatments at P≤ 0.05.

The amount of rutin was between 0.04 (KS8, KS9) and 0.66 (mg g^{-1} FW) (A95) in different cultivars (Table 1).

Maghdori *et al*. (2015) reported a higher amount of chlorogenic acid and catechin in KS6 Asian pear fruit tissues that were grown under Tehran environment conditions. The highest amount of phenolic compounds among the two measured phenolic compounds belonged to chlorogenic acid. It is the most crucial derivative of cinnamic acid in fruits and is known as a disinfectant and radical modifier. These antifungal properties were also evaluated in vitro and the results were satisfying (Martínez *et al*., 2017).

Pyrus pashia and *Pyrus pyrifolia* are two important sources of chlorogenic acid and rutin (Tiwari *et al*., 2023). Rutin is a phenolic compound found in other plants, including peaches (Chang *et al*., 2000). In this study, the amount of rutin in the A95 promising genotype, which is one of the European pears, was higher than in the others. Due to the role of phenolic compounds in human health, cultivars and genotypes with higher amounts of these compounds are important. Also, in another experiment, several phenolic compounds such as chlorogenic acid and rutin were measured in some popular pear cultivars. The highest and lowest values of chlorogenic acid were 0.69±0.033 mg g^{-1} as well as 0.32±0.005 mg g^{-1} in `Graboid' and `Grabova' cultivars, respectively. Also, the highest and lowest routine values of 0.09±0.001 and 0.01±0.001 were reported in 'Patten' and 'Conference' cultivars (Liaudanskas *et al*., 2017). It has been reported that the amount of phenolic compounds may vary among Asian and European pears (Lin and Harnly, 2008).

According to Figure 3, for every 484.34 mg 100 g^{-1} FW of total phenol, the amount of rutin increased by 1 mg g^{-1} FW, which showed a linear relationship.

pH, TSS, TA, Color, and Firmness

The results showed that the amount of the Total Soluble Aolids (TSS) was significant among the studied cultivars, and the highest amount was observed in cultivar KS8 (17.33 ºBrix) while the lowest was observed in KS10 (13.67 ºBrix), KS11 (13.34 ºBrix), and KS14 (13.33 ºBrix) cultivars (Table 1). TA was 0.53% in `Sebri' and 0.17% in the KS13 cultivar. Also, according to the results, the amount of TSS/TA ratio was higher in KS13 (84.95%) and less in `Sebri' (29.32%) than in other cultivars (Table 1). Three European pear cultivars had lower pH levels than Asian cultivars. KS13 (5.72) had the highest pH among other cultivars. In general, firmness was higher in Asian pear cultivars than in European ones (Table 1). The highest amount of *L** was in KS7 (40.55) and the lowest in KS12 (14.26) as well as KS13 (14.78). The a* value was higher in KS9 (11.65), KS12 (11.70), and KS13 (10.39) than in the others, and b* was significantly higher in `Sebri' (29.25) than in the other cultivars (Table 2).

The acidity concentration and pH extraction were among the studied traits and had a great influence on the aroma, taste, as well as quality of edibility, and fruit storage. It was shown in an experiment that the amount of pH pear fruit was within the range of 3.94 -4.28. Also, the pH in fruit depends on the cultivar and the condition of the planting location (Ozturk *et al*., 2009). In this experiment, the pH was between 3.9 and 5.72. It has been reported that the Titratable Acidity (TA) of pear fruit was in the range of 0.5-0.21% in different parts of Turkey, which was consistent with the results of the present research (Ozturk *et al*., 2009). In another published report, the range of 0.1 to 46% was mentioned (Chen *et al*., 2007).

The aroma and taste of fruit are a combination of the amount and type of sugars, organic acids, and aromatic substances. The standard titratable acidity varies depending on the cultivar and season. Malic acid is the main acid in most pear cultivars at maturity (Colaric *et al*., 2007). Fruit skin color is one of the most important indicators of determining quality and maturity in pears. Previous experiments have shown a link between fruit ripening, L*, a*, and b* (Kawamura, 2000). Also, L*, a*, and b* are different in pear cultivars (Feng *et al*., 2023). In addition, fruit tissue firmness is one of the most important traits of quality and physiology that directly affect the texture of the fruit. In many fruits, softening is a programmed process to ripen fruit. Much of this process is a consequence of the chemical alteration of the cell wall, which eventually results in variations in the fruit tissue at the time of maturity (Chen *et al*., 2006; Ozturk *et al*., 2009; Wang and Arzani, 2019; Arzani, 2019). Our results showed that pear firmness in the commercial maturity stage was 8.66 to 4.06 (kg cm^{-2}). Overall, Asian pear showed more firmness than European pear cultivars (Arzani, 2019). In the present research, `Sebri', as one of the European pear cultivars, showed higher firmness within the studied cultivars.

