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Partial Least Squares Analysis of the Relationship Among Organic Acid, Total Soluble Solids, Total Phenolic, and Total Flavonoids in *Ficus carica*

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Abstract: Figs (*Ficus carica* Linn.) are a new generation of economic forest crops with high nutritional value. This study aimed to clarify the intrinsic association between organic acids and the quality of figs after introducing multispecies. The figs introduced in Shandong are rich in organic acids and contain a wide variety of highly concentrated bioactive compounds. A total of 24 organic acids were detected in this experiment, 13 of which were newly detected. Citric acid was the main organic acid in Shandong-introduced figs, accounting for 66% of the total acid on average. This was followed by malic and citric acids, accounting for 15.9% and 11.6%, respectively. The mean total phenolic, flavonoid, and soluble solid contents were 1.627 mg/g, 0.588 mg/g, and 16.217 °Brix, respectively. The fig cultivar Banane had

the highest total organic acid content and high total phenolic and flavonoid contents. The results of the partial least squares regression showed that the regression coefficients of caffeic acid, ferulic acid, chicoric acid, p-hydroxybenzoic acid, and quinic acid on the total soluble solids were in the range of 0.194–0.279, favoring the accumulation of total soluble solids. Trans-aconitic acid, citric acid, cis-aconitic acid, pyruvic acid, and tartaric acid promoted the accumulation of total phenolics and flavonoids. The regression coefficients ranged from 0.200 to 0.310 for total phenolics and 0.233 to 0.290 for total flavonoids. The discovery of a close intrinsic association between organic acids and nutrients provides a new reference basis for screening good fig cultivars and their nutritional development.

Keywords: *Ficus carica* L., Chemical composition, Organic acid, Phenolic compounds, Flavonoids, PLS

1. INTRODUCTION

Fig (*Ficus carica* Linn.), one of the first plants cultivated by humans (Teruel-Andreu et al. 2023), is a cash crop of the genus *Ficus* in the family *Moraceae* and is widely cultivated in subtropical regions worldwide. Figs are flavorful, nutritious, and have antioxidant activity that is thought to slow aging and promote human health (Solomon et al. 2006; Meziant et al. 2021). Figs have been identified for the treatment of diseases related to the endocrine system (diabetes), gastrointestinal tract (ulcers and vomiting), respiratory system (liver disease, asthma, and cough), reproductive system (menstrual cramps), and infectious diseases (dermatosis, scabies, and gonorrhea) (Hajam and H 2022). Figs are rich in dietary fiber, minerals (copper, manganese, magnesium, iron, calcium, and potassium), amino acids (aspartic acid and glutamine), vitamins

(thiamine and riboflavin), organic acids, and sugars and are low in fat (Solomon et al. 2006; Wojdyło et al. 2016; Nawaz et al. 2019). In addition, figs are a good source of antioxidant phytochemicals, especially organic acids, flavonoids, and phenolic compounds (Fongang et al. 2015; Farooq et al. 2019; Jagtap and Bapat 2019).

In China, figs are cultivated in all provinces, autonomous regions, and municipalities. Areas with higher levels of large-scale cultivation mainly include Weihai on the eastern coast of Shandong, Kashgar, and Atushi in Xinjiang and Weiyuan in Sichuan. Weihai in Shandong Province is one of the three main fig-producing areas in China, with a cultivation area of approximately 0.33 million hm². There are approximately 700 cultivars of figs worldwide, and Chinese germplasm resources have reached more than 120. However, not all cultivars are adapted to promote planting in China, so selecting new species is an important means of expanding the fig industry. Simultaneously, the nutritional value of different cultivars of figs is different, so it is very important to clarify the quality of figs inherent nutrient composition. Total phenolics and flavonoids are phytochemicals that have attracted significant attention.

Phenolic compounds are ubiquitous secondary metabolites with favorable physiological effects in plants. They are beneficial to human health because of their antioxidant activities through various means, such as reducing agents, hydrogen donors, free-radical scavengers, and single-linear oxygen bursts. Phenolic compounds have potential health benefits for preventing and treating a wide range of chronic conditions, especially those related to oxidative stress (Rahman et al. 2022). Studies have shown that the *in vivo* efficacy of phenolic compounds in figs is synergistic with that of the drug product (sylmarin) in treating carbon tetrachloride-induced hepatotoxicity (S. Hira et al. 2021). Flavonoids are ubiquitous plant polyphenolic compounds that are categorized as flavonols, flavones,

isoflavones, flavanols, flavanones, and anthocyanins. Flavonoids are strong antioxidants in vitro with both anti-inflammatory activity and antimicrobial effects (Gregory et al. 2009; Benmaghnia et al. 2019). In addition, as one of the best natural enzyme inhibitors, flavonoid compounds are useful in treating diabetes, skin hyperpigmentation, Alzheimer's disease, and microbial infections (González-Gallego et al. 2014; Meziant et al. 2021). Therefore, phenolic and flavonoid compounds have long been studied to enhance the phenolic content of fruits (Wang et al. 2023). As important secondary metabolites of fruits, the components and content of organic acids are closely related to fruit nutrition.

Organic acids are involved in photosynthesis and respiration in the metabolism of fruits, and in the metabolic process of synthesizing phenols, amino acids, esters, and aromatic substances, which soften blood vessels, promote the absorption of trace elements, and aid in the digestion of gastric juices. Based on the type of most abundant organic acid, fruits can be categorized into two main types: malic acid dominant (apple and cherry) (Zhou et al. 2023; Natić et al. 2024) and citric acid dominant (citrus) (Wang et al. 2021). In addition, flavor is a key determinant of food quality and an important driver of consumer preference for fruits (Shu et al. 2023). Fruit flavor is influenced by several factors, among which soluble solid content, expressed in °Brix, is often used to assess sweetness (Aprea et al. 2017). Fruit flavor is largely influenced by the composition of sugars and organic acids (Gonçalves et al. 2020). Therefore, it is important to study the effect of organic acids on the accumulation of total phenolic, flavonoid, and soluble solid contents to improve the nutritional and flavor quality of fig fruits. Only a few studies have investigated the effects of organic acids and fruit chemical composition on fig cultivars.

This experiment used six new excellent Chinese fig cultivars (108 B, Stella, Ameiniya, Borji

Red, Orphan, and Banane) screened by the Shandong Academy of Forestry as research subjects. Fig cultivars were uniformly planted in Weihai, Shandong Province, China, to ensure uniform soil, climate, and crop management conditions. The organic acid, soluble solid, total phenolic, and total flavonoid contents were determined for the six fig cultivars, and the relationship between the organic acid components and the above chemical components was analyzed using partial least squares (PLS). In addition, the relative importance of each component was determined using principal component analysis (PCA), and the fig cultivars were grouped. This study provides a scientific basis for screening high-quality fig cultivars and quality improvement and lays a theoretical foundation for an in-depth study of the specific relationship between the chemical components of fig cultivar fruits.

2. MATERIALS AND METHODS

2.1 Sample collection and preparation

Fig cultivars are sourced from the Weihai Ziguang Science and Technology Park, and the fruits were picked in the morning to ensure they are physically ripe. Fruits were stored in polyethylene boxes, sterilized, and stored in a -18°C freezer. The original sources of the different fig cultivars used in this experiment are shown in Table 1. The cultivars used included 108B (1B), Stella (SA), Ameiniya (B1011), Borji Red (A132), Orphan (A212), and Banane (BE).

2.2 Reagents

The standards for fumaric acid, maleic acid, pyruvic acid, PEP, malonic acid, 3-phenylpropionic acid, caffeic acid, gallic acid, ferulic acid, benzoic acid, salicylic acid, cichoric acid, 4-hydroxybenzoic acid, trans-aconitic acid, cis-aconitic acid, quinic acid, malic acid, citric acid, lactic acid, succinic acid, tartaric acid, oxalic acid, gluconic acid, and acetic acid had purity $> 90\%$

using high-performance liquid chromatography and purchased from the Center of National Standard Reference Materials of Beijing, China. All reagents were of analytical grade and were purchased from Sinopharm Chemical Reagent Company (Shanghai, China). These reagents included hydrochloric acid, sulfuric acid, sodium hydroxide, boric acid, methyl red, bromocresol green, anhydrous ethanol, petroleum ether, anhydrous sodium sulfate, anhydrous aluminum chloride, sodium carbonate, ethanol, methanol, formic acid, and Folin-Ciocalteu reagent.

