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# 枇杷果肉有机酸组分及有机酸在果实内的分布

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**摘要**：用高效离子交换色谱(HPIC)测定了枇杷(*Eriobotrya japonica* Lindl.)18 个品种(小毛枇杷、夹脚、卓南 1 号、解放钟、富阳、森尾早生、华宝 2 号、香钟 10 号、白花、土肥、多宝 2 号、乌躬白、洛阳青、茂木、早钟 6 号、白梨、塘头 4 号和长红 3 号)的成熟果肉和 2 个品种(解放钟和早钟 6 号果)成熟果实不同组织有机酸含量。结果表明,成熟果肉中均含有苹果酸、奎尼酸、柠檬酸、异柠檬酸、α-酮戊二酸、富马酸、草酰乙酸、酒石酸 8 种有机酸,有的还含有微量的阿魏酸、顺乌头酸和 β-香豆酸。大多数品种果肉中苹果酸含量最高,平均含量为 4 399 mg $kg^{-1}$ FW,占总酸的 62.7%;其次是奎尼酸,其平均含量为 2 042 mg $kg^{-1}$ FW,占总酸的 29.1%。品种之间可滴定酸和有机酸含量差异很大。通过对果肉可滴定酸进行聚类分析,可把 18 个枇杷品种分为五个组群:极高酸(小毛枇杷)、高酸(夹脚、卓南 1 号、解放钟和富阳)、中酸(森尾早生、华宝 2 号、香钟 10 号、白花、土肥和多宝 2 号)、低酸(乌躬白、洛阳青、茂木和早钟 6 号)和极低酸(白梨、塘头 4 号和长红 3 号)。解放钟和早钟 6 号果肉和果皮的总酸含量及可滴定酸均无显著差异,但果皮和果肉的总酸含量和可滴定酸均大大高于种子。相似于果肉,果皮和种子的主要有机酸也是苹果酸和奎尼酸。果皮中苹果酸含量远高于奎尼酸,但种子中苹果酸含量比奎尼酸稍低。此外,种子中苹果酸和奎尼酸比果肉和果皮中的低得多。

**关键词**：枇杷；果实；苹果酸；有机酸组分；果肉；奎尼酸；种子；果皮
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# Organic Acid Composition in the Pulp of Loquat (*Eriobotrya japonica* Lindl.) and Distribution in Fruits

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**Abstract**: Organic acids from the ripe pulp of 18 loquat (*Eriobotrya japonica* Lindl.) cultivars (‘Xiaomaopipa’, ‘Jiajiao’, ‘Zhuonan 1’, ‘Jiefangzhong’, ‘Fuyang’, ‘Moriowase’, ‘Huabao 2’, ‘Xiangzhong 10’, ‘Baihua’, ‘Toi’, ‘Duobao 2’, ‘Wugongbai’, ‘Luoyangchin’, ‘Mogi’, ‘Zaozhong 6’, ‘Baili’, ‘Tantou 4’, ‘Changhong 3’) and their distribution in the ripe fruit of 2 cultivars (‘Jiefangzhong’ and ‘Zaozhong 6’) were determined by high-performance ion-exchange chromatography (HPIC). Eight organic acids (malic, quinic, citric, iso-citric, α-ketoglutaric, fumaric, oxaloacetic and tartaric acids) were identified in ripe pulp, while trace quantities of ferulic, *cis*-aconitic and β-coumaric acids were identified in several cultivars. The predominant organic acid of ripe pulp of most cultivars was malic acid, with an average content of 4 399 mg $kg^{-1}$ FW for all cultivars, accounting for 62.7% of the total acids. Quinic acid was the second in abundance, with an average content of 2 042 mg $kg^{-1}$ FW, accounting for 29.1% of the total acids. Other acids ranged from trace to 3.0% of the total acids. Considerable