In an experiment, the degree of fruit firmness in different pear genotypes was reported at 3.4 to 8 kg cm^{-2} (Tatari *et al*., 2020). In this research, we found that by increasing 484.34 mg 100 g^{-1} FW total phenol of a pear, and rutin increased by 1 mg g^{-1} FW.

Table 2. Fruit color L*, a*, b*, firmness, and pH of the studied pear cultivars.[a]

Cultivar	L*	a*	b*	Firmness (kg cm^{-2})	pH
KS6	21.16±0.88g	7.99±0.39bc	20.68±0.99d	5.5±0.288de	5.17±0.088b
KS7	40.55±0.44a	5.75±0.53c	25.97±0.52bc	6.16±0.166d	4.77±0.033bc
KS8	17.00±0.38h	6.36±0.16c	14.26±0.07e	8.66±0.333a	4.63±0.033c
KS9	24.16±0.13f	11.65±1.28a	20.98±0.17d	5.26±0.145e	4.83±0.033bc
KS10	40.32±0.07ab	7.02±0.28bc	26.72±0.49ab	7.4±0.264bc	5±0.057bc
KS11	38.19±0.35c	6.39±0.21c	23.78±0.68c	7.9±0.208abc	5.17±0.033b
KS12	14.26±0.52i	11.70±2.17a	13.10±0.46e	7.33±0.202c	4.58±0.346c
KS13	14.87±0.58i	10.39±0.63a	14.04±0.51e	8.23±0.145ab	5.72±0.044a
KS14	31.67±0.27e	7.59±0.82bc	25.94±0.57bc	7.43±0.296bc	4.92±0.044bc
A95	36.36±0.11d	6.96±0.26bc	26.31±0.27bc	4.06±0.166f	3.9±0.054d
Shahmiveh	38.19±0.62c	7.41±0.59bc	28.28±1.35ab	4.76±0.066ef	4.1±0.057d
Sebri	35.47±0.44d	6.60±0.72c	29.25±0.46a	7.33±0.145c	3.93±0.033d

[a] Values represent the mean±Standard Errors (SE). Different letters in the same column indicate significant differences between treatments at P≤ 0.05.

Also, by increasing the total phenol by 125.69 mg 100 g^{-1} FW, one ºBrix was increased in fruit TSS. It has been reported that the fruit TSS is an important indicator that is used for the proper time of harvest (Arzani *et al*., 2008). According to the reported results of the experiments, the Total Soluble Solids (TSS) in different cultivars of pears was 12.5-14 (Bexiga *et al*., 2017). Besides, TSS is one of the ways to control the quality of fruit, which is important in the grading of fruits in the agricultural industry. Also, the fruit TSS monitoring is a fast, easy, and cheap record used by the orchardist for considering as one of the good indicators for proper pear fruit harvest (Bexiga *et al*., 2017; Wang and Arzani 2019; Arzani, 2019).

In another study, TSS was measured in 9 pear genotypes and was reported to be 7-13% (Tatari *et al*., 2020). The ratio of TSS/TA is an indicator of fruit flavor. Natanz and Arbakhoj genotypes had the highest and lowest TSS/TA ratios with averages of 97.54 and 94.11, respectively (Rezaeirad *et al*., 2013).

