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Characterization of the physico-chemical and antioxidant properties of Taiwanese kiwifruit (*Actinidia setosa*)

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ABSTRACT. In Taiwan the kiwifruit *Actinidia setosa* grows higher than 1,500 m above sea level. The National Chung Hsing University of Taiwan maintains a collection of experimental vines grown from cuttings of the native *A. setosa* collection. *Actinidia setosa* 'No.9', which produced the largest fruit, was selected for a study of its physicochemical and antioxidant characteristics, which were compared with those of *A. deliciosa* 'Chung Hsing No.3' and 'Chung Hsing No.4'. Kiwifruit fresh weight, soluble solids content, flesh firmness, titratable acidity, quinic, malic, ascorbic and citric acid contents, chlorophyll content, total phenol compound content, peroxidase activity, polyphenolic oxidase activity, free radical scavenging (DPPH) effect, and chelating effect were measured. Anthesis of *A. setosa* and *A. deliciosa* occurs in late April and late May, and fruit maturity occurs in late September and late October, respectively. The strong insect and disease-resistant characteristics of *A. setosa* 'No.9' can be attributed to the long down on the branches, leaves, and fruit. *Actinidia setosa* 'No.9' has a yellow rust leaf infection rate of 14±3% while that of 'Chung Hsing No.3' and 'Chung Hsing No.4' leaves was 77±5% and 92±7%, respectively. The *A. setosa* 'No.9' fruit has a flat, long shape with a down length of 33±4 μm, and the down length on 'Chung Hsing No.3' and 'Chung Hsing No.4' fruit was 18.2±0.7 and 17±4 μm, respectively. Under organic cultivation, *A. setosa* 'No. 9' had a mature fruit fresh weight of 66±10 g, soluble solids content of 6.2±0.1 °Brix, and titratable acidity of 2.2±0.0%. In *A. setosa* 'No.9' the ascorbic acid concentration was 83±6 mg/100 g, malic acid was 565±9 mg/100 g, and the total phenol compound content was 0.4±0.1 mg/g of fresh weight, all significantly higher than those of 'Chung Hsing No.4'. The peroxidase and polyphenolic oxidase activities of *A. setosa* 'No.9' were 0.02±0.0 ΔA_{470}/min/g.fw and 0.01±0.0 ΔA_{420}/min/g.fw at 150 days after anthesis (DAA), respectively. The DPPH ability of *A. setosa* 'No.9', 'Chung Hsing No.3' and 'Chung Hsing No.4' was 96.1±0.2%, 93±1% and 95±1%, respectively. The experimental results indicate that *A. setosa* 'No.9' has great potential for commercial production and breeding.

Keywords: *Actinidia setosa* 'No.9'; *Actinidia deliciosa*; Ascorbic acid content; 'Chung Hsing No.3'; 'Chung Hsing No.4'; DPPH and soluble solids content.

INTRODUCTION

Kiwifruit (genus *Actinidia*) originated in China, and although more than 60 species belong to the genus *Actinidia*, few have economic importance (Ferguson, 1990). Rassam and Laing (2005) observed that *A. deliciosa* and *A. chinensis* are the most common species worldwide. The eight species: *A. setosa*, *A. latifollia* Merr, *A. arguta*, *A. callosa* Lindl. var. *callosa*, *A. callosa* Lindl. var. *ephippioidea*, *A. rubricaulis*, *A. rufa* Planch, and *A. tetramera* are native to Taiwan (Flora of Taiwan, 1996). In 1990, *A. setosa* branches were collected from different areas on Ma Mountain in Taichung County for the Department of Horticulture at the National Chung Hsing University, Taiwan. These cuttings were grafted, and the experimental vine *A. setosa* 'No. 9' was selected because it produced the largest fruit. *Actinidia deliciosa* 'Chung Hsing No.3' ('CH3') and 'Chung Hsing No.4' ('CH4') were seedlings from *A. deliciosa* 'Bruno' (Chou and Nee, 2004; 2005; 2006).

Kiwifruit typically requires 25 weeks from anthesis to reach physiological maturity—the earliest time at which fruit can be picked and continue to ripen satisfactorily (Beever and Hopkirk, 1990). The fruit is very hard while developing; however, firmness declines slightly during the latter stages of development (Gallego and Zarra, 1998).

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These changes in firmness involve changes to cell wall structure. Internal soluble solid concentrations (SSCs) are utilized as the maturity index for kiwifruit in New Zealand (Beever and Hopkirk, 1990), and in Chile and New Zealand, a value of at least 6.2% SSC is used (Crisosto and Crisosto, 2001). According to the University of California, 'Hayward' fruit can be harvested when its SSC reaches a minimum of 6.5% (Crisosto and Crisosto, 2001).