2.3 Instrumentation

The instruments used were: Electronic balance (ME203T, Mettler Toledo, USA); Fully automated Kjeldahl nitrogen analyzer (Kjeltec 8400, FOSS, Denmark); Soxhlet extractor; muffle furnace (BF51894C-1, Thermo Fisher, Massachusetts, USA); refractometer (Pocket Brix-Acidity Meter Master Kit, ATAGO, Tokyo, Japan); ultraviolet spectrophotometer (Shimadzu, Columbia, Maryland, USA); centrifuges (5424R, Eppendorf, German); Vortex Oscillator (Vortex-6, Kylin-Bell, Haimen, China); ultrasonic cleaner (KQ5200E, Kun Shang Shu Mei, Kunshan, China); Liquid Phase Secondary Mass Spectrometer (Sciex 4500, Sciex, Shanghai, China).

2.4 Methods

2.4.1 Chemical composition

The chemical composition of figs was analyzed using three replicates, including the quantification of moisture, ash, fat, protein, and soluble solids (AOAC. 2016). The moisture content was determined using the vacuum drying method, and the crude protein content was determined using the macro-Kjeldahl method. The ash content via incineration at $550 \pm 25^{\circ}\text{C}$ and the crude fat were estimated by extracting a known weight of *Ficus carica* sample with petroleum ether in a

Soxhlet apparatus. The total soluble solid content was measured using a refractometer (Pocket Brix-Acidity Meter Master Kit; ATAGO, Tokyo, Japan).

2.4.2 Determination of total phenolic and total flavonoids

Total phenolic content was determined using an improved version of the Folin-Ciocalteu colorimetric method (Barros et al. 2008). Extracts (0.5 mL) were mixed with 2.5 mL of Folin-Ciocalteu reagent (10 %) and 2 mL of sodium carbonate solution (4 %). The mixture was stirred at room temperature in the dark for 2 h. The absorbance was measured at 765 nm using an ultraviolet-visible spectrophotometer (Shimadzu, Columbia, Maryland, USA). Gallic acid was used as the standard solution. Results are expressed as gallic acid equivalents ($\mu\text{g/g}$).

Total flavonoid content was measured using a modified Folin-Denis method (Kebal et al. 2022). Briefly, 1 mL of extract or standard was mixed with 1 mL of 2 % aluminum chloride solution (w/v) in methanol. The absorbance of the mixture was measured using an ultraviolet-visible spectrophotometer (Shimadzu, Columbia, Maryland, USA) at 430 nm and compared with a blank after 30 min of standing in the dark at room temperature. Gallic acid was used as a standard for the calibration curve ($R^2 = 0.991$). Gallic acid was used as the standard solution. Results are expressed as gallic acid equivalents ($\mu\text{g/g}$).

2.4.3 Determination of organic acids

Organic acids were determined using a Sciex 4500 liquid secondary mass spectrometer (LC-MS/MS, Shanghai, China) on a Thermo Synchronis HILIC column (2.1×100 , 5 μm). The fig samples were pre-crushed in a centrifuge (Eppendorf Centrifuge 5424R, Germany). Then, 100 mg of sample powder with 1.0 mL of extract (0.1% formic acid aqueous solution) was placed in a 2-mL centrifuge tube and spun and mixed using a vortex oscillator (Kylin-Bell Vortex-6, Haimen, China). The mixture was extracted using an ultrasonic cleaner (Kun Shang Shu Mei KQ5200E, Kunshan, China)

for 30 min, centrifuged at 12000 rpm for 5 min, and then the supernatant was transferred to a new centrifuge tube, filtered through 0.22-μm polytetrafluoroethylene filtration membranes, and transferred to injection vials to be detected using liquid-quality coupled assay.

2.4.4 PLS method to test organic acids associated with total phenolic, flavonoids, and soluble solids

PLS regression was used to analyze the relationship between the 24 organic acids and total phenolics, flavonoids, and soluble solids. Regression analysis was performed using 24 organic acids as x-variables and total phenolics, total flavonoids, and total soluble solids as y-variables.

First, x and y were subjected to a standardized treatment (1/Sdev) to eliminate the effect of different units and obtain a standardized independent variable matrix E_0 and a dependent variable matrix F_0 .

Second, the first principal component t_1 is extracted from E_0 , and then E_0 and F_0 are regressed on t_1 to obtain Equations (1) and (2).

$$E_0 = t_1 p_1 + E_1 \quad (1)$$

$$F_0 = t_1 r_1 + F_1 \quad (2)$$

where p_1 and r_1 are the regression coefficients and E_1 and F_1 are the residual matrices. The relationship between the regression coefficients is used to obtain the $F_0 = E_0 A_1 + F_1$.

Again, the second principal component t_2 is extracted from the residual matrix E_1 , and E_1 and F_1 are regressed on t_2 to obtain:

$$E_1 = t_2 p_2 + E_2$$

$$F_1 = t_2 r_2 + F_2$$

Using the relationship between the regression coefficients to obtain: $F_0 = E_0 A_2 + F_2$.

Finally, repeat the above operation to get:

$$E_n = t_n p_n + E_n = t_1 p_1 + t_2 p_2 + \cdots + t_n p_n$$

$$F_n = t_n r_n + F_n$$

The relationship between the regression coefficients is used to obtain a regression equation between x and y: $F_0 = E_0 A_n + F_n$.

2.4.5 PCA method to analyze organic acids, total phenolic, total flavonoids, and total soluble solids

The present study used PCA to downscale 24 organic acids, total soluble solids, phenolics, and flavonoids.

The matrix $X_{n \times P}$ is obtained in the first step by normalizing the raw data.

In the second step, the covariance of matrix X is solved to obtain the variance matrix CovX.

In the third step, the eigenvalues and the corresponding eigenvectors are of the variance matrix CovX. Thus, we solved the principal component $Y_k = XT_k, 1 \leq k \leq m$.

In the fourth step, the contribution of each principal component is calculated using Equation (5).

$$\varphi_k = \frac{\lambda_k}{\sum_{i=1}^m \lambda_i} \quad (5)$$

In general, the selection of the cumulative contribution rate follows the following formula:

$$\Psi_s = \frac{\sum_{j=1}^s \lambda_j}{\sum_{i=1}^m \lambda_i} = \sum_{j=1}^s \varphi_j > 80\%$$

2.5 Statistical analysis

All test indicators were replicated thrice. Analysis of variance (ANOVA), followed by Tukey's test, was performed using SPSS statistical software (IBM, Chicago, IL, USA). Sample data were analyzed using PLS using Unscrambler X (Version 10.4; CAMO, Trondheim, Norway). Models

were generated using correlation coefficients (R^2) and the root mean square error of cross-validation (RMSECV), and uncertainty tests were applied to assess the statistical significance of each x-variable. PCA was performed using SIMCA 14.1 (UMetrics AB, Umea, Sweden). Origin 2023b software was used to visualize the organic acid data and the PLS analysis results.

3. Result

3.1 Chemical composition

Table 2 lists the chemical composition of the six fig cultivars. Moisture content ranged from 757.171–850.707 mg/g. Ash content ranged from 5.330–8.550 mg/g. The fat content ranged from 9.590–13.330 g/kg, with 1B and A132 cultivars having lower fat content than the rest. The crude protein content of figs ranged from 4.180–6.790 mg/g, with KZ and A212 cultivars having relatively higher content. The soluble solids content of fig cultivars ranged from 13.833–19.600 °Brix, with SA and 1B samples reaching more than 17 °Brix, while KZ had a soluble solids content below 14 °Brix. The total phenolic content in figs ranged from 0.920–2.490 mg/g, with BE significantly higher than the other samples. The total flavonoid content ranged from 0.350–0.840 mg/g, and the contents of SA and BE were higher than in the other samples.

