

# 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 flesh and peel of 12 Asian and European pears. Chlorogenic acid and rutin were found the important phenolic compounds in the 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<sup>2</sup>), 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 (638.01 mg/100 g FW), while the KS7 cultivar had the lowest (420.02 mg/100 g FW). Potassium was the most abundant nutrient (1.16 mg/100g 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 European and Asian pear cultivars were categorized and placed into two distinct groups. In conclusion, the different European and Asian pear 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:** Pear. Rutin. Chlorogenic acid. Macronutrients. Micronutrients. Total phenol.

## Introduction

*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 & 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

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29 countries such as Korea, China, and Japan in East Asia. They have been cultivated in various parts  
30 of Asia for over 3,000 years. Currently, this species is grown commercially in more than 50  
31 countries under temperate climate regions. At least 22 early *Pyrus* species have been identified, all  
32 of which are native to Asia, Europe, and the mountainous regions of North America (Bell et al.;  
33 1996). This crop is cultivated mainly due to its commercial value and desirable fruit taste (Arzani,  
34 2002; Wang & Arzani, 2019; Arzani, 2019; Arzani, 2021).

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

54 Phenolic compounds are chemicals found in most plant tissues of fruits and vegetables. Also,  
55 chlorogenic acid (5-Ocaffeoylquinic acid) is a secondary metabolite of phenolic acids and is found  
56 in many plants it has an obese anti-obesity mechanism (He et al., 2021). Chlorogenic acid (CGA)  
57 is a natural product that has medicinal properties such as anti-cancer, light protection, antioxidant,  
58 anti-inflammatory, hypoglycemic, and hypoglycemic effects. After absorption, CGA is further  
59 metabolized into sulfate metabolites, glucuronic acid, and glycosides (Sanchez et al., 2017;

60 Nwafor et al.,2022). Rutin is an important flavonoid also known as vitamin P and quercetin-3-o-  
61 rotinoside and has a protective role against liver and gastrointestinal problems (Hosseinzadeh &  
62 Nassiri-Asl, 2014), with anti-inflammatory, anti-tumor, antioxidant, and neuroprotective effects (  
63 Muvhulawa et al., 2022; Song et al., 2014). Recently, eight phenolic compounds have been  
64 identified in the fruit peel of Asian pear (Lee et al., 2011). Pear fruit peel has far higher and more  
65 varied phenolic contents than its flesh (Chen et al., 2006). In addition, it is highly recommended  
66 that natural products are eaten with their peels because if they reduce oxidation, they will be useful  
67 for well-being and disease reduction (Nazir et al., 2020). Previous studies on pears have shown  
68 that they contain minerals (Brunetto et al., 2015; Ozturk et al., 2009), and pear fruit is rich in macro  
69 and micro-nutrients (Nazir et al., 2020). Mineral nutrients play an important role in plant growth  
70 and metabolic functions and are heavily involved in maintaining the health and proper functioning  
71 of an organism (Tewari et al., 2021). There are human, plant, and animal diseases associated with  
72 micronutrient deficiencies. Also, efforts should be made to produce aggregating microelements of  
73 genotypes with an overexpression approach (bio-genetic enhancement) (Izydorczyk et al., 2021).  
74 'Shahmiveh' and 'Sebri' are native commercial European pears cultivars to Iran, in addition A95  
75 promising chance seedling genotype showed superiority in some qualitative fruit characteristics  
76 (Wang & Arzani, 2019; Kadkhodaei et al., 2021; Yadegari & Arzani, 2023). The objective of this  
77 research was to explore the phenolic and biochemical compounds of 'Shahmiveh', 'Sebri' and  
78 A95 promising genotype in compare with some commercial Asian pear cultivars that grown under  
79 Tehran, Iran environmental conditions.