Fruit Nutrients

Nitrogen content in KS8 and `Sebri' was 0.44 and 0.5 (mg 100 g^{-1} DW), respectively, and significantly higher than in other cultivars. The KS13 (0.18 mg 100 g^{-1} DW) cultivar had less N than other cultivars (Table 3). The highest phosphorus levels were observed in KS14 (0.24 mg 100 g^{-1} DW) and the lowest levels were in `Shahmiveh' as well as A95 promising genotype (0.14 and 0.16 mg 100 g^{-1} DW). Potassium in KS14 (1.15 mg 100 g^{-1} DW) and KS9 (1.16 mg 100 g^{-1} DW) was higher than in other cultivars and had the highest potassium among pears cultivars (Table 3). KS8 (0.42 mg 100 g^{-1} DW) showed the higher amount and `Shahmiveh' (0.04 mg/100g DW) had the minimum amount of calcium. In KS7 (0.15 mg 100 g^{-1} DW) and KS13 (0.13 mg 100 g^{-1} DW) Asian pears, the amount of magnesium was higher than in the other studied cultivars (Table 3). In the KS9 (100 mg kg^{-1} DW) cultivar, Fe was higher than in the other cultivars. `Shahmiveh' (29 mg kg^{-1} DW) and KS9 (25.67 mg kg^{-1} DW) had also less iron than other cultivars. The highest amount of Mn was found in cultivar KS9 (3.46 mg kg^{-1} DW). KS12 (11.27 mg kg^{-1} DW) had the highest amount of Zn while KS6 (7.26 mg kg^{-1} DW) had the lowest amount of Zn compared to the other cultivars. The Cu was also higher in KS12 (18.5 mg kg^{-1} DW) and lower in KS8 (8.5 mg kg^{-1} DW), while the highest B was observed in the KS12 cultivar (96.53 mg kg^{-1} DW) (Table 4).

Principal Component Analysis (PCA) and Heat Map

In this research, PCA showed two groups of pears: Asian pear (*Pyrus serotina* Rehd.) cultivars in one group and European pear (*Pyrus communis* L.) and A95 promising pear genotype in another (Figure 1). The heat map shows a positive (light color) and negative (dark color) relationship between all the measured traits in the study of the two groups. There is a positive relationship between total phenol and TSS, firmness, calcium, TA and Na, pH and TSS/TA, chlorogenic acid, K, and Ca (Figure 2).

Nutrients play an important role in increasing the quantity, quality, and shelf life and reducing fruit physiological disorders in European as well as Asian pears (Wang and Arzani, 2019; Arzani, 2019). The proper concentration of nitrogen can improve the color, taste, and size of the fruit (Brunetto *et al*., 2015). Potassium affects fruit size, firmness, color, acidity, and TSS of fruit juice and its aroma. The imbalance in the K:Ca ratio in the plant could cause the cork spot in the 'D Anjou' cultivar (Brunetto *et al*., 2015; Wang and Arzani, 2019). Many physiological

Table 3. Fruit macronutrient composition of different pear cultivars (mg 100 g^{-1} DW).[a]

Cultivar	Mg	Ca	K	P	N
KS6	0.06±0.01bc	0.21±0.02bcd	1.13±0.008ab	0.23±0.02ab	0.28±0.008bc
KS7	0.15±0.01a	0.19±0.03bcde	1.07±0.008c	0.19±0.01abc	0.34±0.02b
KS8	0.12±0.02ab	0.42±0.04a	1.13±0.01ab	0.19±0.01abc	0.44±0.03a
KS9	0.06±0.005c	0.22±0.04bc	1.16±0.01a	0.22±0.01ab	0.26±0.02c
KS10	0.06±0.01bc	0.16±0.03bcdef	1.09±0.005bc	0.19±0.02abc	0.29±0.008bc
KS11	0.04±0.008c	0.21±0.05bcd	1.13±0.01ab	0.19±0.01abc	0.24±0.02cd
KS12	0.03±0.007c	0.07±0.01def	1.14±0.008ab	0.21±0.02abc	0.3±0.01bc
KS13	0.13±0.01a	0.25±0.06b	1.13±0.008ab	0.23±0.02ab	0.18±0.008d
KS14	0.04±0.01c	0.06±0.01def	1.15±0.01a	0.24±0.01a	0.30±0.01bc
A95	0.03±0.006c	0.08±0.01cdef	1.06±0.03c	0.16±0.01bc	0.30±0.01bc
Shahmiveh	0.03±0.008c	0.04±0.01f	1.07±0.008c	0.14±0.008c	0.29±0.02bc
Sebri	0.03±0.008c	0.05±0.01ef	1.03±0.01c	0.22±0.02ab	0.5±0.02a

[a] Values represent the mean±Standard Errors (SE). Different letters in the same column indicate significant differences between treatments at P≤ 0.05.