3.2 Organic acid

Table 3 lists the organic acid content of the figs, and Figure 1 shows the differences in the content of each organic acid. Citric acid had the highest average content of 16363.575 µg/g, with a range of 8253.631–29173.767 µg/g, followed by malic acid (average content of 3937.604 µg/g, with a range of 2493.621–5943.303 µg/g) and gluconic acid (average content of 2861.940 µg/g, with a range of 1437.925–3943.189 µg/g); again acetic acid (average content of 403.163 µg/g, with a range

of 264.455–600.947 $\mu\text{g/g}$), quinic acid (mean value 364.345 $\mu\text{g/g}$, content variation range 266.380–452.797 $\mu\text{g/g}$), and oxalic acid (mean value 349.719 $\mu\text{g/g}$, content variation range 332.395–384.889 $\mu\text{g/g}$). The average content of the other 18 organic acids was less than 200 $\mu\text{g/g}$. Lactic acid ranged from 145.462–197.195 $\mu\text{g/g}$; maleic acid ranged from 57.582–167.105 $\mu\text{g/g}$; amber acid ranged from 52.267–87.248 $\mu\text{g/g}$; cis-aconitic acid ranged from 13.601–163.811 $\mu\text{g/g}$; fumaric acid ranged from 12.435–31.869 $\mu\text{g/g}$; tartaric acid ranged from 2.782–3.922 $\mu\text{g/g}$; benzoic acid ranged from 1.815–2.284 $\mu\text{g/g}$; trans-aconitic acid ranged from 0.737–2.056 $\mu\text{g/g}$; PEP ranged from 0.105–0.385 $\mu\text{g/g}$; caffeic acid ranged from 0.115–0.258 $\mu\text{g/g}$; pyruvic acid ranged from 0.087–0.140 $\mu\text{g/g}$; 3-phenylpropionic acid ranged from 0.052–0.108 $\mu\text{g/g}$; 4-hydroxybenzoic acid ranged from 0.051–0.121 $\mu\text{g/g}$; malonic acid ranged from 0.048–0.112 $\mu\text{g/g}$; cichoric acid ranged from 0.021–0.062 $\mu\text{g/g}$; salicylic acid ranged from 0.016–0.032 $\mu\text{g/g}$; gallic acid ranged from 0.008–0.012 $\mu\text{g/g}$ and ferulic acid ranged from 0.006–0.015 $\mu\text{g/g}$.

3.3 Relationship between total phenolic and organic acids

The relationship between the measured and predicted values of total phenolic content is shown in Figure 2. The regression data SA#1 were deleted to remove the fitted disturbances. The principal factor 1 of the PLS method explained 82% of the total variance. The results showed that the RMSECV was 0.0143, and the correlation coefficient was 0.92983. The PLS regression coefficients for total phenolic content are shown in Figure 3. Higher regression coefficients (positive or negative) indicated a greater effect on metabolite bioactivity and vice versa. There were 15 organic acids with positive regression coefficients and nine with negative regression coefficients. The regression coefficients of TAA, CA3, QA, CAA, PA, and GA2 ranged from 0.202–0.310, indicating a large contribution to the total phenolic content accumulation. In contrast, the regression coefficients of

MA1, FA1, MA3, and PEP were less than -0.200 , which was unfavorable for the accumulation of total phenolic content.

3.4 Relationship between total flavonoids and organic acids

Figure 4 shows a scatter plot of the PLS model for the relationship between the observed and predicted values of total flavonoid content. Regression data SA#3 and A212#1 were deleted to remove fitted disturbances. The principal factor 1 of the PLS method explained 59% of the total variance. The results showed a low RMSECV of 0.00774 and a correlation coefficient of 0.84660. Figure 5 shows the variable importance of each organic acid on the total flavonoid content. The results showed that the effect of organic acids on the total flavonoid content was similar to that of the total phenolic content, and only the effect of SA2 on the content of total phenolic and total flavonoids showed an opposite relationship. This is not surprising because flavonoids are polyphenols. Among all the organic acids, CA1, TAA, CA3, and QA had the greatest effect on the total flavonoid content, with regression coefficients ranging from 0.286 to 0.367. MA1, MA3, FA1, and PEP were detrimental to the accumulation of total flavonoids, which was the same as the total phenolic content. Overall, PA, CA1, GA1, FA2, BA, CA2, 4HA, TAA, CAA, QA, CA3, LA, TA, GA2, and AA were positively correlated with total phenolic and flavonoid content, whereas FA1, MA1, PEP, MA2, 3PA, SA1, MA3, and OA were negatively correlated with total phenolic and flavonoid content.

3.5 Relationship between total soluble solids and organic acids

The relationship between the measured and predicted values of total soluble solid content is shown in Figure 6. Regression data 1B#3 were deleted to remove fitted disturbances. The principal

factor 1 of the PLS method explained 47% of the total variance. The results showed that the RMSECV was 0.6379, and the correlation coefficient was 0.91121. The PLS regression coefficients for the total soluble solid content are shown in Figure 7. The regression coefficients for CA2, FA2, QA, 4HA, PA, CA1, and AA were in the range of 0.194–0.386, suggesting that they are important organic acid markers for accumulating total soluble solids. Overall, PA, CA1, FA2, BA, CA2, 4HA, TAA, CAA, QA, CA3, LA, TA, GA2, and AA were positively correlated with soluble solids. FA1, MA1, PEP, MA2, 3PA, GA1, SA1, MA3, SA2, and OA were negatively correlated with soluble solids. The results of the study suggest that PLS not only helps to predict fig chemical composition but also helps highlight important organic acid markers.

3.6 PCA

To understand the relationship between chemical composition and organic acids, it is necessary to use PCA. After determining the seven principal components of figs, the first six principal components accounted for 92.8% of the total information. Of these six, the first two accounted for 60.8% of the information (Table 4). Principal component 1 was positively correlated with QA, TAA, CA3, TP, PA, CAA, CA2, TF, GA2, 4HA, TA, CA1, TSS, AA, GA1, FA2, BA, and LA and negatively correlated with SA2, MA2, OA, 3PA, SA1, PEP, FA1, MA3, and MA1. Principal component 2 was significantly and positively correlated with MA2 and BA and significantly and negatively correlated with SA2 and FA2. Figure 8 shows SA1, FA1, and MA3 on the far-right side of principal component 1. They are very close to each other but far from the center, near the 100% variance ellipse. Thus, SA1, FA1, and MA3 were closely related, which also implied that they were higher in A212. BE had higher levels of CA2 and GA2 and lower levels of SA1, FA1, and MA3. Based on these results, figs can be divided into three main groups, with A212 being the most suitable

for separate groups (Fig. 9). Overall, FA1, MA3, MA1, PA, CA3, TAA, QA, total phenolics, and total flavonoids provided references for evaluating the intrinsic characteristics and quality of figs.

4. DISCUSSION

Figs introduced in Shandong are rich in organic acids, with the highest content of citric acid, and have a high concentration of bioactive compounds and nutrients, rich in moisture, fat, total soluble solid, total phenolic, and total flavonoid compounds. Compared with the US Department of Agriculture database

(<https://fdc.nal.usda.gov/fdc-app.html#/food-details/746768/nutrients>), Shandong-introduced fig cultivars had higher moisture and fat contents and lower ash and crude protein contents. The moisture content of the Shandong-introduced fig cultivars was higher than the values determined for a very common and appreciated fig variety in Portugal (Pingo de Mel), whereas the values of ash, fat, and crude protein were lower, and the total phenolic content was similar. BE showed the highest bioactivity, as its total phenolic and flavonoid contents were higher than those of the Portuguese fig variety (Palmeira et al. 2019). The TSS content determined for the four fig cultivars (1B, SA, A132, and BE) was slightly higher than the mean value of the four fig varieties from Spain (Cuello de Dama Negro, San Antonio, SuperFig1, and Colar). Compared with the values determined by Lin et al. (2024) in Guangdong Province, the TSS contents of BE, B1011, and A132 in this study were lower, whereas that of SA was slightly higher. Differences between the nutrient characteristics of figs measured in this experiment and those described in other studies can be attributed to differences in environmental factors (e.g., soil and moisture).

In this study, 24 organic acids were detected in six fig cultivars. Organic acids in the figs mainly

included CA3, MA3, GA1, AA, QA, and OA, with significant differences in the content and proportion of organic acids in the different cultivars. CA3 content accumulated the most in all six fig cultivars, accounting for 66% of the total organic acid content. This suggests that CA3 plays a crucial role in figs, which are citric acid-type fruits, consistent with the findings of Palmeira et al. (2019). Other studies have shown that the main organic acid in figs is MA3 (Núñez-Gómez et al. 2021; Teruel-Andreu et al. 2023). MA3 and GA1 contents were second only to CA3 in the total organic acid content of figs, accounting for 15.9% and 11.6% of the total organic acid content, respectively. AA, QA, and OA contents accounted for 1.6%, 1.5%, and 1.4% of the total organic acid content, respectively. MA1, CAA, TAA, BA, PEP, PA, 3PA, 4HA, MA2, CA2, SA1, GA2, and FA2, which have rarely been reported in previous studies, were newly detected organic acids with relatively low content. The variety of figs, the maturity of the berries at harvest, and the harvesting technique may affect the organic acid content.