80

### 81 **Materials and methods**

82 In this experiment, 9 Asian pear cultivars including KS6, KS7, KS8, KS9, KS10, KS11, KS12,  
83 KS13, and KS14 (Arzani, 2002), as well as 3 European pear cultivars, 'Shahmiveh', 'Sebri', and  
84 A95 promising genotypes (Najafzadeh, 2015; Wang and Arzani, 2019), were used. Trees were  
85 planted under Tehran environmental conditions at Tarbiat Modares University (TMU) Asian pear  
86 collection orchard with the geographic locations of latitude 35° 41' 39.80" N, longitude 51° 25'  
87 17.44" E. Besides, fruit were harvested at the commercial maturity harvest index (Arzani, 2019)  
88 mainly based on the fruit background color, flesh firmness, and total soluble solids (TSS) for  
89 further assessments.

90

**91 Determination of total phenolic content**

92 **Fruit samples (fruit with the peel)** were freeze-dried for 48 hours and then powdered. For **the**  
93 extraction of phenolic compounds, **2 g. of powdered pulp** was used according to the method  
94 described previously by Lister et al (1994) with a slight modification. Then, 5 ml of extraction  
95 solvent consisting of 85% methanol and 15% acetic acid was added. The samples were placed at  
96 4° C for 24 h and then centrifuged at 10,000 rpm for 10 min. About 1 ml of the supernatant of each  
97 sample was filtered using a 0.45 µm syringe filter.

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

101

**102 Determination of the phenolic content and components**

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

111

**112 Fruit sample preparation for TSS, TA, pH, firmness, and color**

113 To determine total soluble solids (TSS), a few drops of **fruit flesh** extract were poured onto the  
114 refractometer. For this purpose, Japan's portable refractometer Model 9703 was used (Bexiga et  
115 al., 2017). For titratable acidity (TA) and pH of fruit extract, **10 g** of smashed **fruit flesh** was used,  
116 with the addition of about **30 ml** of distilled water. The extract was centrifuged at 50 °C for 30 min  
117 at 4000 rpm. To determine the TA with 0.1 normal solutions, it was titrated to reach pH 8.3 (pH  
118 meter Consort- model C860), after which the acidity was calculated based on a milligram of malic  
119 acid per 100 g of fruit tissue. To measure the flesh firmness of the fruit tissue, after removing a  
120 thin layer of fruit peel, an 8 mm diameter probe by penetrometer (Wagner) was used and fruit

121 firmness was measured in kg/cm<sup>2</sup>. The pear fruit peel color was measured via the Lutron RGB-  
122 1002 color analyzer and converted to L\* (lightness), a\* (green to red), and, b\* (blue to yellow).

123

#### 124 **Extraction to measure nutrients**

125 Initially, the fruit samples (fruit with the peel) were washed with tap water, followed by 0.1 M  
126 hydrochloric acid (HCl), and then rinsed again with distilled water. The sample was dried in an  
127 oven at 70 °C and then powdered. The 0.5 mm sieve mesh was used for collecting the clean  
128 powdered samples. Extraction steps were performed as follows. Briefly, 2 g of the dried sample  
129 was heated in an oven at 550 °C for 4 hours; the ash was slightly moistened with distilled water,  
130 and 10 ml of 2 M HCl was added. The final extract was delivered in a volume of 100 ml (Waling  
131 et al., 1989). Distillation and sample titration were used to measure the percentage of plant nitrogen  
132 (Waling et al., 1989). Phosphorus was measured using a colorimetric (Vanadate-Molybdate)  
133 method. The absorbance was measured via a spectrophotometer at 470 nm (Chapman & Pratt,  
134 1962). Potassium and sodium were measured by atomic emission spectrometry.

135 The absorbance was read by a flame photometer with 766.5 nm for K and 589 nm for N (Waling  
136 et al., 1989) The Azomethine colorimetric method was employed to measure the amount of boron  
137 and the spectrophotometer device was used at 430 nm (31). An atomic absorption device was  
138 utilized to measure the percentage of magnesium (285.2 nm) and calcium (422.7 nm) in the plant  
139 (Waling et al., 1989). Measurement of microminerals (iron-manganese-zinc and copper) was  
140 performed by atomic absorption spectrometry (A.A.S) method. Measurement of the resulting  
141 extraction was carried out by dry burning and the use of HCl. The absorption rate of Fe, Mg, Zn,  
142 and Cu was measured at 248.3, 289.5, 213.9, and 324.7 nm, respectively (Elmer & Conn, 1982).