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variations in titratable acidity and organic acid content exist among cultivars. Based on titratable acidity, 18 cultivars could be separated into 5 groups by clustering analysis: very high acidity ('Xiaomaopipa'), high acidity ('Jiajiao', 'Zhuonan 1', 'Jiefangzhong' and 'Fuyang'), medium acidity ('Moriowase', 'Huabao 2', 'Xiangzhong 10', 'Baihua', 'Toi', 'Duobao 2'), low acidity ('Wugongbai', 'Luoyangchin', 'Mogi' and 'Zaozhong 6'), and very low acidity ('Baili', 'Tantou 4' and 'Changhong 3'). No significant difference was found in the absolute amounts of total acids and titratable acidity between pulp and skins, while the amounts of total acids and titratable acidity in seeds was far lower than those in pulp and skins. The major organic acids identified in skins and seeds were malic and quinic acids. In skins, the content of malic acid was far higher than quinic acid, but in seeds it was slightly lower than quinic acid. In addition, malic acid and quinic acid content in seeds was far lower than those in pulp and skins.

**Key words**: Loquat; Fruit; Malic acid; Organic acid composition; Pulp; Quinic acid; Seed; Skin

Many kinds of fruits accumulate considerable amounts of organic acids during various development stages. These compounds are used extensively as additatives, namely antioxidants (tataric, malic and citric acids) or preservatives (sorbic and benzoic acids)[1-2]. Knowledge of the qualitative and quantitative distribution of organic acids in fruit is of considerable importance, since they influence fruit organoleptic and nutritional property. Organic acids also affect the nature and contents of other organic compounds in fruit.

Loquat (*Eriobotrya japonica* Lindl.) is a subtropical evergreen fruit tree and now commercially grown in many countries, including China, Japan, Italy, Brazil, Spain etc. In China, loquat is cultivated in 19 provinces, ranging from the Yangtze River to Hainan Island. There are many cultivars or selections in various provinces of China. The largest collection of germplasm, more than 250 cultivars, is located in Fuzhou, China[3].

Information regarding the nature and amounts of organic acids of loquat fruit has been known[4-8], but limited data are available on the organic acids of different loquat cultivars. Shaw and Wilson[8] determined the organic acid composition in the fruit of 3 loquat cultivars ('Tanaka', 'Thales' and 'Christmas'). Although Rajput and Singh[7] investigated the total acids of edible portion from 9 loquat cultivars, the quantities of individual acid present had not been determined. It has been known that organic acids are not evenly distributed within fruit[9-11]. To our best knowledge, such data have not been reported for loquat fruit. The objective of this study was to investigate organic acid profile of pulp from the ripe fruit of 18 loquat cultivars grown in the Germplasm Repository for Loquat in Fujian Fruit Research Institute, Fujian Academy of Agricultural Sciences located at Fuzhou, China. We also reported the distribution of organic acids within the ripe fruit of 2 loquat cultivars.

# 1 Materials and methods

## 1.1 Fruit materials

Eighteen loquat (*Eriobotrya japonica* Lindl.) cultivars were investigated in this study in 2004. All the samples were collected from 15-year old trees grown in the Germplasm Repository for Loquat in Fujian Fruit Research Institute, Fujian Academy of Agricultural Sciences located at Fuzhou, China. The trees were grown at a spacing of 3 m × 4 m. They received standard horticultural practices, and disease and insect control. Thirty ripe fruit from each cultivar were collected. The excised fruit were kept on ice and brought to laboratory. Fruit were carefully dissected into pulp, skins and seeds, frozen in liquid $N_2$ and then stored at -80℃ until analysis.

## 1.2 Chemicals

All chemicals used were HPLC grade or analytical reagents. Quinic, *cis*-aconitic and oxaloacetic acid were purchased from Fluka Chemical Co.; L-Malic acid was purchased from Amresco Inc.; Tartaric, cinnamic and α-ketoglutaric acids were purchased from Shanghai Chemical Reagent Co. Ltd.; Fumaric, citric, β-coumaric, ferulic and iso-citric acids were purchased from Sigma Chemical Co.

### 1.3 Analysis of titratable acidity

Titratable acidity was titrated with 0.1 mmol/L NaOH to the end point pH 8.1 and the total acidity calculated as malic acid[12].