Organic acids and soluble sugars, as indispensable contributors to fruit quality, affect fruit flavor and indirectly have both favorable and unfavorable effects on commercial fruit quality (Li et al. 2023). Soluble sugars and organic acids are nutrients and key indicators of fruit crop quality, flavor, and ripeness. Aprea et al. (2017) reported that soluble solid content was positively correlated with apple sweetness, and MA3 was negatively correlated with sweetness. The results of the correlation analysis showed a negative correlation between the soluble solid content and MA3. This is consistent with the results of the present study, in which FA1, an intermediate product of the citric acid cycle, was converted to MA3 by fumarase; therefore, it was also negatively correlated with soluble solids. Wu et al. (2022) studied the relationship between organic acid content and the ripening stage of pear fruit and found that MA3, CA3, and QA accumulated with the development

of pear fruit, and the soluble solid content increased with fruit ripening. Jawad et al. (2020) studied the expression patterns of sugar and organic acid regulatory genes during watermelon fruit development and found that the expression level of WMNI-1-SW was significantly positively correlated with MA3 content, negatively correlated with CA3 content, and negatively correlated with OA content. During fruit ripening, the expression levels of different transport genes may cause the accumulation of MA3, OA, and soluble solids, which play a negative role, whereas CA3 may play a positive role. In general, PA, CA1, FA2, BA, CA2, 4HA, TAA, CAA, QA, CA3, LA, TA, GA2, and AA were positively correlated with soluble solids. FA1, MA1, PEP, MA2, 3PA, GA1, SA1, MA3, SA2, and OA were negatively correlated with soluble solids.

Phenolic substances in figs are the main bioactive components that are beneficial for health (Qin et al. 2015; Sertkaya et al. 2021). Phenolic compounds are among the main secondary metabolites of plants, with one or more hydroxyl substituents on their aromatic rings and can be divided into water-soluble compounds (phenolic acids, phenylpropanoids, flavonoids, and quinones) and water-insoluble compounds (condensed tannins, lignin, and hydroxycinnamic acids) (Rispaïl et al. 2005). PA, CA1, GA1, FA2, BA, CA2, 4HA, TAA, CAA, QA, CA3, LA, SA2, TA, GA2, and AA were positively correlated with total phenolic. FA1, MA1, PEP, MA2, 3PA, SA1, MA3, and OA were negatively correlated with total phenolic. Among the 24 organic acids detected, CA1, FA2, CA2, 4HA, QA, and GA2 are phenolic acids, which may be the reason for the positive correlation observed. In addition, PA, an intermediate metabolite of the TCA cycle, is oxidized to carbon dioxide and water to complete the aerobic oxidation of glucose and to provide energy for the synthesis of phenolic substances. The antioxidant activities of PA and MA3 may also protect phenolic compounds. In contrast, the increase in MA3 had a negative effect on the total phenolic

content. CAA and TAA, the new organic acids found in figs, accounted for 0.3% and 0.005% of the total organic acid content, respectively, with regression coefficients of 0.256 and 0.310, which had a very positive effect on the accumulation of total phenol content.

Flavonoids are among the most effective natural antioxidants and are widely found in plants. Increasing PA, CA1, GA1, FA2, BA, CA2, 4HA, TAA, CAA, QA, CA3, LA, TA, GA2, and AA levels increased total phenolic and total flavonoids. However, increasing the concentration of FA1, MA1, PEP, MA2, 3PA, SA1, MA3, and OA reduced the total phenolic and flavonoid contents. In addition, SA2 succinate had the opposite effect on total phenolic and flavonoid content. The effects of the organic acids on total phenolics and flavonoids were similar. Overall, the present study provides a new theoretical basis for changing the total phenolic and total flavonoid content of figs.

5. CONCLUSION

The organic acids in figs introduced in Shandong Province were mainly citric acid, malic acid, gluconic acid, acetic acid, quinic acid, and oxalic acid, the proportions of which varied with the cultivar, with citric acid playing a leading role. In this study, the organic acids, total phenolics, and total flavonoids of figs showed significant differences between the cultivars. The cultivars with higher total organic acid content (BE, 1B, SA with 1518.634, 1225.228, and 1043.518 $\mu\text{g/g}$, respectively) had higher total phenolic and total flavonoid content. This study shows that organic acids have a significant impact on the accumulation of chemical components in figs. Organic acids with relatively high (citric acid, gluconic acid, and quinic acid) and relatively low contents (caffeic acid, trans-aconitic acid, and cis-aconitic acid) can have a positive impact on the total phenolic and flavonoid contents. Fumaric acid, maleic acid, PEP, and malic acid had negative effects on total

phenolic and flavonoid content. Therefore, regulating the concentration of organic acids in figs could potentially result in improved products. Organic acids and soluble sugars are important factors that affect fruit flavor. Phenolic acids (caffeic acid, ferulic acid, cichoric acid, 4-hydroxybenzoic acid, and quinic acid) facilitate the accumulation of total soluble solids. The results of this study confirmed that organic acids were closely related to total phenolics, total flavonoids, and total soluble solids of figs, providing a new reference for improving the quality and nutritional development of fig cultivar fruits.

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Data availability Statements: The datasets analysed during the current study are available from the corresponding author on reasonable request.

Statements and Declarations

Ethics Approval: This article does not contain studies with human or animal participants.

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References

- AOAC, Dr. George W, Latimer, Jr (2016) Official Methods of Analysis of AOAC International - 20th Edition, 2016. https://www.techstreet.com/standards/official-methods-of-analysis-of-aoac-international-20th-edition-2016?product_id=1937367. Accessed 18 Jan 2024
- Apréa E, Charles M, Endrizzi I, et al (2017) Sweet taste in apple: The role of sorbitol, individual sugars, organic acids and volatile compounds. *Scientific Reports* 7:. <https://doi.org/10.1038/srep44950>
- Barros L, Venturini BA, Baptista P, et al (2008) Chemical Composition and Biological Properties of Portuguese Wild Mushrooms: A Comprehensive Study. *J Agric Food Chem* 56:3856–3862. <https://doi.org/10.1021/jf8003114>
- Benmaghnia S, Meddah B, Aicha TTM, Gabaldon J (2019) Phytochemical analysis, antioxidant and antimicrobial activities of three samples of dried figs (*Ficus carica* L.) from the region of Mascara (Western Algeria). *Journal of microbiology, biotechnology and food sciences* 9:208–215. <https://doi.org/10.15414/jmbfs.2019.9.2.208-215>

-
- Farooq SA, Singh R, Saini V (2019) Evaluation of phytochemical constituents and antioxidant potential of hydro-alcoholic and aqueous extracts of *Murraya koenigii* L. And *Ficus carica* L. *Herba Polonica* 65:7–17. <https://doi.org/10.2478/hepo-2019-0021>
- Fongang YSF, Bankeu JJK, Ali MS, et al (2015) Flavonoids and other bioactive constituents from *Ficus thonningii* Blume (Moraceae). *Phytochemistry Letters* 11:139–145. <https://doi.org/10.1016/j.phytol.2014.11.012>
- Gonçalves AC, Campos G, Alves G, et al (2020) Physical and phytochemical composition of 23 Portuguese sweet cherries as conditioned by variety (or genotype). *Food Chemistry* 335:127637. <https://doi.org/10.1016/j.foodchem.2020.127637>
- González-Gallego J, García-Mediavilla MV, Sánchez-Campos S, Tuñón MJ (2014) Chapter 32 - Anti-Inflammatory and Immunomodulatory Properties of Dietary Flavonoids. In: Watson RR, Preedy VR, Zibadi S (eds) *Polyphenols in Human Health and Disease*. Academic Press, San Diego, pp 435–452
- Gregory M, Vithalrao KP, Franklin G, Kalaichelavan V (2009) Anti-ulcer (ulcer-preventive) activity of *Ficus arnottiana* Miq. (Moraceae) leaf methanolic extract. *American Journal of Pharmacology and Toxicology* 4:89–93. <https://doi.org/10.3844/ajptsp.2009.89.93>
- Hajam TA, H S (2022) Phytochemistry, biological activities, industrial and traditional uses of fig (*Ficus carica*): A review. *Chemico-Biological Interactions* 368:110237. <https://doi.org/10.1016/j.cbi.2022.110237>
- Jagtap UB, Bapat VA (2019) Exploring Phytochemicals of *Ficus carica* L. (Fig). In: Murthy HN, Bapat VA (eds) *Bioactive Compounds in Underutilized Fruits and Nuts*. Springer International Publishing, Cham, pp 1–16