Table 4. Fruit micronutrient composition of different pear cultivars (mg kg^{-1} DW).[a]

Cultivar	B	Cu	Zn	Fe	Mn
KS6	74.67±1.76cd	12±0.28cd	7.26±0.21f	35.57±1.68g	2.8±0.11b
KS7	56.67±0.88g	17.83±0.72a	10.06±0.47cd	51.77±1.47cd	1.67±0.17c
KS8	78±1.15bc	8.5±0.50f	8.33±0.32ef	43.97±0.84f	2.8±0.20b
KS9	52.7±1.56g	11.67±0.66cd	8.43±0.12e	100±1.53a	3.46±0.27a
KS10	73.4±0.83de	10±0.57def	8.9±0.11e	48.9±1.16def	1.7±0.15c
KS11	73.33±0.88de	16.5±0.28ab	8.13±0.34ef	56±1.53c	1.83±0.12c
KS12	96.53±0.74a	18.5±0.28a	11.27±0.21a	56.33±0.88c	2.26±0.23bc
KS13	68.33±1.36f	15.67±0.88b	11.13±0.13abc	50.66±1.20de	2.2±0.05bc
KS14	70.33±0.88ef	12.43±0.34c	10.5±0.50abcd	46.33±1.45ef	2.23±0.14bc
A95	56.67±0.66g	9.1±0.30ef	11.2±0.26ab	25.67±1.76h	1.7±0.15c
Shahmiveh	78.5±0.76bc	10.33±0.33def	10.13±0.08bcd	29±0.57h	2.3±0.05bc
Sebri	79±0.57b	11±0.57cde	10.03±0.08d	94.67±1.20b	2.2±0.15bc

[a] Values represent the mean±Standard Errors (SE). Different letters in the same column indicate significant differences between treatments at P≤ 0.05.

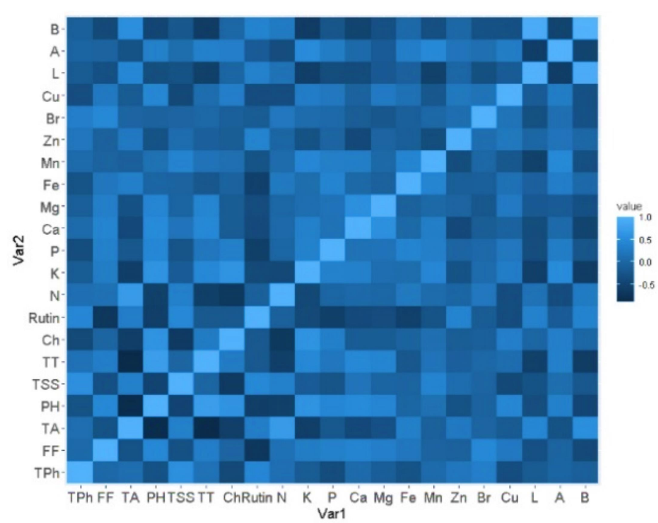

Figure 1. Heat map of Spearman's correlations between chemical traits of the studied Asian and European pear cultivars.

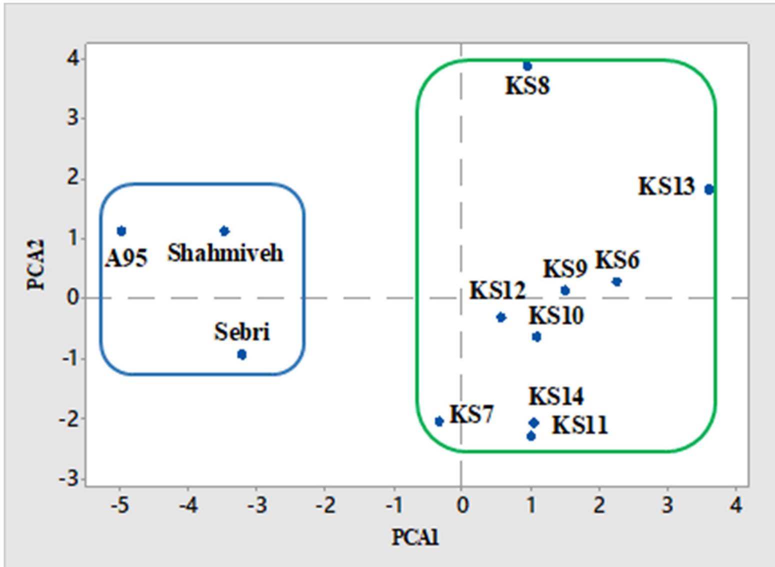

Figure 2. Principal component analysis of the studied Asian and European pear cultivars based on chemical traits. Each point represents one genotype and the surrounding green and blue lines are drawn to indicate the division of cultivars and genotypes into two large groups of the Asian and European pears, respectively.