### 1.4 Determination of organic acids

Organic acids were extracted according to the method of Ding et al.[5] with some modifications. One gram of frozen sample was ground in 3 ml of 95% (V/V) ice-cold methanol, shaken for 10 min, and filtered. The pellet was extracted twice again with 3 ml of 80% (V/V) ice-cold methanol. The combined extracts were evaporated under vacuum at less than 35℃ until the methanol was removed, and the residue was dissolved in 25 ml water and centrifuged to remove undissolved materials. One ml of aliquot was passed through the 0.45 μm membrane filter, and the filterate was then analysed by high-performance ion-exchange chromatography (HPIC, Dionex DX-320, Dionex Corp., Sunnyvale, California) according to the method of Chen et al.[4]. Figs. 1 and 2 show the chromatograms of organic acids in loquat plup and a standard mixture of organic acids, respectively.

## 2 Results and discussion

As shown in Table 1, ripe pulp from 18 cultivars all composed of, at least, 8 identified organic acids:

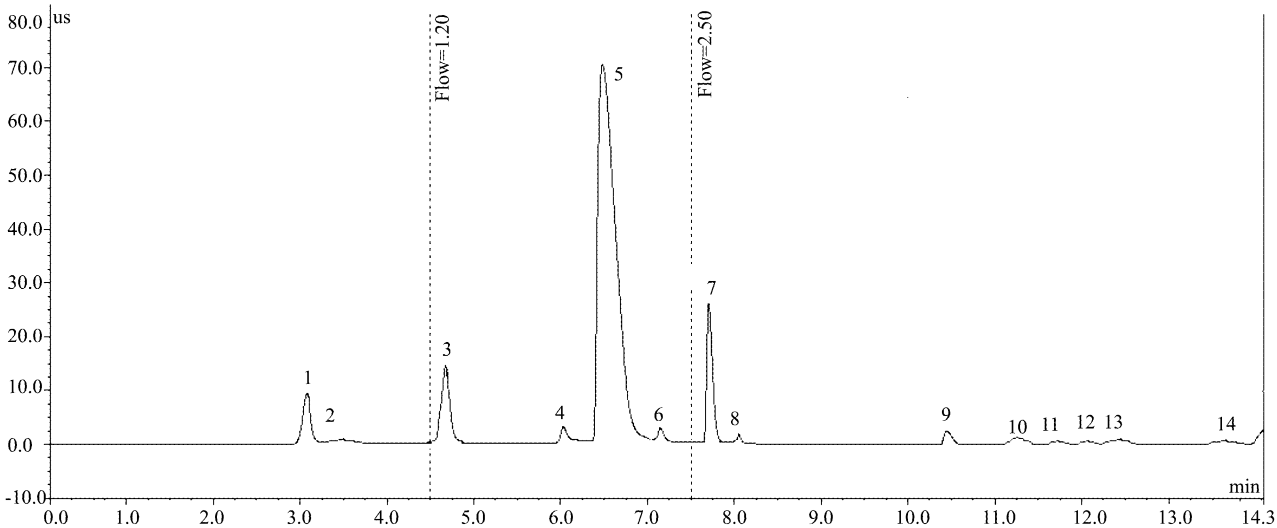


Fig. 1 Chromatogram of organic acids in pulp from ‘Jiegfangzhong’ loquat

1. Quinic acid; 2. Oxaloacetic acid; 3 ~ 4. Unknowns; 5. L-Malic acid; 6. Tartaric acid; 7. α-Ketoglutaric acid; 8. Fumaric acid; 9. Unknown; 10. Citric acid; 11. Iso-citric acid; 12. *cis*-Aconitic acid; 13. Ferulic acid; 14. β-Coumaric acid.