143

#### 144 **Statistical Analysis**

145 The obtained data were initially checked for normality and analyzed using SAS (Ver. 9.3, SAS  
146 Institute, Cary, NC). The results were statistically evaluated by analysis of variance (ANOVA)  
147 and expressed as mean ± standard error (SE). Biochemical data for principal component analysis  
148 (PCA) and cluster analysis were used. PCA and cluster analysis were performed using Minitab  
149 software (Ver. 17). For the Heat map, R 3.5.3 software was used.

150

151

152

153 **Results and discussion**154 **Total Phenol**

155 The highest total phenol amount was observed in the 'Shahmiveh' cultivar and the lowest in KS7  
156 which were 638.01 and 420.02 (mg/100 g FW), respectively. Based on the results, the total phenol  
157 amount in different cultivars and the studied genotype showed significant differences (Table 1).  
158 The differences in the phenolic composition of different cultivars confirm the genetic role in the  
159 synthesis of phenolic compounds since the amount of polyphenols is affected by genotype,  
160 rootstock, and climatic conditions (Lin & Harnly, 2008; Manila et al., 2011; Maleki Asayesh et  
161 al., 2023). Phenolic compounds may impair callus formation by affecting cell division,  
162 development, and differentiation (Bennett & Wallsgrove, 1994). The total phenolic compound in  
163 the fruit tissue of the KS13 was higher than KS6 and KS9 Asian pear cultivars (Maghdori et al.,  
164 2015). In another study performed on several Australian pear cultivars, the highest amount of total  
165 phenol was observed in 'Beurre Bosc' ( $3.14 \pm 0.02$  a mg GAE/g) and the lowest in 'Winter Nelis'  
166 European pear ( $1.89 \pm 0.03$  a mg GAE/g) (Wang et al., 2021).

167

168 **Phenolic compounds**

169 The minimum amount of chlorogenic acid was observed in 'Sebri' and KS8 which were 3.48 and  
170 3.55 (mg/g FW), respectively, while its maximum was obtained in KS14 and was 9.48 (mg/g FW).  
171 The amount of Rutin was between 0.04 (KS8, KS9) and 0.66 (mg/g FW) (A95) in different  
172 cultivars (Table 1).

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

179 *Pyrus pashia* and *Pyrus pyrifolia* are two important sources of chlorogenic acid and rutin (Tiwari  
180 et al., 2023). Rutin is a phenolic compound found in other plants, including peaches (Chang et al.,  
181 2000). In this study, the amount of rutin in the A95 promising genotype, which is one of the  
182 European pears, was higher than in the others. Due to the role of phenolic compounds in human  
183 health, cultivars and genotypes with higher amounts of these compounds are important. Also, in

184 another experiment, several phenolic compounds such as chlorogenic acid and rutin were  
185 measured in some popular pear cultivars. The highest and lowest values of chlorogenic acid were  
186  $0.69 \pm 0.033$  mg/g as well as  $0.32 \pm 0.005$  mg/g in 'Graboid' and 'Grabova' cultivars, respectively.  
187 Also, the highest and lowest routine values of  $0.09 \pm 0.001$  and  $0.01 \pm 0.001$  were reported in  
188 'Patten' and 'Conference' cultivars (Liudanskas et al., 2017). **It has been reported that the amount**  
189 **of phenolic compounds may vary among Asian and European pears (Lin & Harnly, 2008).**

190 According to Fig 3, for every 484.34 (mg/100 g FW) of total phenol, the amount of Rutin  
191 increased by 1 (mg/g FW), **which showed** a linear relationship.