Ascorbic acid (Vitamin C) in fruits and vegetables is considered an important component for human nutrition. More than 90% of the ascorbic acid in the human diet comes from fruits and vegetables (Lee and Kader, 2000). Ascorbic acid, as an antioxidant, is associated with a decreased risk of arteriosclerosis, cardiovascular diseases, and some forms of cancer (Harris, 1996). The polyphenolic compounds (flavonoids) also have antioxidant characteristics and can account for some benefits associated with the consumption of fruits and vegetables (Wong et al., 2006).

Peroxidase (POD, EC 1.11.1.7) is an enzyme located in several subcellular compartments such as chloroplasts (Kuroda et al., 1990). Polyphenolic oxidase (PPO, EC 1.10.3.2) is a copper-containing enzyme which acts on phenols in the presence of oxygen (Haruta et al., 1999). The pro- and anti-oxidant enzymes, such as peroxidase (POD), superoxide dismutase (SOD), and catalase (CAT) (Wang et al., 2005). POD requires a hydrogen donor for its degradation of H_2O_2 (Abassi et al., 1998). PPO is suggested to act as a defensive enzyme (Mayer and Harel, 1990). The oxidation of phenolic compounds by PPO may, however, also enhance the bioavailability of iron in food from plants containing polyphenol (Matuschek and Svanberg, 2005). Oxidation of phenolic compounds may result in a reduced iron-binding capacity and a higher availability of iron (Matuschek and Svanberg, 2005). Health professionals advocate the consumption of fruit and vegetables to protect against degenerative diseases such as coronary heart disease, cancers, and other free radical-mediated conditions (Kritchevsky, 1999). Fruits and vegetables contain numerous compounds which display antioxidant activities. These compounds include vitamin C and E, phenolics, and carotenoids (Burns et al., 2003; Kondo et al., 2005).

Actinidia setosa is a kiwifruit endemic to Taiwan at elevations above 1,500 meters (m). This species displays a greater resistance to Yellow rust infection and *Sympiezomios velatus* infestation compared to *A. deliciosa* and *A. chinensis* (Xiao, 2000). In this paper we describe the measurement of some physicochemical and antioxidant components and the characteristics of *A. setosa* fruit.

MATERIALS AND METHODS

Materials

Actinidia setosa 'No.9', *A. deliciosa* 'CH3' and 'CH4' fruit were harvested from vines, grown in the experimental farm at the Department of Horticulture at the National Chung Hsing University (altitude 1,900-2,100 m), during the 2003 growing season in Taiwan. Kiwifruit samples were collected at the start of anthesis to calculate the date at 100 and 150 DAA. After harvesting, the fruit was stored at 4°C in a laboratory refrigerator for fruit analysis. The anthesis seasons of *A. setosa* and *A. deliciosa* are late April and late May, respectively. Mature *A. setosa* fruit was harvested on September 24 and mature 'CH3' and 'CH4' fruits were harvested on November 1. Each laboratory test on these fruits was performed six times.

Microscope observation and infection percentage

The branches, leaves, and fruit were examined utilizing an anatomy microscope (WILD LFITZ, M 32) at magnifications of 16× (branches and fruit) and 40× (leaves) (Ontivero et al., 2005). The down length of branches, leaves and fruit were measured for the objective micrometer under the eyepiece on the anatomy microscope. The percentage of yellow rust infection on leaves was measured.

Fresh weight, fruit length, and diameter

The fruit were weighed using a digital balance (METTLER TOLEDO, PB3002-S). Fruit length (from stem and distal end) and maximum diameter were measured using digital calipers (MITUTOYO CORPORATION, CD-6" BS, Japan) (Smith et al., 1995).

Flesh firmness, SSC and titratable acidity

Flesh firmness was recorded by puncturing the fruit using a penetrometer (EFFEGI, Italy) fitted with a flat 7.2-mm-diameter tip. The SSC in the fruit juice was measured using a refractometer (ATAGO N-1E, Japan) (Antunes and Sfakiotakis, 2002). The titratable acid content was measured using an automatic titrator (METTLER DL25 Titrator, Sweden). Titration was conducted with 0.1 N NaOH at pH 8.1, and the percentage of citric acid equivalents was determined (Agar et al., 1999; Luo, 2006).

Flesh color

A hand-held colorimeter (Nippon Denshoku, NR-3000) was utilized to measure flesh in the CIE L*a*b* mode. (Agar et al., 1999; Antunes and Sfakiotakis, 2002). The L* value represents the lightness of colors. The a* value is negative for green and positive for red. The b* value is positive for yellow and negative for blue (Lee et al., 2005).

Organic acid content

20-30 g of fruit was ground in a juicer and added to a 90-ml volume of distilled water. The extract was centrifuged at 15,000 rpm and 4°C and filtered through a 0.45 μm filter. Quinic, malic, ascorbic, and citric acid analyses were performed by HPLC (Hitachi L-6000 pump), on a reverse phase C-18 column 250×4.6 mm and a mobile phase of 2% KH_2PO_4 in H_3PO_4. Flow rate was 1.0

ml min^{-1}, and injection volume was 10 µl. A UV detector (Model L-4000 UV Detector) was set at 214 nm. All data were compared to standard curves of authentic quinic, malic, ascorbic, and citric acids (Iwasa, 1975; Wang, 2006).

