Juice Constituents in *Actinidia arguta* Fruits Produced in Shinjo, Okayama

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*Actinidia arguta* fruits were collected from cultivated and wild vines in Shinjo Village, Okayama Prefecture, in order to evaluate their compositional characteristics, especially as a possible “healthy fruit”. Imported kiwifruit (cv. Hayward) and lemon (cultivar unknown), and domestic apple (cv. Fuji) were purchased at a market in Okayama and analyzed for the reference. Hard-mature and soft-ripe fruits of normal size were harvested from each vine as well as soft-ripe small-sized fruit. Juice vitamin C contents were as high as 220 mg/100 mL in hard-mature Mine-ko fruit with a normal size and 260 mg/100 mL in soft-ripe small Mitsuko fruit. Vitamin C contents in kiwifruit, lemon, and apple were about 100 mg/100 mL, 50 mg/100 mL, and 4 mg/100 mL, respectively. Juice total polyphenol content and DPPH radical scavenging activity in *A. arguta* fruit were insignificantly higher than those in kiwifruit but significantly higher than in apple. Among the juice constituents, quinic acid content was highest in *A. arguta* fruit but the total sugar content was the lowest. Flesh Ca, Mg, Mn contents were higher in *A. arguta* fruit than in kiwifruit and apple. From these results, *A. arguta* fruit produced in Shinjo can be evaluated as vitamin C-rich fruit with abundant polyphenol substances, and several useful minerals such as Ca, Mg, and Mn.

**Key words:** *Actinidia arguta*, fruit composition, vitamin C, polyphenol, minerals

**Introduction**

Wild vines of *Actinidia arguta* are commonly found in mountainous areas of the Japanese Islands. The fruit is very sour and faintly sweet, favorable characteristic aromas, so that it has been utilized for fresh eating and/or processed jam and wine. Recently *A. arguta* fruit has become famous for its high content of vitamin C, and a special digesting enzyme named actinidin. Production of *A. arguta* fruits has been expanding in several prefectures in the north-east of Japan, such as Yamagata Prefecture. In Shinjo Village, located at the north-western part of Okayama Prefecture, cultivation of *A. arguta* vines has been encouraged as a regional agricultural production. In this investigation, we analyzed *A. arguta* fruit compositions and compare them with those of several other kinds of fruit to evaluate their fruit quality as a healthy food.

**Materials and Methods**

**Tested vines and fruit harvesting**

Young vines (3-year-old) of cv. Mitsuko and Mineko, introduced from Yamagata Prefecture in 2000 and cultivated in a commercial vineyard located in Odokoro in Shinjo Village, were selected as test vines because of their normal development of canopy and shoots. The vines were trained on a horizontal trellis (Fig. 1). A mature vine of a native cultivar cultivated in the neighboring district and a wild vine growing in the forest near to the district were also chosen for fruit collection.

The fruits on each test vine were variable in size at the ordinal harvest time, mid-September, as shown in Fig. 2. Most fruits ranged between 7-10 g (normal fruit) and the rest between 3-4 g (small fruit). Furthermore, some fruit were already soft-ripe but others remained hard. One hundred grams of each type of fruit were sampled from each test vine on September 12, 2003.

Commercially shipped Mitsuko fruit that had been stored at 0-2°C in Hiruzen Wine Com. Ltd. for two months was also utilized for evaluating general fruit compositions. As a comparison, apple fruit (cv. Fuji, imported from Nagano), kiwifruit (cv. Hayward, from
New Zealand), and yellow lemon (cultivar unknown, from Florida) were purchased at a supermarket in Okayama City in mid-November.

**Fruit analysis**

The sample fruits were peeled and 20 g of flesh were homogenized in a homogenizer, then centrifuged at 8000 rpm for 20 min. The obtained juices were used for determination of the following juice constituents.

- Vitamin C; Indophenol method
- Total polyphenol; Polyphenol analyzer (TOYOBO PA-20)
- Free radical scavenging activity; DPPH method
- Soluble solids; Refractometer (ATAGO N-α)
- Total acidity; Titration with 0.1 N NaOH
- Sugars; GC after juice separation with ion exchange resin
- Acids; HPLC after juice separation with ion exchange resin

**Results and Discussion**

**Vitamin C**

Vitamin C contents in various types of *A. arguta* fruit are shown in Fig. 3. In each cultivated and wild vine, soft-ripe fruit tended to have lower levels of vitamin C than hard mature ones. Small fruit of Mitsu-ko contained a significantly higher level of vitamin C than normal ones, although no difference was found between them in Mine-ko. The fruit harvested from the native cultivar vine contained the lowest amount of vitamin C in each type of the fruit, but soft-ripe fruit from the wild vine had higher vitamin C than soft-ripe fruit of other cultivars.
Comparison of vitamin C levels among several kinds of fruit revealed that *A. arguta* fruit (cv. Mitsu-ko) had the highest level, 80–100 mg/100 mL (Fig. 4). Kiwifruit had a similar level to that of *A. arguta*. Their vitamin C contents were about double and fifty times of those in lemon and apple fruit, respectively. In general, vitamin C contents in most fruit ranged from 10 to 50 mg/100 g. Persimmon, kiwifruit, and strawberry are generally known as vitamin C-rich fruit, containing 70–80 mg/100 g of vitamin C\(^6\). In our present data, *A. arguta* fruit, even after storage for two months, contained a similar vitamin C level to that of kiwifruit. Furthermore, freshly harvested fruits from Mitsu-ko, Mine-ko and the wild vine contained as high as 150–200 mg/100 g of vitamin C. These data prove the *A. arguta* fruit to be an extremely vitamin C-rich fruit. Kataoka *et al.*\(^7\) also reported the high vitamin C content of *A. arguta* fruit produced in Kagawa Prefecture.