192

### 193 **PH, TSS, TA, color, and firmness**

194 The results showed that the amount of the total soluble solids (TSS) was significant among the  
195 studied cultivars and the highest amount was observed in cultivar KS8 (17.33 °Brix) while the  
196 lowest was observed in KS10 (13.67 °Brix), KS11 (13.34 °Brix), and KS14 (13.33 °Brix) **cultivars**  
197 (Table 1). TA was 0.53 % in 'Sebri' and 0.17% in the KS13 cultivar. Also, according to the results,  
198 the amount of TSS/TA ratio was higher in KS13 (84.95 %) and less in 'Sebri' (29.32%) than in  
199 other cultivars (Table 1). Three European pear cultivars had lower pH levels than Asian cultivars.  
200 KS13 (5.72) had the highest pH among other cultivars. In general, firmness was higher in Asian  
201 **pear** cultivars than in European ones (Table 1). The highest amount of  $L^*$  was in KS7 (40.55) and  
202 the lowest was in KS12 (14.26) as well as KS13 (14.78). **The  $a^*$  value** was higher in KS9 (11.65),  
203 KS12 (11.70), and KS13 (10.39) than in **the other studied cultivars**, and  $b^*$  was significantly higher  
204 in 'Sebri' (29.25) cultivars than in the other cultivars (Table 2).

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

213 The **aroma** and taste of **fruit** are a combination of the amount and type of sugars, organic acids,  
214 and aromatic substances. The standard titratable acidity varies depending on the cultivar and

215 season. Malic acid is the main acid in most pear cultivars at maturity (Colaric et al., 2007). Fruit  
216 skin color is one of the most important indicators of determining quality and maturity in pears.  
217 Previous experiments have shown a link between fruit ripening,  $L^*$ ,  $a^*$ , and  $b^*$  (Kawamura, 2000).  
218 Also,  $L^*$ ,  $a^*$ , and  $b^*$  are different in pear cultivars (Feng et al., 2023). In addition, fruit tissue  
219 firmness is one of the most important traits of quality and physiology that directly affects the  
220 texture of the fruit. In many fruits, softening is a programmed process to ripen fruit. Much of this  
221 process is a consequence of the chemical alteration of the cell wall, which eventually results in  
222 variations in the fruit tissue at the time of maturity (Chen et al., 2006; Ozturk et al., 2009; Wang  
223 & Arzani, 2019; Arzani, 2019). Our results showed that pear firmness in the commercial maturity  
224 stage was 8.66 to 4.06 (kg/cm<sup>2</sup>). Overall, Asian pear fruits showed more firmness than European  
225 pear cultivars (Arzani, 2019). In the present research, 'Sebri' as one of the European pear cultivars  
226 showed higher firmness within the studied Asian and European pear cultivars.

227 In an experiment, the degree of fruit firmness in different pear genotypes was reported at 3.4 to  
228 8 kg/cm<sup>2</sup> (Tatari et al., 2020). In this research, we found that by increasing 484.34 mg/100 g FW  
229 total Phenol of a pear, and rutin increased by 1 mg/g FW.

230 Also, by increasing the total phenol by 125.69 mg/100 g FW, one °Brix was increased in fruit  
231 TSS. It has been reported that the fruit TSS is an important indicator that is used for the proper  
232 time of harvest (Arzani et al., 2008). According to the reported results of the experiments, the total  
233 soluble solids (TSS) in different cultivars of pears was 12.5-14 (Bexiga et al., 2017). Besides, TSS  
234 is one of the ways to control the quality of fruit, which is important in the grading of fruits in the  
235 agricultural industry. Also, the fruit TSS monitoring is a fast and easy as well as cheap record used  
236 by the orchardist for considering as one of the good indicators for proper pear fruit harvest (Bexiga  
237 et al., 2017; Wang & Arzani 2019; Arzani, 2019).

238 In research, TSS was measured in 9 pear genotypes and was reported to be 7-13% (Tatari et al.,  
239 2020). The ratio of TSS/TA is an indicator of fruit flavor. Natanz and Arbakhøj genotypes had the  
240 highest and lowest TSS/TA ratios with averages of 97.54 and 94.11 respectively (Rezaeirad et al.,  
241 2013).