-
- Kebal L, Pokajewicz K, Djebli N, et al (2022) HPLC-DAD profile of phenolic compounds and In vitro antioxidant activity of *Ficus carica* L. fruits from two Algerian varieties. *Biomedicine & Pharmacotherapy* 155:113738. <https://doi.org/10.1016/j.biopha.2022.113738>
- Li W, Wu Z, Xu Y, et al (2023) Emerging LC-MS/MS-based molecular networking strategy facilitates foodomics to assess the function, safety, and quality of foods: recent trends and future perspectives. *Trends in Food Science & Technology* 139:104114. <https://doi.org/10.1016/j.tifs.2023.07.011>
- Lin X, Wu G, Zhao T, et al (2024) Introduction and Selection of Fresh *Ficus Carica* Linn in Guangdong. *Chinese Journal of Tropical Agriculture* 1–13
- Meziant L, Bachir-bey M, Bensouici C, et al (2021) Assessment of inhibitory properties of flavonoid-rich fig (*Ficus carica* L.) peel extracts against tyrosinase, α -glucosidase, urease and cholinesterases enzymes, and relationship with antioxidant activity. *European Journal of Integrative Medicine* 43:101272. <https://doi.org/10.1016/j.eujim.2020.101272>
- Muhammad Jawad U, Gao L, Gebremeskel H, et al (2020) Expression pattern of sugars and organic acids regulatory genes during watermelon fruit development. *Scientia Horticulturae* 265:109102. <https://doi.org/10.1016/j.scienta.2019.109102>
- Natić M, Dabić D, Jakanovski M, et al (2024) Fruit Quality Attributes of Organically Grown Norwegian Apples Are Affected by Cultivar and Location. *Plants* 13:147. <https://doi.org/10.3390/plants13010147>
- Nawaz H, Waheed R, Nawaz M, et al (2019) Phytochemical Composition, Antioxidant Potential, and Medicinal Significance of *Ficus*. In: *Modern Fruit Industry*. IntechOpen
- Núñez-Gómez D, Legua P, Martínez-Nicolás JJ, Melgarejo P (2021) Breba Fruits Characterization

-
- from Four Varieties (*Ficus carica* L.) with Important Commercial Interest in Spain. *Foods* 10:3138. <https://doi.org/10.3390/foods10123138>
- Palmeira L, Pereira C, Dias MI, et al (2019) Nutritional, chemical and bioactive profiles of different parts of a Portuguese common fig (*Ficus carica* L.) variety. *Food Research International* 126:108572. <https://doi.org/10.1016/j.foodres.2019.108572>
- Qin H, Zhou G, Peng G, et al (2015) Application of Ionic Liquid-Based Ultrasound-Assisted Extraction of Five Phenolic Compounds from Fig (*Ficus carica* L.) for HPLC-UV. *Food Anal Methods* 8:1673–1681. <https://doi.org/10.1007/s12161-014-0047-9>
- Rahman MM, Rahaman MS, Islam MR, et al (2022) Role of Phenolic Compounds in Human Disease: Current Knowledge and Future Prospects. *Molecules* 27:233. <https://doi.org/10.3390/molecules27010233>
- Rispail N, Morris P, Webb KJ (2005) Phenolic Compounds: extraction and analysis. In: Márquez AJ (ed) *Lotus japonicus Handbook*. Springer-Verlag, Berlin/Heidelberg, pp 349–354
- S. Hira, M. Gulfraz, S. M. Saqlan Naqvi, et al (2021) Protective effect of *ficus carica* fruit against carbon tetrachloride induced hepatic toxicity in mice. *THE JAPS* 31:.. <https://doi.org/10.36899/JAPS.2021.5.0343>
- Sertkaya M, Guclu G, Buyukkurt OK, et al (2021) GC-MS-Olfactometric Screening of Potent Aroma Compounds in Pulps and Peels of Two Popular Turkish Fig (*Ficus carica* L.) Cultivars by Application of Aroma Extract Dilution Analysis. *Food Anal Methods* 14:2357–2366. <https://doi.org/10.1007/s12161-021-02057-6>
- Shu N, Chen X, Sun X, et al (2023) Metabolomics identify landscape of food sensory properties. *Critical Reviews in Food Science and Nutrition* 63:8478–8488.

<https://doi.org/10.1080/10408398.2022.2062698>

Solomon A, Golubowicz S, Yablowicz Z, et al (2006) Antioxidant Activities and Anthocyanin Content of Fresh Fruits of Common Fig (*Ficus carica* L.). *J Agric Food Chem* 54:7717–7723.

<https://doi.org/10.1021/jf060497h>

Teruel-Andreu C, Sendra E, Hernández F, Cano-Lamadrid M (2023) Nutritional and functional compounds and antioxidant activity of edible and non-edible fruit part of brebas and figs (*Ficus carica* L.) among different varieties. *Scientia Horticulturae* 318:112069.

<https://doi.org/10.1016/j.scienta.2023.112069>

Wang H, Zhang Z, Song J, et al (2023) Phenolic compound identification in tomato fruit by UPLC-QTOF-MS. *LWT* 182:114791. <https://doi.org/10.1016/j.lwt.2023.114791>

Wang L, Yue H, Liu Z, et al (2021) Somatic variations led to the selection of acidic and acidless orange cultivars. *Nature Plants* 7:1–12. <https://doi.org/10.1038/s41477-021-00941-x>

Wojdyło A, Nowicka P, Carbonell-Barrachina ÁA, Hernández F (2016) Phenolic compounds, antioxidant and antidiabetic activity of different cultivars of *Ficus carica* L. fruits. *Journal of Functional Foods* 25:421–432. <https://doi.org/10.1016/j.jff.2016.06.015>

Wu J, Fan J, Li Q, et al (2022) Variation of organic acids in mature fruits of 193 pear (*Pyrus* spp.) cultivars. *Journal of Food Composition and Analysis* 109:104483.

<https://doi.org/10.1016/j.jfca.2022.104483>

Zhou J, Yang S, Ma Y, et al (2023) Soluble sugar and organic acid composition and flavor evaluation of Chinese cherry fruits. *Food Chemistry: X* 20:100953.

<https://doi.org/10.1016/j.fochx.2023.100953>

Table 1 Sources of cultivated *Ficus carica* cultivars.

Code	Variety	Cultivar origin
1B	108B	Source unknown
SA	Stella	Existing cultivars in Yunnan, China
B1011	Ameiniya	1998: Introduced from California, USA
A132	Borji Red	1998: Introduced from Texas, USA
A212	Orphan	1998: Introduced from California, USA
BE	Banane	Introduced from Japan

Table 2 Chemical composition of cultivated *Ficus carica* varieties.

Cultivar	Moisture	Ash	Fat	Crude protein	TSS	Total phenolic	Total flavonoids
1B	757.171 ± 32.539 c	7.870 ± 0.720 ab	11.660 ± 1.000 ab	4.650 ± 0.050 d	17.200 ± 0.721 b	2.050 ± 0.040 b	0.550 ± 0.040 b
SA	783.980 ± 29.640 bc	5.690 ± 0.280 d	12.400 ± 2.330 a	4.180 ± 0.100 f	19.600 ± 1.054 a	1.710 ± 0.040 c	0.840 ± 0.080 a
KZ	850.707 ± 1.400 a	7.210 ± 0.060 bc	13.300 ± 2.250 a	6.790 ± 0.040 a	13.833 ± 0.351 d	1.340 ± 0.020 d	0.470 ± 0.070 b
A132	819.331 ± 10.460 ab	5.330 ± 0.230 d	9.590 ± 0.300 ab	5.480 ± 0.120 c	16.600 ± 0.346 b	0.920 ± 0.020 e	0.350 ± 0.060 c
A212	826.530 ± 22.460 ab	6.760 ± 0.150 c	10.600 ± 5.490 ab	6.140 ± 0.070 b	14.733 ± 0.569 cd	1.250 ± 0.040 d	0.510 ± 0.080 b
BE	773.499 ± 27.950 c	8.550 ± 0.670 a	6.600 ± 1.560 b	4.440 ± 0.010 e	15.333 ± 0.751 c	2.490 ± 0.110 a	0.810 ± 0.020 a
Mean	801.870 ± 35.836	6.902 ± 1.242	10.692 ± 2.393	5.280 ± 1.037	16.217 ± 2.060	1.627 ± 0.575	0.588 ± 0.195

*Fresh weight expressed in mg per gram. Total soluble solids (TSS) were expressed as °Brix. Data are expressed as the mean ± standard deviation, n = 3. Different lowercase letters in the same column indicate significant differences (P < 0.01).

Table 3 Organic acid fractions and contents of six cultivars of *Ficus carica*.