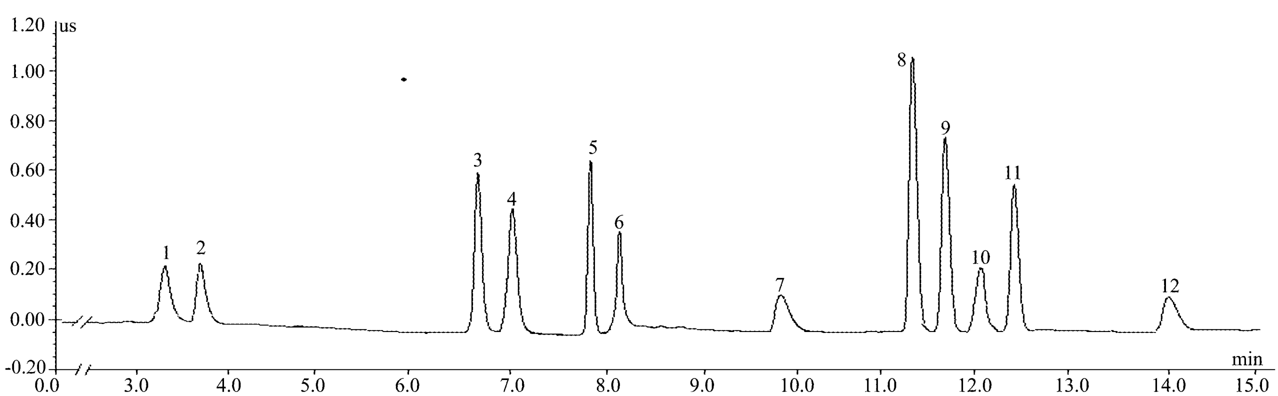


Fig. 2 Chromatogram of a standard mixture of organic acids

1. Quinic acid; 2. Oxaloacetic acid; 3. L-Malic acid; 4. Tartaric acid; 5. α-Ketoglutaric acid; 6. Fumaric acid; 7. Cinnamic acid; 8. Citric acid; 9. Iso-citric acid; 10. *cis*-Aconitic acid; 11. Ferulic acid; 12. β-Coumaric acid.

malic, quinic, citric, iso-citric, α-ketoglutaric, fumaric, oxaloacetic and tartaric acids. Ripe pulp of several cultivars also contained trace quantities of ferulic, *cis*-aconitic and β-coumaric acids. This is in general agreement with previous reports[5–6,8,13]. As with other studies, we found that the predominant organic acid of pulp from the ripe fruit of major loquat cultivars was malic acid with an average content of 4 399 mg $kg^{-1}$ FW for all cultivars, accounting for 62.7% of the total acids. The highest malic acid content, 8 912 mg $kg^{-1}$ FW, was found in ‘Xiaomaopipa’ and the lowest content, 1 299 mg $kg^{-1}$ FW in ‘Changhong 3’. Malic acid was reported to be 83% of the total acids and citric acid was the only other acid present in loquat fruit[6]. Shaw and Wilson[8] determined the organic acid composition in the fruit of 3 loquat cultivars (‘Tanaka’, ‘Thales’ and ‘Christmas’). Malic acid was the predominat organic acid and citric acid was the second in the abundance. Two acids were quantified in all samples. In addition, trace quantities of several unknown acids was observed in ‘Tanake’ fruit. Randhawa and Singh[13] reported the presence of succinic and tartaric acids in addition to malic and citric acids in loquat fruit, but no succinic acid was detected in our study (Table 1).

Our data showed clearly that quinic acid was the second abundant acid in ripe pulp. Quinic acid content ranged from 1 001 mg $kg^{-1}$ FW for ‘Zaozhong 6’ to 3 296 mg $kg^{-1}$ FW for ‘Zhuonan 1’, with an average content of 2 042 mg $kg^{-1}$ FW, accounting for 29.1% of the total acids. Except for ‘Changhong 3’ and ‘Wugongbai’, content of malic acid was much higher than that of quinic aid (Table 1). This is consistent with our previous report that loquat fruit and leaves contained large quantities of quinic acid[4]. To our best knowledge, quinic acid had not been reported previously in loquat fruit by other workers. Quinic acid is formed by quinate dehydrogenase (EC 1. 1. 1. 25) from 3-dehydroquinate[14] and has been reported to present in large quantities in sea buckthorn (*Hippohae rhamnoides* L.)[15], peach (*Prunus spersica* (L.) Batsch)[16–18], *Prunus davidiana* (Carr.) Franch.[19], apple (*Malus domestica* Borkh.), pear (*Pyrus communis* L.)[20–21], highbush blueberry (*Vaccinium corymbosum* L.), rabbiteye blueberry (*V. ashei* Reade)[22], *V. acrtostaphylos* L., *V. myrtillus* L.[23], satsuma mandarin (*Citrus unshiu* Marc.)[24], kiwifruit (*Actinidia chinensis* Planch.)[10,25–27], and quince (*Cydonia oblonga* Miller)[28]. Other acids in ripe pulp ranged from trace to 3.0% of the total acids (Table 1). The quantities of malic acid and total acids, and titratable acidity of pulp are similar to previous reports[6–8].