#### 242 243 **Fruit nutrients**

244 Nitrogen content in KS8 and 'Sebri' was 0.44 and 0.5 (mg/100g DW), respectively, and  
245 significantly higher than in other cultivars. The KS13 (0.18 mg/100g DW) cultivar had less N than



246 other cultivars (Table 3). The highest phosphorus levels were observed in KS14 (0.24 mg/100g  
247 DW) and the lowest levels were in 'Shahmiveh' as well as the A95 promising genotype (0.14 and  
248 0.16 mg/100g DW). Potassium in KS14 (1.15 mg/100 g DW) and KS9 (1.16 mg/100g DW) was  
249 higher than in other cultivars and had the highest potassium among pears cultivars (Table 3). KS8  
250 (0.42 mg/100g DW) showed the higher amount and 'Shahmiveh' (0.04 mg/100g DW) had the  
251 minimum amount of calcium. In KS7 (0.15 mg/100 g DW) and KS13 (0.13 mg/100 g DW) Asian  
252 pears, the amount of magnesium was higher than in the other studied cultivars (Table 3). In the  
253 KS9 (100 mg/kg DW) cultivar, Fe was higher than in the other cultivars. 'Shahmiveh' (29 mg/kg  
254 DW) and KS9 (25.67 mg/kg DW) had also less iron than other cultivars. The highest amount of  
255 Mn was found in cultivar KS9 (3.46 mg/kg DW). KS12 (11.27 mg/kg DW) had the highest amount  
256 of Zn while KS6 (7.26 mg/kg DW) had the lowest amount of Zn compared to other cultivars. The  
257 Cu was also higher in KS12 (18.5 mg/kg DW) and lower in KS8 (8.5 mg/kg DW), while the highest  
258 B was observed in the KS12 cultivar (96.53 mg/kg DW) (Table 4).

259

### 260 **Principal component analysis (PCA) and heat map**

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

267 Nutrients play an important role in increasing the quantity, quality, and shelf life and reducing  
268 fruit physiological disorders in European as well as Asian pears (Wang & Arzani, 2019; Arzani,  
269 2019). The proper concentration of nitrogen can improve the color, taste, and size of the fruit  
270 (Brunetto et al., 2015). Potassium affects fruit size, firmness, color, acidity, and TSS of fruit juice  
271 and its aroma. The imbalance in the K to Ca ratio in the plant could cause the cork spot in the 'D  
272 Anjou' cultivar (Brunetto et al., 2015; Wang & Arzani, 2019). Many physiological disorders in  
273 pear fruits are closely related to calcium deficiency whose prevention requires adequate  
274 application of calcium fertilizers (Duan et al., 2019; Wang & Arzani, 2019; Arzani, 2019). In this  
275 study, K was found to be the most abundant nutrient (Table 3). Also, previously published research  
276 results showed the amount of this element was higher than other nutrients (Chen et al., 2007). As

277 reported the presence of K under stress enhanced the function of photosystem II, the biosynthesis  
278 of chlorophyll, and the antioxidant enzyme activity (Shahid et al., 2019). Besides, Fe deficiency  
279 causes disturbances in the photosynthetic system, a decrease in chlorophyll content, and leads to  
280 the reduction of crop yield. Also, iron deficiency causes photosynthetic system abnormalities and  
281 diminished chlorophyll content (Pestana et al., 2001). The amount of iron in pear fruit is low and  
282 has been reported between 20 and 35 mg Fe /kg DW (Brunetto et al., 2015). In our study, the  
283 amount of iron varied from 29 to 100 mg/kg DW (Table 4). Manganese deficiency, which is more  
284 likely to occur under alkaline conditions, can markedly reduce the pear yield (Brunetto et al.,  
285 2015). Zinc deficiency in the soil disrupts the growth of the plant and the fruit set conditions,  
286 accordingly, the fruits get miniaturized, and the yield decreases (Wójcik & Popińska, 2009). In  
287 another experiment, the amount of zinc among pears was reported from 14 to 27 (mg. kg<sup>-1</sup> dry  
288 weight) (Arzani et al., 2008). Also, Boron plays an important role in pollen tube growth, pollen  
289 germination, fruit size, sourness, and early ripening (Wojcik & Wojcik, 2003).