Code	Organic acid	1B	SA	B1011	A132	A212	BE
CA3	Citric acid	20602.630 ±	17587.833 ±	11564.361 ±	10999.225 ±	8253.631 ±	29173.767 ±
		271.253 b	539.495 c	271.143 d	209.936 e	178.539 f	277.924 a
MA3	Malic acid	2927.023 ± 26.362 d	3218.345 ± 120.277	4582.210 ± 98.214 b	4461.124 ± 57.366 b	5943.303 ±	2493.621 ± 40.936 e
			c			172.285 a	
GA1	Gluconic acid	3943.189 ± 218.554	2508.285 ± 102.335	3229.748 ± 111.794	2740.026 ± 11.034 c	1437.925 ± 32.612	3312.465 ± 90.915 b
		a	d	b		e	
AA	Acetic acid	600.947 ± 23.796 a	560.129 ± 50.641 a	349.531 ± 20.970 b	382.384 ± 44.773 b	261.529 ± 26.225 c	264.455 ± 28.227 c
QA	Quinic acid	452.797 ± 8.349 a	415.338 ± 13.657 c	332.672 ± 3.650 d	283.326 ± 5.705 e	266.380 ± 1.170 f	435.555 ± 3.891 b
OA	Oxalic acid	331.770 ± 48.295 a	341.098 ± 55.079 a	384.889 ± 61.711 a	343.419 ± 52.237 a	364.740 ± 66.279 a	332.395 ± 74.495 a
LA	Lactic acid	191.509 ± 17.254 a	176.736 ± 26.543 a	197.195 ± 56.023 a	163.361 ± 31.312 a	145.462 ± 48.213 a	173.606 ± 29.003 a
MA1	Maleic acid	85.045 ± 7.052 c	84.501 ± 5.784 c	149.096 ± 8.206 b	160.082 ± 10.663 ab	167.105 ± 3.644 a	57.582 ± 3.247 d
SA2	Amber Acid	84.063 ± 3.825 ab	52.267 ± 0.747 e	61.976 ± 1.775 d	70.186 ± 0.738 c	87.248 ± 5.739 a	80.665 ± 0.185 b
CAA	cis-Aconitic acid	163.811 ± 35.051 a	73.336 ± 18.593 b	30.037 ± 2.800 c	20.206 ± 4.439 c	13.601 ± 2.109 c	101.696 ± 8.739 b
FA1	Fumaric acid	14.901 ± 0.745 d	18.505 ± 0.078 c	23.736 ± 0.587 b	24.749 ± 0.890 b	31.869 ± 0.229 a	12.435 ± 0.739 e
TA	Tartaric acid	3.378 ± 0.487 abc	3.604 ± 0.200 ab	3.577 ± 0.574 ab	2.925 ± 0.275 bc	2.782 ± 0.303 c	3.922 ± 0.424 a
BA	Benzoic acid	2.017 ± 0.364 a	2.231 ± 0.474 a	2.076 ± 0.207 a	2.284 ± 0.262 a	1.815 ± 0.216 a	2.240 ± 0.135 a
TAA	trans-Aconitic acid	1.644 ± 0.122 b	1.405 ± 0.018 c	0.889 ± 0.010 d	0.902 ± 0.015 d	0.737 ± 0.024 e	2.056 ± 0.010 a
PEP	PEP	0.145 ± 0.003 d	0.168 ± 0.014 d	0.385 ± 0.022 a	0.216 ± 0.010 c	0.337 ± 0.011 b	0.105 ± 0.014 e
CA1	Caffeic acid	0.145 ± 0.003 c	0.258 ± 0.032 a	0.132 ± 0.009 cd	0.115 ± 0.015 d	0.150 ± 0.011 c	0.214 ± 0.004 b
PA	Pyruvic acid	0.140 ± 0.011 a	0.122 ± 0.011 ab	0.101 ± 0.008 cd	0.116 ± 0.012 bc	0.087 ± 0.003 d	0.131 ± 0.009 ab
3PA	3-Phenylpropionic acid	0.052 ± 0.003 c	0.064 ± 0.002 c	0.089 ± 0.010 b	0.108 ± 0.009 a	0.098 ± 0.013 ab	0.095 ± 0.011 ab
4HA	4-Hydroxybenzoic acid	0.121 ± 0.014 a	0.078 ± 0.005 b	0.058 ± 0.019 b	0.058 ± 0.005 b	0.051 ± 0.011 b	0.069 ± 0.024 b
MA2	Malonic acid	0.055 ± 0.002 c	0.045 ± 0.005 c	0.112 ± 0.011 a	0.088 ± 0.005 b	0.026 ± 0.003 d	0.048 ± 0.004 c
CA2	Cichoric acid	0.041 ± 0.003 c	0.046 ± 0.005 bc	0.029 ± 0.002 d	0.047 ± 0.003 b	0.021 ± 0.002 e	0.062 ± 0.003 a
SA1	Salicylic acid	0.020 ± 0.000 bc	0.024 ± 0.004 b	0.032 ± 0.004 a	0.022 ± 0.003 b	0.032 ± 0.002 a	0.016 ± 0.002 c

GA2	Gallic acid	0.010 ± 0.001 ab	0.011 ± 0.002 ab	0.010 ± 0.002 ab	0.008 ± 0.002 b	0.011 ± 0.001 ab	0.012 ± 0.001 a
FA2	Ferulic acid	0.015 ± 0.001 a	0.010 ± 0.001 b	0.006 ± 0.000 d	0.006 ± 0.000 d	0.011 ± 0.001 b	0.008 ± 0.001 c
	Total organic acids	1225.228	1043.518	871.373	818.958	707.456	1518.634

*Data are expressed as mean microgram/gram means ± standard deviation, n = 3. Different lowercase letters within the same column indicate significant differences (P < 0.01).

Table 4 Explained variance of the first six principal components (PCs) from the principal component analysis.

Parameters	Explained variance					
	PC_1	PC_2	PC_3	PC_4	PC_5	PC_6
FA1	-0.96	-0.215	-0.025	-0.102	-0.028	0.067
MA1	-0.971	0.009	0.168	0.053	-0.095	0.031
PA	0.863	0.172	0.23	0.088	-0.192	0.108
PEP	-0.878	-0.005	0.077	0.05	0.368	-0.211
MA2	-0.271	0.682	0.38	0.205	0.006	-0.494
3PA	-0.596	0.48	-0.499	0.127	-0.225	0.223
CA1	0.597	-0.095	-0.377	-0.648	0.16	-0.006
GA1	0.398	-0.271	-0.63	0.054	0.202	-0.233
FA2	0.356	-0.848	0.266	0.1	0.057	0.192
BA	0.25	0.614	0.147	-0.285	-0.289	0.267
SA1	-0.778	-0.228	0.052	-0.131	0.324	-0.305
CA2	0.756	0.455	-0.23	-0.062	-0.337	0.107
4HA	0.643	-0.324	0.5	0.182	-0.073	-0.011
TAA	0.958	0.061	-0.229	0.136	0.002	0.035
CAA	0.863	-0.257	0.212	0.317	0.051	-0.046
QA	0.964	-0.066	0.09	0.029	0.164	-0.123
MA3	-0.97	-0.207	-0.047	0.009	0.045	0.071
CA3	0.923	0.135	-0.299	0.158	0.018	0.018
LA	0.23	0.371	0.425	0.038	0.637	0.395

SA2	-0.011	-0.391	-0.258	0.751	-0.094	0.423
TA	0.604	0.361	-0.121	-0.039	0.458	-0.171
OA	-0.285	0.328	0.207	-0.058	0.596	0.605
GA2	0.664	0.328	0.396	0.46	0.057	-0.258
AA	0.484	-0.242	0.761	-0.275	-0.073	-0.077
TSS	0.5	-0.204	0.371	-0.654	-0.268	0.167
TP	0.886	-0.089	-0.294	0.19	0.197	0.002
TF	0.701	-0.158	-0.421	-0.419	0.278	-0.062
Total %	48.86	60.785	72.114	80.602	87.34	92.825

*TP: Total phenolic content; TF: Total flavonoid content.