As shown in Table 1, titratable acidity and contents of total acids and individual organic acid in ripe pulp depended largely upon cultivars. The highest coefficient of variation (CV), 158.8%, was observed in tartatic acid and the lowest CV, 27.9% in quinic acid. The CVs for titratable acidity, total acids and malic acid were 40.6%, 29.7% and 39.6%, respectively. Despite of this variation, there are features common to these analyzed samples. Except for ‘Wugongbai’ (78.2%) and ‘Xiaomaopipa’ (88.0%), the sum of malic acid and quinic acid represented 90.2% ~ 95.6% of the total acids in the other 16 cultivars, with an average of 91.9% and a CV of 4.3% (data not shown). Similar results have been obtained in quince (*Cydonia oblonga* Miller) pulp and peel[28].

Table 2 shows the correlation coefficients among organic acids of ripe pulp. The highest relationship was observed between total acids and titratable acidity, with a correlation coefficient of 0.9644. The titratable acidity, total acids, malic acid and iso-citric acid were positively correlated with each other at $P < 0.001$. Citric acid was also positively correlated with titratable acidity ($P < 0.01$), total acids ($P < 0.01$), malic acid ($P < 0.05$), and iso-citric acid ($P < 0.001$). Quinic acid was correlated with titratable acidity, citric and iso-citric acids at $P < 0.05$, but it was not significantly correlated with total acids and malic acid. Oxaloacetic acid was positively correlated with titratable acidity ($P < 0.001$), total acids ($P < 0.01$), malic acid ($P < 0.01$), and iso-citric acid ($P < 0.01$).