290 In this research, we found a linear relationship between total phenol and rutin, total phenol and  
291 TSS, firmness, and Ca, and TSS and rutin (Fig. 3). Due to the importance of Ca in the cell wall  
292 structure which led to the increase in fruit storage and shelf life, it was observed that for the  
293 increase of 5.9249 (kg/cm<sup>2</sup>) of fruit firmness, one (mg/100g DW) of Ca increased (Fig. 3). It has  
294 been reported that (Wang & Arzani, 2019) Ca deficiency in the pear fruit also causes disorders  
295 such as cork spot (bitter pit). Also, calcium treatment decreased the peak of ethylene production  
296 and decreased respiration rate during fruit storage (Han et al., 2021).

297 We found in another linear relationship that by increasing one (mg/100 g FW) of total phenol in  
298 the pear, 125.69 TSS (°Brix) increased. It was also observed that for every increase of 14.61 TSS,  
299 the amount of rutin increased by 1 (mg/g FW) (Fig.3).

300

### 301 Conclusions

302 In general, the results showed that the amounts of nutrients and biochemistry measurements in  
303 this study were different across pear cultivars. Important factors including mineral compounds and  
304 sugars affect the quality of pears. Identifying promising genotypes of native pears in the world is  
305 important. Recently, A95 as a promising pear genotype has been identified through the breeding  
306 program at Tarbiat Modares University, Iran. Also, 'Shahmiveh' and 'Sebri' are native to Iran  
307 belonging to the European pear group (*Pyrus communis* L.), and have been compared to Asian

308 pear cultivars in terms of chemical characteristics. It is necessary to examine indigenous cultivars  
309 that also have commercial properties. The genotype of A95 could be one of them. In addition to  
310 genetics, factors such as climate, region, and orchard management also affect fruit quality. The  
311 highest amount of phenol was found in the 'Shahmiveh' cultivar, which is one of the important  
312 native cultivars of Iran. Chlorogenic acid and rutin were relatively high in KS14 and A95.  
313 However, in previous experiments, the highest amounts of TA, TSS, and PH were observed in  
314 KS8, 'Sebri', and KS13, respectively. Finally, pears can be considered important fruits in terms of  
315 minerals and phenolic compounds, and their role in human health is important. The above  
316 experiment, which was conducted among 12 European and Asian pear genotypes, will help us  
317 choose the best pear genotype in terms of the highest phenolic content and nutrients, both for fresh  
318 consumption and in the juice industry.

319

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325

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525 **Table 1.** Total Phenole, Chlorogenic acid, Rutin, TSS, TA, and TSS/TA of pear cultivars.

Cultivar	Total Phenol (mg/100 g FW)	Chlorogenic acid (mg/g FW)	Rutin (mg/g FW)	TSS °Brix	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

526 Values represent the mean ± standard errors (SE). Different letters in the same column indicate significant differences  
527 between treatments at  $P \leq 0.05$ .

528

529 **Table 2.** Fruit color  $L^*$ ,  $a^*$ ,  $b^*$ , firmness, and pH of the studied pear cultivars.

Cultivar	$L^*$	$a^*$	$b^*$	Firmness (kg/cm <sup>2</sup> )	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

530 Values represent the mean ± standard errors (SE). Different letters in the same column indicate significant differences  
531 between treatments at  $P \leq 0.05$ .

532

533

534 **Table 3.** Fruit macronutrient composition of different pear cultivars (mg/100g DW).

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

535 Values represent the mean ± standard errors (SE). Different letters in the same column indicate significant differences  
 536 between treatments at  $P \leq 0.05$ .

537

538 **Table 4.** Fruit micronutrient composition of different pear cultivars (mg/kg DW)..

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

539 Values represent the mean ± standard errors (SE). Different letters in the same column indicate significant differences  
 540 between treatments at  $P \leq 0.05$ .