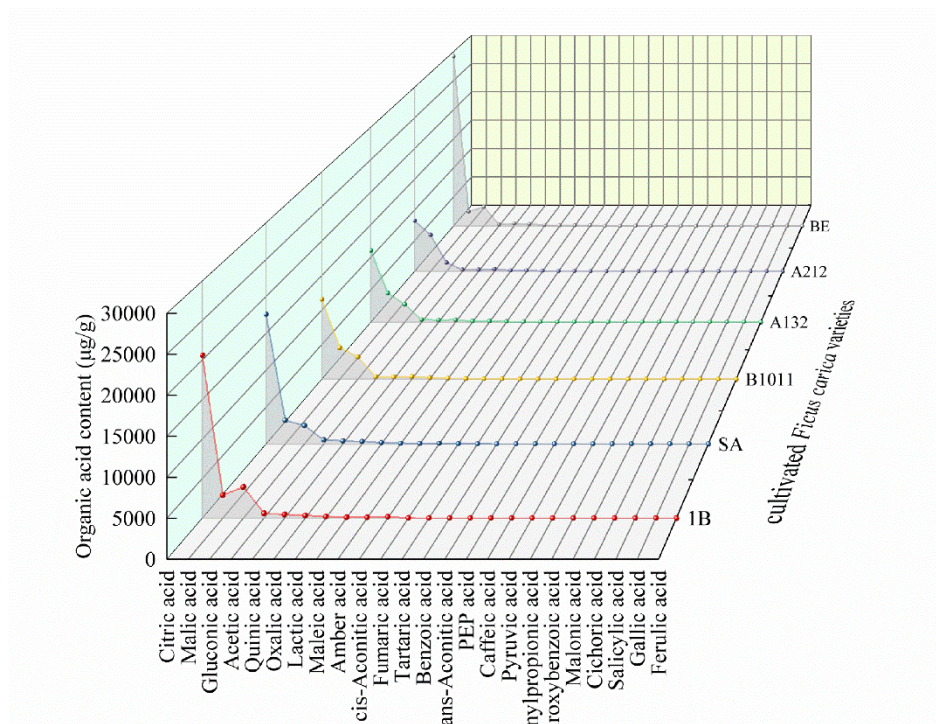


Fig. 1 Organic acid content of different cultivars of *Ficus carica*

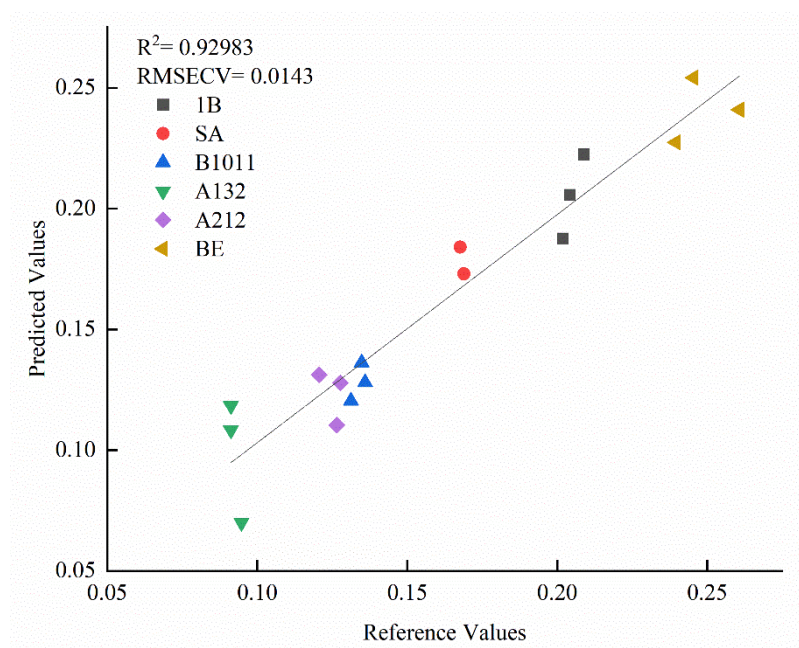


Fig. 2 Linear regression plot of the measured versus predicted total phenolic content values of *Ficus carica* samples.

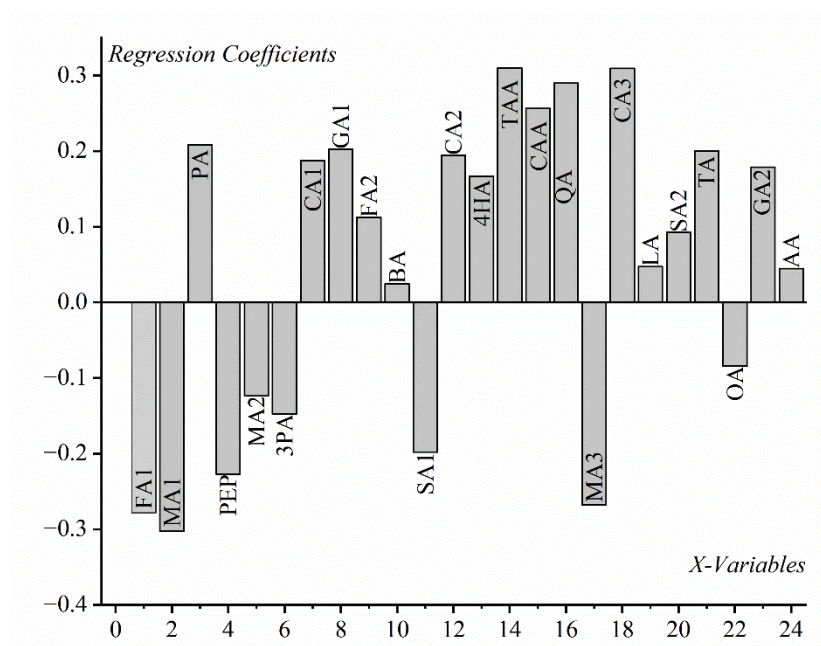


Fig. 3 Regression coefficients of total phenolic content versus each organic acid

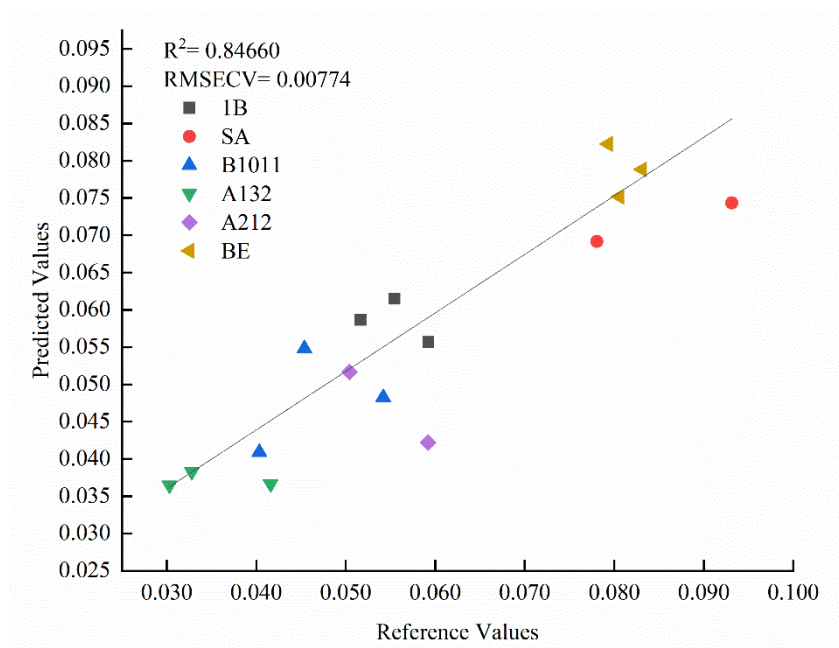


Fig. 4 Linear regression plot of the measured versus predicted total flavonoids content values of *Ficus carica* samples.

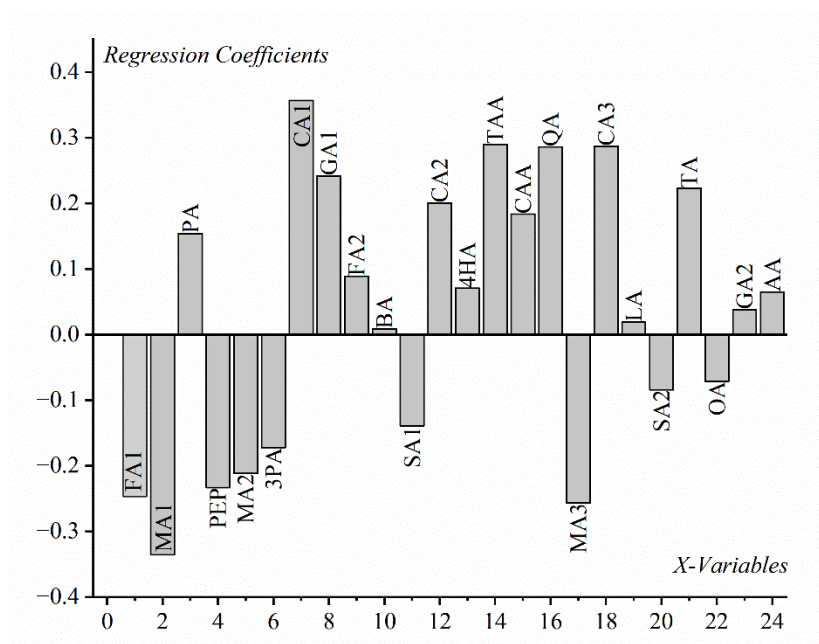


Fig. 5 Regression coefficients of total flavonoids versus each organic acid.