**Table 1 Organic acid composition ( mg $kg^{-1}$ FW) in ripe pulp of 18 loquat cultivars**

| Cultivars | Malic | Quinic | Citric | Iso-citric | α-Ketoglutaric | Fumaric | Oxaloacetic | Tartaric | Ferulic | *cis*-Aconitic | β-Coumaric | Total acids | Titratable acidity (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Xiaomaopipa | 8912 ±92a | 2490 ±85bc | 114 ±2ab | 38 ±3a | 260 ±22a | 101 ±14ab | 126 ±17a | 900 ±181a | 7 ±0a | 10 ±0a | nd | 12958 ±129a | 1.270 ±0.119a |
| Jiajiao | 5987 ±422c | 2431 ±29bc | 52 ±5c | 17 ±1cd | 259 ±17a | 65 ±13bcd | 81 ±10b | Trace | 3 ±0b | 7 ±0c | nd | 8902 ±416b | 0.818 ±0.073b |
| Zhuonan 1 | 5433 ±498cd | 3296 ±352a | 135 ±11a | 31 ±3b | 121 ±3de | 73 ±1abcd | 30 ±1cde | 58 ±3de | nd | nd | nd | 9177 ±855b | 0.794 ±0.075b |
| Jiefangzhong | 6964 ±510b | 1401 ±279g | 55 ±5c | 18 ±2c | 95 ±8e | 42 ±6d | 10 ±3de | 177 ±29cd | 1 ±0d | 8 ±0b | 2 ±0a | 8773 ±778b | 0.736 ±0.101bc |
| Fuyang | 4909 ±365de | 2163 ±156bcde | 72 ±5bc | 10 ±1ef | 222 ±22abc | 80 ±10abcd | 17 ±2de | 215 ±52bc | nd | nd | nd | 7688 ±272c | 0.692 ±0.066bcd |
| Moriowase | 4140 ±238ef | 2538 ±125bc | 42 ±7c | 16 ±2cd | 277 ±32a | 85 ±11abc | 20 ±3de | 2 ±1e | nd | nd | nd | 7120 ±176cd | 0.659 ±0.070cde |
| Huabao 2 | 4797 ±349de | 2115 ±103bcde | 29 ±6c | 11 ±1ef | 211 ±2abcd | 49 ±9cd | 12 ±3de | 4 ±1e | nd | nd | nd | 7228 ±394cd | 0.633 ±0.057cdef |
| Xiangzhong 10 | 4576 ±324de | 2335 ±326bcd | 30 ±1c | 12 ±0de | 247 ±12ab | 51 ±2cd | 59 ±4bc | 355 ±38b | nd | nd | nd | 7665 ±380c | 0.628 ±0.064cdef |
| Baihua | 4149 ±385ef | 1982 ±107cdef | 62 ±8bc | 12 ±2de | 261 ±11a | 72 ±13abcd | 17 ±1de | 232 ±17bc | nd | nd | nd | 6787 ±445cde | 0.613 ±0.055cdef |
| Toi | 3577 ±133fg | 1997 ±273cdef | 44 ±7c | 10 ±1ef | 259 ±12a | 74 ±11abcd | 38 ±14cde | 159 ±47cde | nd | nd | nd | 6158 ±293defg | 0.613 ±0.046cdef |
| Duobao 2 | 3109 ±362gh | 2339 ±243bcd | 57 ±1c | 20 ±1c | 219 ±4abc | 62 ±3bcd | 56 ±2bc | 32 ±2b | 2 ±0c | 4 ±0e | nd | 5900 ±608efg | 0.599 ±0.043def |
| Wugongbai | 2418 ±671h | 2616 ±592b | 73 ±5bc | 10 ±0ef | 257 ±34a | 52 ±5cd | 16 ±1de | 994 ±191a | nd | nd | nd | 6436 ±905def | 0.537 ±0062ef |
| Luoyangchin | 4370 ±466ef | 1390 ±344g | 27 ±5c | 8 ±1ef | 272 ±22a | 54 ±1cd | 36 ±14cd | 2 ±0e | 3 ±0b | nd | nd | 6162 ±176defg | 0.507 ±0.061f |
| Mogi | 4424 ±290ef | 1460 ±166fg | 31 ±1c | 10 ±0ef | 222 ±6abc | 50 ±3cd | 37 ±3cd | 4 ±1e | 1 ±0d | nd | nd | 6239 ±224defg | 0.502 ±0.060f |
| Zaozhong 6 | 4156 ±833ef | 1001 ±54g | 31 ±5c | 12 ±1de | 157 ±12bcde | 65 ±9bcd | 15 ±2de | 29 ±2de | nd | nd | nd | 5466 ±320fgh | 0.440 ±0.0589f |
| Tantou 4 | 2518 ±706h | 1725 ±29efg | 23 ±4c | 8 ±2ef | 210 ±16abcd | 110 ±16a | 18 ±3de | 2 ±0e | nd | nd | nd | 4614 ±741hi | 0.330 ±0.056g |
| Baili | 3438 ±86fg | 1377 ±115g | 70 ±2bc | 13 ±0de | 127 ±16cde | 96 ±10ab | 4 ±0e | 129 ±81cde | 1 ±0d | 6 ±0d | 1 ±0b | 5262 ±67gh | 0.240 ±0.034gh |
| Changhong 3 | 1299 ±137i | 2107 ±182bcd | 27 ±1c | 7 ±0f | 102 ±7e | 88 ±5abc | 9 ±1de | 54 ±5de | 1 ±0d | 1 ±0f | nd | 3695 ±422i | 0.165 ±0.033h |
| Meam | 4399 | 2042 | 54 | 15 | 210 | 71 | 33 | 186 | | | | 7013 | 0.599 |
| Max | 8912 | 3296 | 135 | 38 | 277 | 110 | 126 | 994 | | | | 12958 | 1.270 |
| Min | 1299 | 1001 | 23 | 7 | 95 | 42 | 04 | Trace | | | | 3695 | 0.165 |
| SD | 1741 | 569 | 31 | 8 | 62 | 20 | 31 | 295 | | | | 2080 | 0.243 |
| CV (%) | 39.6 | 279 | 56.9 | 55.8 | 29.4 | 27.9 | 92.2 | 158.8 | | | | 29.7 | 40.6 |

n = 5; Data followed by different letters within the same column are significantly different by Duncan's multiple range test at 0.05 level; CV: Coefficient of variation; nd: not detected.