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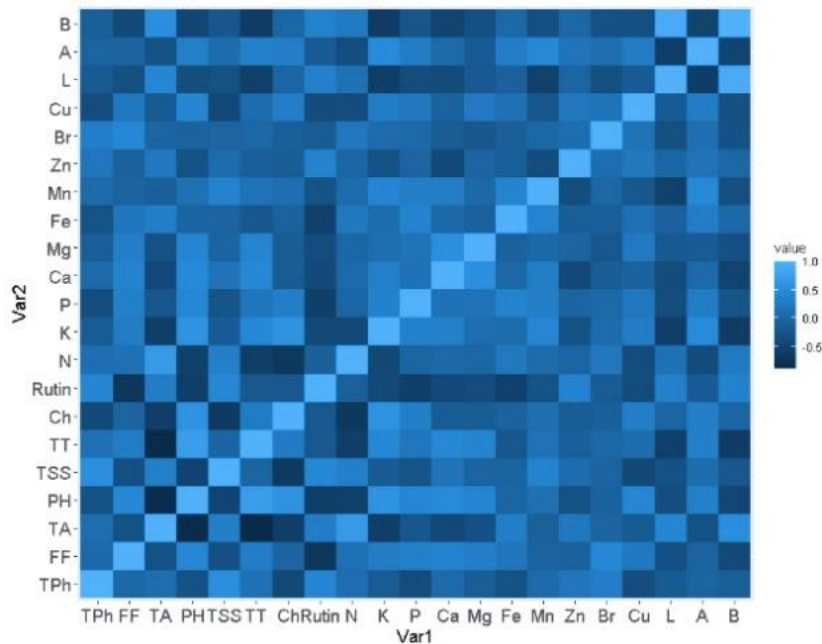
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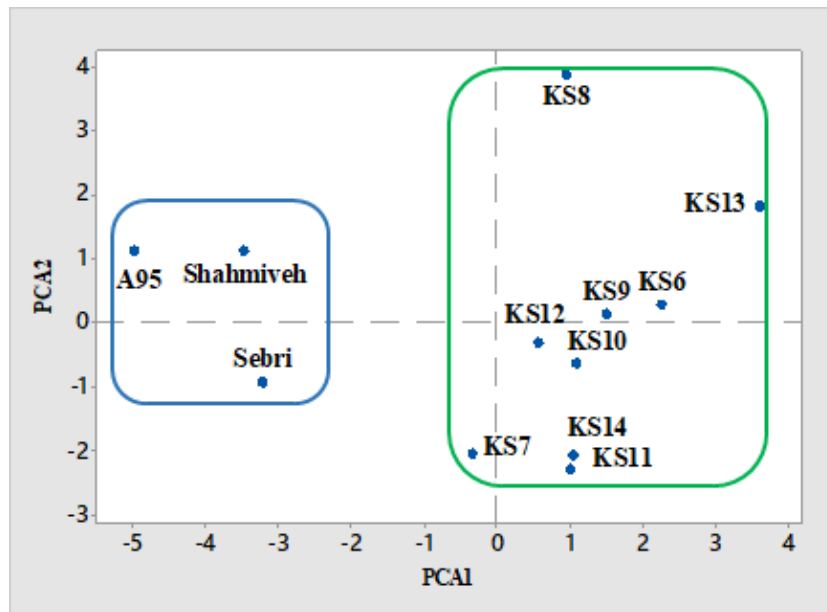
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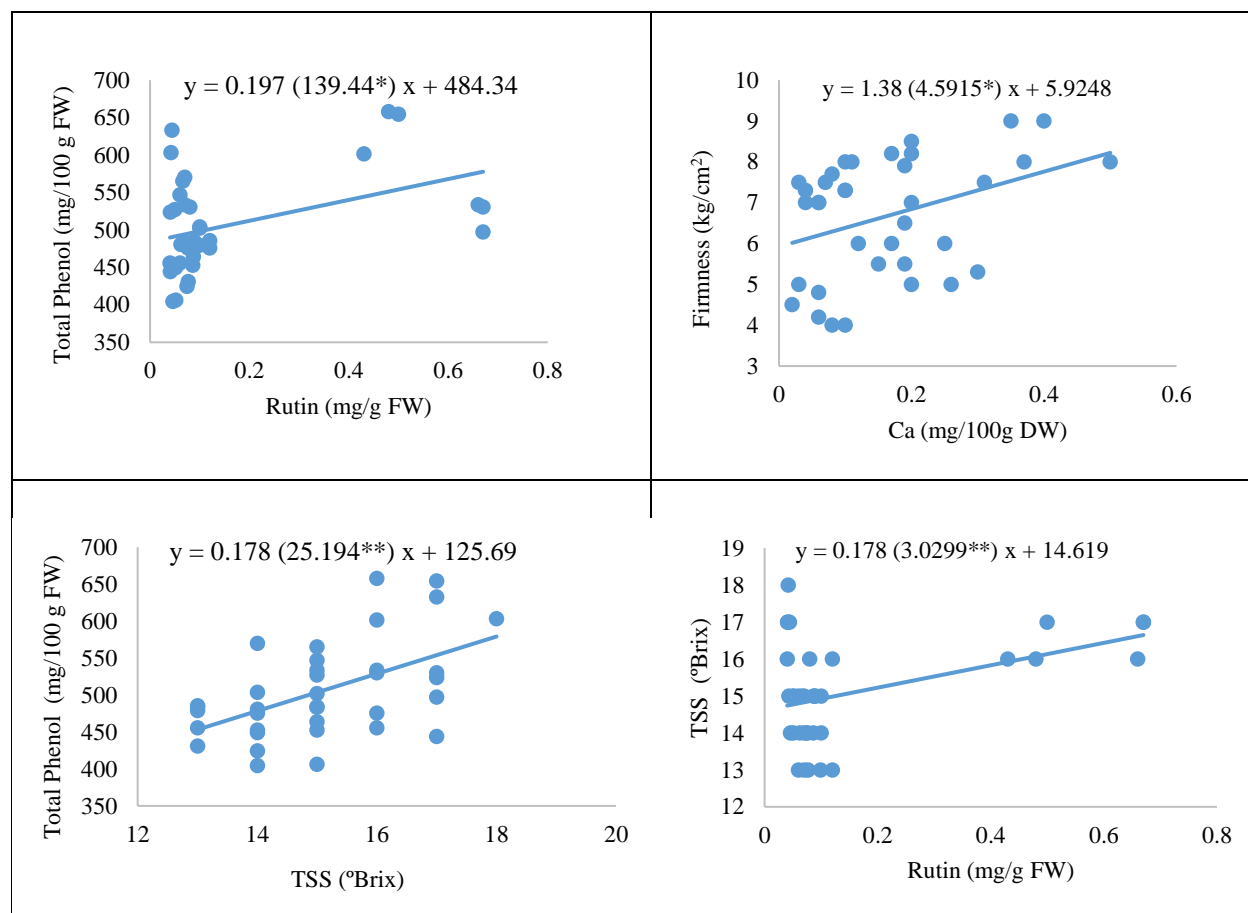
558 **Figure 1.** Heat map of Spearman's correlations between chemical traits of the studied Asian and  
559 European pear cultivars.  
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562 **Figure 2.** Principal component analysis of the studied Asian and European pear cultivars based on  
563 chemical traits. Each point represents one genotype and the surrounding green and blue lines are  
564 drawn to indicate the division of cultivars and genotypes into two large groups of the Asian and  
565 European pears, respectively.  
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570 **Figure 3.** Linear regression between total Phenol and rutin, total Phenol and TSS, firmness and  
 571 Ca, and TSS and rutin of the studied European, and Asian pear genotypes. The Pearson correlation  
 572 coefficient between total Phenol and rutin was 0.413\*, total Phenol and TSS 0.532\*, firmness and  
 573 Ca 0.369\*, and TSS and rutin 0.426\*\*. In correlations, \* and \*\* were used to show the significance  
 574 at  $P \leq 0.05$  and  $P \leq 0.01$  respectively.