**Total polyphenol substances**

Total polyphenol contents in *A. arguta*, kiwifruit, and apples are shown in Fig. 5. *A. arguta* fruit contained about 300 ppm of total polyphenol, which were about 1.4 times and 8.8 times higher than that of kiwifruit and apple, respectively. It is generally known that polyphenol substances in foods have positive effects on human health, such as preventing high blood pressure, heart injuries, and also from cancer development\(^10\). The high polyphenol contents of *A. arguta* fruit might be evaluated as a healthy fruit. However, we already reported that *Vitis coignetiae* berries, harvested from the vineyards in Hiruzen, Okayama Prefecture, contained as high as 2000 ppm of polyphenol substances\(^9\). We must conclude that *A. arguta* fruit is not the highest producer of polyphenol substances.

**Free radical scavenging activity**

Fig. 6 indicates free radical scavenging activity in three kinds of fruit by presenting the juice volume that decreased the given free radicals in DPPH to below half in this experimental system. Needed juice volume was 5.70 µL in apple, 4.00 µL in kiwifruit, and 3.51 µL in *A. arguta*. These data indicate that *A. arguta* fruit has significantly higher activity of free radical scavenging than apple, but there was no significance between the activity of kiwifruit.

Free radicals are produced in the human body accompanied with various physiological and biochemical processes, which in turn produce various diseases and cancers. Fruits possessing radical scavenging activity are generally evaluated as healthy foods. In most cases free radical scavenging activities are generated from polyphenol substances. A close relationship between the polyphenol contents and free radical scavenging activities in the three kinds of fruits tested (Fig. 5 and Fig. 6) may be reasonable.
**Sugars and acids**

Compositions of juice sugar and acid in three kinds of tested fruits are summarized in Table 1. Total soluble solid (TSS) content in *A. arguta* fruit was about 11 Brix which was significantly lower than that in kiwifruit and apple. It should be noted that *A. arguta* fruit produced in commercial vineyards in Shinjo Village contained low TSS even when they ripened fully. However, it may be possible to obtain higher TSS by optimal adjustment of the fruit-leaf ratio as generally demonstrated in grapes. *A. arguta* fruit contained three kinds of sugars, glucose, fructose and sucrose, in similar proportions, while kiwi-fruit contained glucose and fructose predominantly and apples mainly fructose, respectively.

*A. arguta* fruit contained about 0.6 g/100 mL of total acids (citric acid equivalent), which was significantly lower than that in kiwi-fruit. HPLC analyses revealed that *A. arguta* fruit contained quinic acid at a higher level than kiwifruit. In apples, quinic acid was not detected. Quinic acid is a specific organic acid contained in the fruit of *Actinidia* plants. Phivinil et al.17, who examined the organic acid contents in fruit of various kinds of *Actinidia* species and mutual hybrids, noted that *A. arguta* fruits contain higher levels of citric acid than quinic acid. The inconsistency in the major acid constituent of *A. arguta* fruits may be caused by cultivation conditions such as soil fertility and climatic conditions.

**Amino acids**

Amino acid concentrations in *A. arguta*, kiwifruit, and apples are shown in Fig. 7. Major amino acids in *A. arguta* fruit were aspartic acid, glutamine, and alanine, while glutamine was the major constituent in kiwifruit, and aspartic acid in apples. Aspartic acid, glutamine, and alanine in foods are known to emphasize sourness, deliciousness, and sweetness in foods, respectively, when contained at a concentration of 15 ~20 mmol/L or higher. Present data suggest that these amino acids may play a significant part in the deep and favorable taste of *A. arguta* fruit, because of their higher concentrations.

**Total nitrogen (N)**

Total N contents in *A. arguta* fruit and kiwifruit were 1.85 ± 0.10% (at DW base) and 1.65 ± 0.03%, respectively, which were significantly higher than that in apple (0.95 ± 0.07%). The main nitrogenous substances in fruit are supposed to be enzymes catalyzing various metabolisms for fruit ripening. It is generally known that *Actinidia* fruits contain a protein-catalyzing enzyme, named 'Actinidin', proving a special healthy function in this fruit. The high percentage of total N might stem from high Actinidin contents.