The most common measure of acidity is titratable acidity, since it correlates well with perceived sourness[16]. Sensory analysis experiments with artificial acid solution showed that the perceived acidity closely correlated with titratable acidity, and to a less extent pH[29-30]. As shown in Table 1, considerable variations in titratable acidity of ripe pulp exist between cultivars. Clustering analysis based on titratable acidity showed that all 18 cultivars were basically classified into 5 groups: very high acidity, high acidity, medium acidity, low acidity, and very low acidity. Very high acidity group only included ‘Xiaomaopipa’, with a titratable acidity of 1.270%. High acidity, medium acidity, low acidity, and very low acidity groups consisted of 4, 6, 4 and 3 cultivars, respectively, with a titratable acidity range of 0.692% ~ 0.818%, 0.599% ~ 0.659%, 0.440% ~ 0.537% and 0.165% ~ 0.330%, respectively (Table 1, Fig. 3).

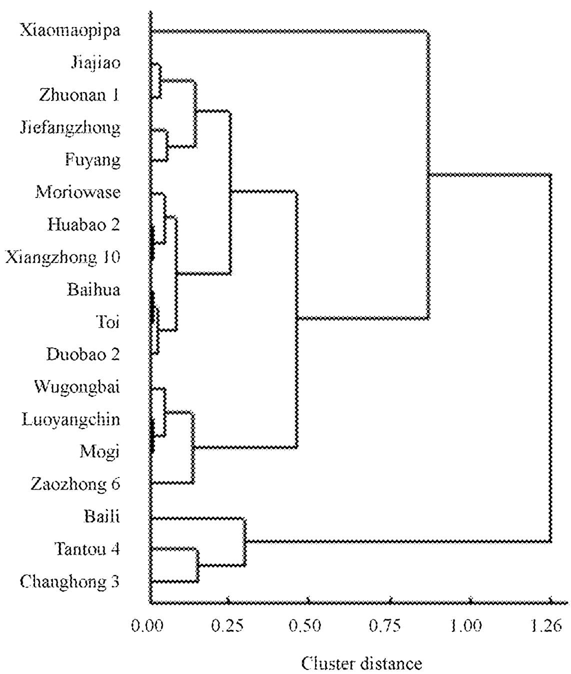


Fig. 3 Cluster analysis for 18 loquat cultivars based on titratable acidity of ripe pulp

Distribution of organic acids in the ripe fruit of 2 cultivars is shown in Table 3. In ‘Jiefangzhong’ and ‘Zaozhong 6’, no significant difference was found in the absolute amounts of total acids and titratable acidity between pulp and skins, while the amounts of total acids and titratable acidity in seeds was much lower than in pulp and skins. Previous study has shown that grape skins have the highest total acid content, followed by pulp and seeds[9]. This is basically consistent with our results. Like pulp, both skins and seeds of ‘Jiefangzhong’ and ‘Zaozhong 6’ presented 8 organic acids: malic, quinic, citric, iso-citric, α-ketoglutaric, fumaric, oxaloacetic and tartaric acids. Skins also contained trace quantities of ferulic, *cis*-aconitic and β-coumaric acids. Malic and quinic acids were the main acids in pulp, skins and seeds. In pulp and skins, content of malic acid was much higher than that of quinic acid, but in seeds, content of malic aicd was slightly lower than that of quinic acid. The sum of malic acid plus quinic acid presented 86.9% ~ 88.6% of the total acids in skins and 94.3% ~ 95.5% in pulp; other acids attained only trace to 5.2% of the total acids in both pulp and skins. In seeds, the sum of malic acid plus quinic acid presented only 53.5% ~ 57.7% of the total acids; citric, α-ketoglutaric and tartaric acids accounted for 15.6% ~ 17.0%, 11.0% ~ 11.8% and 8.3% ~ 12.3% of the total acid content, respectively; other acids presented only 0.1% ~ 5.2%.

It is evident from this study that the composition of organic acids in loquat ripe pulp depends largely on cultivars. This work presents the first report of organic acids in loquat fruit tissues (pulp, skins and seeds). The wide range of diversity in malic acid content and titratable acidity in loquat ripe pulp among different cultivars may enable breeders to breed and select cultivars with improved flavor based on superior phenotypes. Knowledge of the organic acid composition of loquat fruit may be of use to food technologists and consumers.