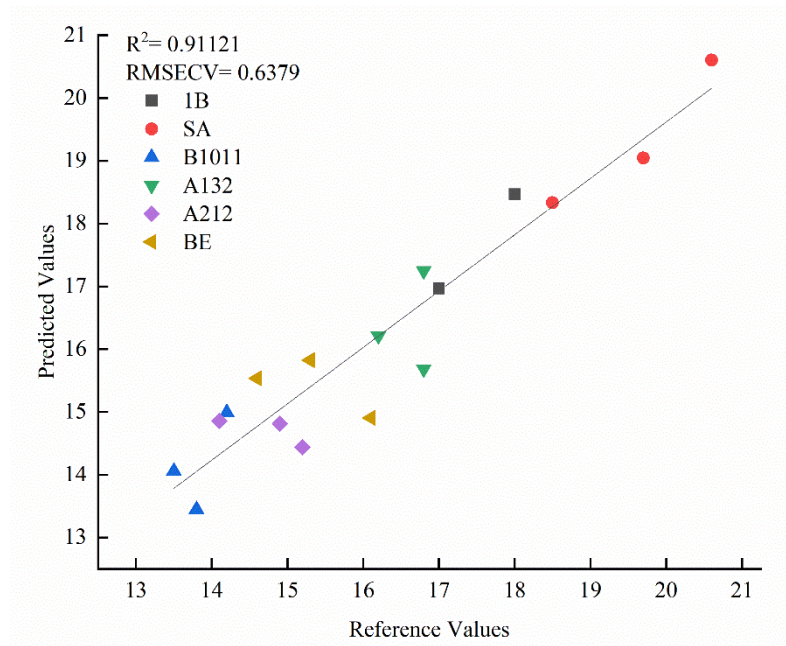


Fig. 6 Linear regression plot of the measured versus predicted total soluble solid content values of *Ficus carica* samples.

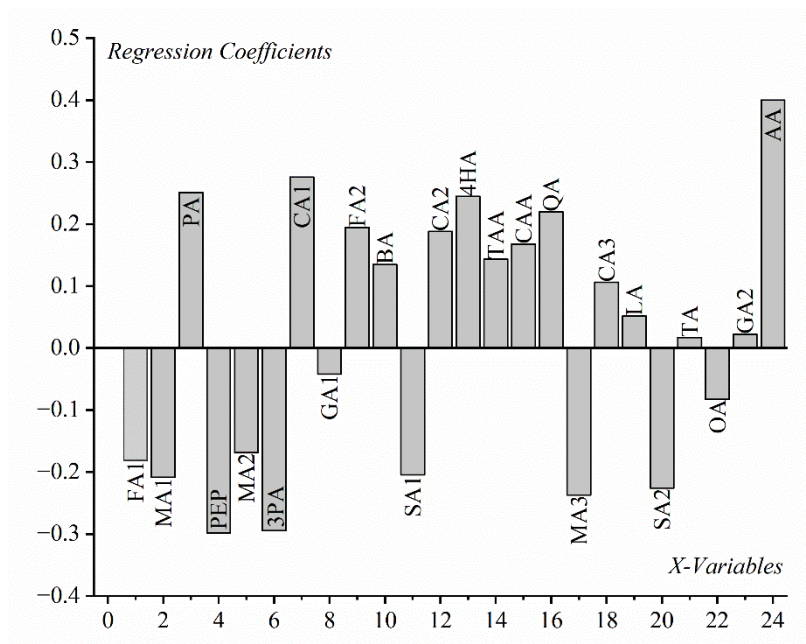


Fig. 7 Regression coefficients of total soluble solids versus each organic acid.

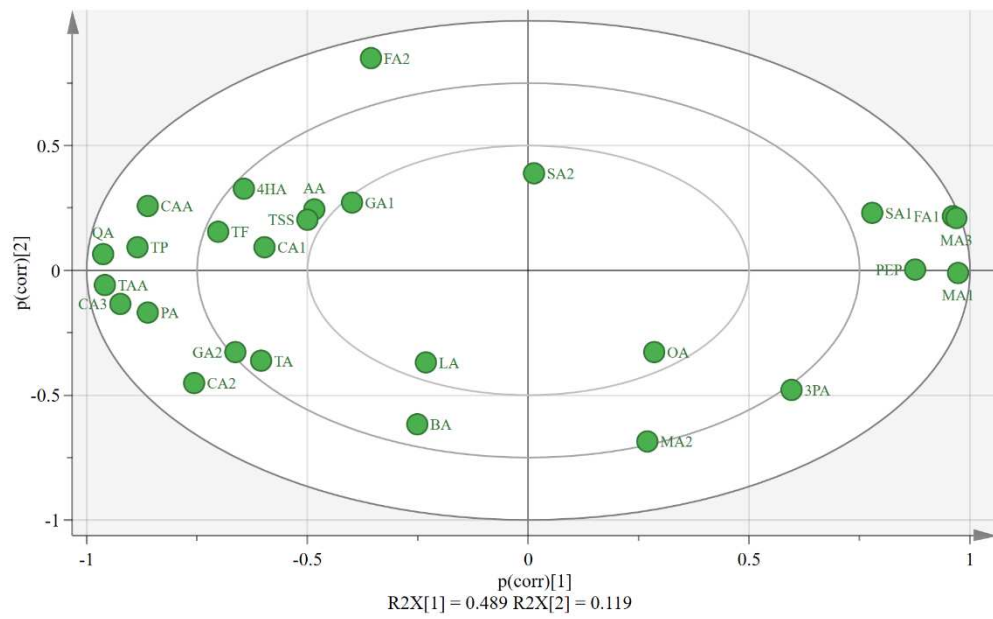


Fig. 8 Principal component analysis among each organic acid, total phenolic, total flavonoids, and total soluble solids.

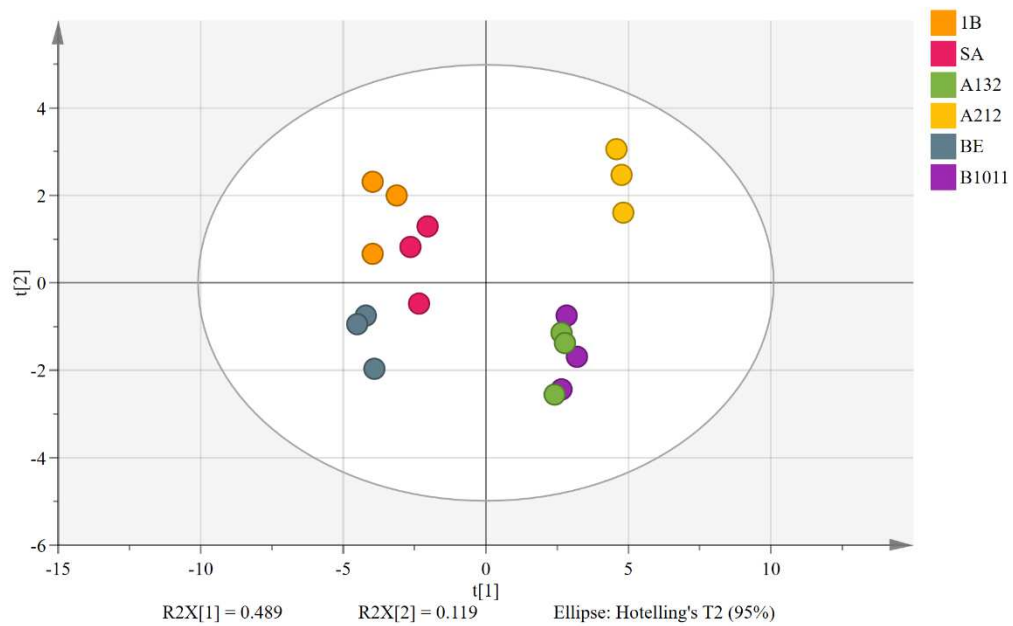


Fig. 9 Biplot obtained from principal component analysis illustrating the separation of groups.