**Minerals**

Mineral contents in tested fruit are shown in Table 2. *A. arguta* fruit contained higher K, Ca, and Mg than kiwifruit and apple. The Ca concentration in *A. arguta* fruit was about 1.8 and 10 times higher than that in kiwifruit and apple, respectively. For micro-element concentrations, Mn in *A. arguta* fruit was significantly higher than the other fruits, and Fe was 1.5 times higher than in apple. No significant difference was found in B and Zn concentrations among the tested

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**Table 1** Juice TSS, TA, and sugar and acid composition in *A. arguta* (cv. Mitsu-ko), kiwifruit (Hayward), and apple (Fuji) fruits

<table>
<thead>
<tr>
<th>Fruit</th>
<th>TSS (Brix)</th>
<th>TA (%)</th>
<th>Sugar</th>
<th>Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Fructose</td>
<td>Glucose</td>
<td>Sucrose</td>
</tr>
<tr>
<td><em>A. arguta</em></td>
<td>10.5±10</td>
<td>0.62±1</td>
<td>2.21</td>
<td>2.27</td>
</tr>
<tr>
<td>Kiwifruit</td>
<td>12.8±1</td>
<td>0.80±1</td>
<td>5.04</td>
<td>0.27</td>
</tr>
<tr>
<td>Apple</td>
<td>12.7±1</td>
<td>0.33±1</td>
<td>6.61</td>
<td>2.13</td>
</tr>
</tbody>
</table>

*Presented as equivalent to quinic acid for *A. arguta*, citric acid for kiwifruit, and malic acid for apple.

*Means of TSS and TA were separated by DMRT (p < 0.05).

**Table 2** Mineral contents in flesh tissue of *A. arguta* (cv. Mitsu-ko), kiwifruit (Hayward), and apple (Fuji) fruits

<table>
<thead>
<tr>
<th>Fruit</th>
<th>K (mg/g·DW)</th>
<th>Ca (mg/g·DW)</th>
<th>Mg (mg/g·DW)</th>
<th>B (mg/g·DW)</th>
<th>Cu (mg/g·DW)</th>
<th>Fe (mg/g·DW)</th>
<th>Mn (mg/g·DW)</th>
<th>Zn (mg/g·DW)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>A. arguta</em></td>
<td>11.8±1</td>
<td>1.21±1</td>
<td>0.93±1</td>
<td>7.55±1</td>
<td>0</td>
<td>14.8±1</td>
<td>5.73±1</td>
<td>7.65±1</td>
</tr>
<tr>
<td>Kiwifruit</td>
<td>12.7±1</td>
<td>1.21±1</td>
<td>0.93±1</td>
<td>7.88±1</td>
<td>15.2±1</td>
<td>3.38±1</td>
<td>7.45±1</td>
<td></td>
</tr>
<tr>
<td>Apple</td>
<td>6.5±1</td>
<td>0.2±1</td>
<td>0.35±1</td>
<td>8.48±1</td>
<td>8.7±1</td>
<td>4.33±1</td>
<td>8.6±1</td>
<td></td>
</tr>
</tbody>
</table>
fruit, and Cu was not detected. Minerals such as Ca and Fe are known to be essential for the human body and tend to be insufficiently ingested by Japanese people\(^5\). *A. arguta* fruit, which contains such important minerals, can be evaluated in this sense as a healthy fruit.

**Conclusion**

*Actinidia arguta* fruits produced in Shinjo Village, Okayama Prefecture, contain much higher vitamin C than market-sold kiwifruit, lemon, and apple. They also contain total phenol substances in abundance, producing a high activity of free radical scavenging. Furthermore, high contents of Ca, Mn, and Fe in *A. arguta* fruit suggest it must be evaluated as a healthy fruit. On the other hand, the fruit has a well-balanced taste caused by optimal concentrations of sugar, acid, and amino acid in the juice. The levels of these juice constituents can be affected by cultivation conditions such as soil fertilization, irrigation, leaf-fruit ratio, etc. This suggests the possibility of producing *A. arguta* fruit with a more delicious taste and healthier attributes.

**References**


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岡山県新庄村で収穫されたサルナシ (*Actinidia arguta*) 果実の成分特性

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岡山県新庄村で栽培されているサルナシ果実の健康食品としての評価を行うために、同地区のサルナシ園で生産された3品種（光香、峰香、在来種）の果実、及び近隣の山地で収穫された野生サルナシ果実の成分分析を行った。参考として、岡山市内のマーケットで購入された輸入のキウイフルーツ（ヘイワード）、レモン（品種不明）、及び国産のリンゴ（ふじ）の成分も調査した。サルナシ栽培品種では、収穫適期でも硬熟状態のものと軟熟状態のものが混在し、さらには果実の半分程度の小果実（すべて軟熟）も混在した。果汁中のビタミンC含量は、峰香の硬熟果と光香の果実で220～260mg/100mLと非常に高い値を示した。市販のキウイフルーツのビタミンC含量は約100mg、レモンで50mg、リンゴは4mg/100mL程度であった。サルナシ果実の全ポリフェノール含量とラジカル消去能はキウイフルーツと大差がなかったが、リンゴに比べれば有意に高かった。サルナシはキナ酸含量が最も高く、無機成分のN, Ca, Mg, Mn含量が高かったが、糖含量は低かった。本分析結果から、サルナシ果実はビタミンとポリフェノールが豊富で、現代人の食事で不足しがちなミネラルも多いことから、健康食品として評価されうる。