**Acknowledgement** We thank Germplasm Repository for Loquat in Fujian Fruit Research Institute, Fujian Academy of Agricultural Sciences for providing loquat fruit.

**Table 2 Correlation of matrix among organic acids of loquat ripe pulp**

| | Malic | Quinic | Citric | Iso-citric | α-Ketoglutaric | Fumaric | Oxaloacetic | Tartaric | Total acids | Titratable acidity |
|---|---|---|---|---|---|---|---|---|---|---|
| Malic | 1.000 | | | | | | | | | |
| Quinic | 0.1264 | 1.0000 | | | | | | | | |
| Citric | 0.4932* | 0.5997** | 1.0000 | | | | | | | |
| Iso-citric | 0.7265*** | 0.5146* | 0.8124*** | 1.0000 | | | | | | |
| α-Ketoglutaric | 0.0988 | 0.2170 | -0.1310 | -0.0611 | 1.0000 | | | | | |
| Fumaric | -0.1028 | 0.1085 | 0.2303 | 0.2021 | -0.0498 | 1.000 | | | | |
| Oxaloacetic | 0.6190** | 0.3483 | 0.3379 | 0.6524** | 0.4588 | 0.1118 | 1.000 | | | |
| Tartaric | 0.2573 | 0.3272 | 0.4705* | 0.3464 | 0.2726 | 0.0394 | 0.3828 | 1.000 | | |
| Total acids | 0.9310*** | 0.4493 | 0.6659** | 0.8253*** | 0.2143 | -0.0366 | 0.7063** | 0.4701* | 1.000 | |
| Titratable acidity | 0.8782*** | 0.4823* | 0.6021** | 0.7902*** | 0.3689 | -0.0672 | 0.7452*** | 0.4417 | 0.9644*** | 1.0000 |

*, **, ***: Significant at $P<0.05$, 0.01 or 0.001 level, respectively.

**Table 3 Organic acid composition ( $mg\ kg^{-1}$ FW) in pulp, skins and seeds from the ripe fruit of 2 loquat cultivars**

| Cultivars | Tissue | Malic | Quinic | Citric | Iso-citric | α-Ketoglutaric | Fumaric | Oxaloacetic | Tartaric | Ferulic | *cis*-Aconitic | β-Coumaric | Total acids | Titratable acidity (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jiefangzhong | Pulp | 6964 ±510a | 1401 ±279b | 55 ±5c | 18 ±2c | 95 ±8c | 42 ±6c | 10 ±3b | 177 ±29b | 1 ±0b | 8 ±0a | 2 ±0b | 8773 ±778a | 0.736 ±0.101a |
| | Skins | 6079 ±42b | 1520 ±123a | 114 ±16b | 49 ±3a | 335 ±23a | 159 ±9a | 17 ±7a | 455 ±13a | 2 ±0a | 7 ±0b | 3 ±0a | 8728 ±92a | 0.710 ±0.021a |
| | Seeds | 466 ±30c | 784 ±48c | 369 ±18a | 39 ±3b | 256 ±8b | 63 ±2b | 10 ±1b | 179 ±9b | nd | nd | nd | 2166 ±147b | 0.220 ±0.019b |
| Zaozhong 6 | Pulp | 4156 ±833a | 1001 ±54b | 31 ±5c | 12 ±1b | 157 ±12c | 65 ±9c | 15 ±2c | 29 ±2b | nd | nd | nd | 5466 ±320a | 0.440 ±0.059a |
| | Skins | 3348 ±78b | 1598 ±42a | 78 ±2b | 13 ±4b | 299 ±15a | 132 ±16a | 25 ±4a | 92 ±3a | Trace | Trace | Trace | 5585 ±49a | 0.433 ±0.018a |
| | Seeds | 458 ±17c | 529 ±18c | 288 ±4a | 40 ±4a | 203 ±7b | 95 ±4b | 2 ±0b | 227 ±15b | nd | nd | nd | 1842 ±58b | 0.148 ±0.010b |

n = 5; Data followed by different letters within the same column for the same cultivar were significantly different by Duncan's multiple range test at 0.05 level; nd: not detected.

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