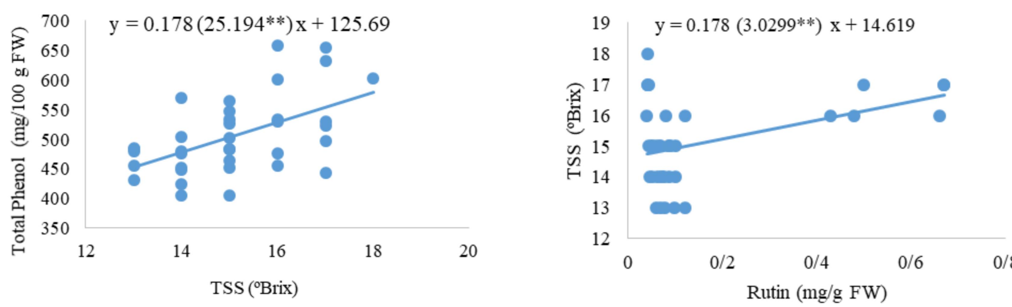

Figure 3. Linear regression between total phenol and rutin, total phenol and TSS, firmness and Ca, and TSS and rutin of the studied European, and Asian pear genotypes. The Pearson correlation coefficient between total phenol and rutin was 0.413*, total phenol and TSS 0.532*, firmness and Ca 0.369*, and TSS and rutin 0.426**. In correlations, * and ** were used to show the significance at $P\leq 0.05$ and $P\leq 0.01$, respectively.

disorders in pear fruits are closely related to calcium deficiency whose prevention requires adequate application of calcium fertilizers (Duan *et al*., 2019; Wang and Arzani, 2019; Arzani, 2019). In this study, K was found to be the most abundant nutrient (Table 3). Also, previously published research results showed the amount of this element was higher than the other nutrients (Chen *et al*., 2007). As reported, the presence of K under stress enhanced the function of photosystem II, the biosynthesis of chlorophyll, and the antioxidant enzyme activity (Shahid *et al*., 2019). Besides, Fe deficiency causes disturbances in the photosynthetic system, a decrease in chlorophyll content, and leads to the reduction of crop yield. Also, iron deficiency causes photosynthetic system abnormalities and diminished chlorophyll content (Pestana *et al*., 2001). The amount of iron in pear fruit is low and has been reported between 20 and 35 mg Fe kg^{-1} DW (Brunetto *et al*., 2015). In our study, the amount of iron varied from 29 to 100 mg kg^{-1} DW (Table 4). Manganese deficiency, which is more likely to occur under alkaline conditions, can markedly reduce the pear yield (Brunetto *et al*., 2015). Zinc deficiency in the soil disrupts the growth of the plant and the fruit set conditions, accordingly, the fruits get miniaturized, and the yield decreases (Wójcik and Popińska, 2009). In another experiment, the amount of zinc among pears was reported from 14 to 27 (mg kg^{-1} dry weight) (Arzani *et al*., 2008). Also, boron plays an important role in pollen tube growth, pollen germination, fruit size, sourness, and early ripening (Wojcik and Wojcik, 2003).

In this research, we found a linear relationship between total phenol and rutin, total phenol and TSS, firmness, and Ca, and TSS and rutin (Figure 3). Due to the importance of Ca in the cell wall structure, which led to the increase in fruit storage and shelf life, it was observed that for the increase of 5.9249 kg cm^{-2} of fruit firmness, one mg 100 g^{-1} DW of Ca increased (Figure 3). Wang and Arzani (2019) reported that Ca deficiency in the pear fruit also causes disorders such as cork spot (bitter pit). Also, calcium treatment decreased the peak of ethylene production and decreased respiration rate during fruit storage (Han *et al*., 2021).

We found in another linear relationship that by increasing 1 mg 100 g^{-1} FW of total phenol in the pear, 125.69 TSS (ºBrix) increased. It was also observed that for every increase of 14.61 TSS, the amount of rutin increased by 1 mg g^{-1} FW (Figure3).

CONCLUSIONS

In general, the results showed that the amounts of nutrients and biochemistry measurements in this study were different across pear cultivars. Important factors, including mineral compounds and sugars, affect the quality of pears. Identifying promising genotypes of native pears in the world is important. Recently, A95 as a promising pear genotype has been identified through the breeding program at Tarbiat Modares University, Iran. Also, `Shahmiveh' and `Sebri' are native to Iran, belonging to the European pear group (*Pyrus communis* L.), and have been compared to Asian pear cultivars in terms of chemical characteristics. It is necessary to examine indigenous cultivars that also have commercial properties. The genotype of A95 could be one of them. In addition to genetics, factors such as climate, region, and orchard management also affect fruit quality. The highest amount of phenol was found in the `Shahmiveh' cultivar, which is one of the important native cultivars of Iran. Chlorogenic acid and rutin were relatively high in KS14 and A95. However, in previous experiments, the highest amounts of TA, TSS, and pH were observed in KS8, `Sebri', and KS13, respectively. Finally, pears can be considered important fruits in terms of minerals and phenolic compounds, and their role in human health is important. Our experiment, which was conducted among 12 European and Asian pear genotypes, will help us choose the best pear genotype in terms of the highest phenolic content and nutrients, both for fresh consumption and in the juice industry.

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ویژگی‌های بیوشیمیایی و تغذیه‌ای میوه برخی از گلابی‌های آسیایی و اروپایی (*Pyrus* spp.) کشت‌شده در شرایط آب و هوایی تهران

سمیه کدخدایی، و کاظم ارزانی

چکیده

گلابی یکی از مهمترین میوه‌های دانه‌دار در بازار جهانی میوه با ارزش غذایی بالا است. این مطالعه به منظور تعیین ترکیبات فنلی و برخی خواص شیمیایی گوشت و پوست میوه ۱۲ گلابی آسیایی و اروپایی انجام شد. اسید کلروژنیک و روتین به عنوان ترکیبات فنلی مهم در پوست میوه یافت شدند که با استفاده از HPLC اندازه‌گیری شدند. نتایج نشان داد که اسیدیته قابل تیتراسیون میوه (TA, ٪۰.۰۵۳-۰.۱۷)، مواد کل جامد محلول ،(۳۳.۱۷-۳۳.۱۳ درجه بریکس ,TSS)، سفتی (۷.۱-۷۵.۲کیلوگرم بر سانتی‌متر مربع) و پارامترهای رنگ افزایش یافت. بالاترین مقدار *L در (40.55) KS7 مشاهده شد، در حالی که کمترین مقدار در (14.26) KS12 و (14.78) KS13 بود. علاوه بر این، این مطالعه میزان مواد مغذی و فنل کل نمونه‌های میوه را ارزیابی کرد. رقم «شاه‌میوه» بالاترین میزان فنل کل (٦٣٨.٠١ میلی‌گرم در ۱۰۰ گرم وزن تازه) را نشان داد، در حالی که رقم KS7 کمترین میزان (٤٢٠.٠٢ میلی‌گرم در ۱۰۰ گرم وزن تازه) را داشت. پتاسیم فراوان‌ترین ماده مغذی (۱.۱٦ میلی‌گرم در ۱۰۰ گرم وزن خشک) بود و پس از آن نیتروژن و کلسیم قرار داشتند. با افزایش فنل کل، مقدار روتین نیز افزایش یافت. تجزیه و تحلیل مؤلفه‌های اصلی تجزیه و تحلیل مولفه‌های اصلی (PCA) تمام داده‌ها نشان داد که ارقام گلابی اروپایی و آسیایی دسته‌بندی شده و در دو گروه مجزا قرار گرفتند. در نتیجه، ارقام و ژنوتیپ‌های مختلف گلابی اروپایی و آسیایی مورد مطالعه از نظر اکثر صفات بیوشیمیایی مورد مطالعه متفاوت بودند و روابط معنی‌داری بین برخی از صفات مشاهده شد. علاوه بر این، نتایج به‌دست‌آمده به انتخاب بهترین ارقام یا ژنوتیپ‌های گلابی از نظر بالاترین میزان فنول و مواد مغذی، هم برای مصرف تازه و هم در صنعت آبمیوه گیری، کمک می کند.