Total phenolic compound content

The total phenolic compound was extracted from 2 g of flesh tissue with 10 ml of cold 0.1 M phosphate buffer, pH 7.0 at 4°C. Total phenolic compounds were measured using the Folin-Ciocalteu method (Keith et al., 1958). One ml of extract was added to 0.1 ml of Folin-Ciocalteu phenol reagent, 0.2 ml of 20% Na_2CO_3, and 8.7 ml distilled water. The mixture was boiled for 3 min and cooled immediately. The resulting blue complex was then measured at 660 nm. Caffeic acid (Sigma) was utilized to plot the standard curve, and analytical results were expressed as mg of caffeic acid equivalent per g of fresh weight (Hou et al., 2004; Huang et al., 2004).

POD and PPO activity

The POD and PPO were extracted from 2 g of flesh tissue with 2 ml of cold 0.1 M phosphate buffer, pH 7.0, containing 1% PVP (polyvinylpyrrolidone) (Sigma) and 0.25% Triton at 4°C. The homogenate was centrifuged for 20 min at 15,000 rpm, and the supernatant was utilized to determine POD and PPO activity (Asada, 1984). The assay mixture contained 0.2 ml enzyme extract, 2 ml 3.6 $\times 10^{-3}$ M guaiacol (2-methoxyphenol) (Sigma), 0.3 ml distilled water, and 0.2 ml 0.0135 M H_2O_2. Oxidative loss of guaiacol was followed by an increase in the absorbance at 470 nm, according to a spectrophotometer (Hitachi U-2000). The POD activity was presented as ΔA_{470}/min/g.fw (Gong et al., 2001; Torres et al., 2003).

To measure PPO activity, the reaction chamber contained 0.1 ml enzyme extract, 1. 9 ml 0.1 M phosphate buffer (pH 8.0), and 0.2 ml 0.5 M catechol (Sigma). The oxidation of catechol to benzoguinone was followed by an increase in its absorbance at 420 nm as measured by spectrophotometer. The PPO activity was presented as ΔA_{420}/min/g.fw.

Scavenging activity of 1, 1-diphenyl-2-picrylhydrazyl (DPPH) radical and chelating effect

Samples were extracted from 4 g of flesh tissue with 20 ml of methanol at 4°C. The homogenate was centrifuged for 20 min and the supernatant was used to determine DPPH-radical scavenging and iron chelating effects. A new paragraph is needed here with the heading "DPPH scavenging" 2 ml of extract was added to 0.5 ml 0.5 mM DPPH-MeOH, and the combination was mixed and kept for 30 min at room temperature in the dark. The reduction in the DPPH absorbance (517 nm) was measured with a spectrophotometer (Kondo et al., 2002). The scavenging activity of DPPH radicals (%) was calculated using the following equation: $[1- (A517_{sample} \div A517_{blank})] \times 100\%$ (Hou et al., 2004).

Iron chelation

1 ml of extract was added to a solution of 3.7 ml of methanol and 0.1 ml of 2 mM $FeCl_2 \cdot 4H_2O$, and allowed to stand at room temperature for 30 seconds. After adding to 0.2 ml 5 mM ferrozine (3-(2-pyridyl)-5,6-di (p-sulfophenyl)-1,2,4-triazine Disodium Salt), the mixture was shaken vigorously and left to stand at room temperature for 10 min. When the mixture reached equilibrium, its absorbance was measured spectrophotometrically at 562 nm. The percentage of inhibition of ferrozine-Fe^{2+} complex formation was obtained using the formula: $[1-(A562_{sample} \div A562_{blank})] \times 100\%$ (Dinis et al., 1994; Gulcin et al., 2004).

Statistical analysis

Data were subjected to an analysis of variance (ANOVA) to determine whether differences existed between treatments. Duncan's least significant differences (LSDs) were calculated to compare the difference between means following a significant ANOVA effect (Marsh et al., 2004). A value of $P<0.05$ was considered statistically significant. Standard errors were calculated using Microsoft Excel.

RESULTS

Characters of branch, leaf and fruit

Table 1 shows the down length on the branches, leaves, and fruit, and the yellow rust coverage on *A. setosa* 'No.9', 'CH3' and 'CH4' leaves. The down length on *A. setosa* 'No.9' branches (18±1 µm), leaves (5±1 µm), and fruit (33 ±4 µm) was significantly longer than that for both 'CH3' and 'CH4' (Figure 1). The low infection rate of *A. setosa* 'No.9' by yellow rust (14±3% coverage) was correlated with its leaf down length. Infection by yellow rust was 77 ±5% for 'CH3' and 92±7% for 'CH4'.

Effects of maturity on the fruit physico-chemical components

Table 2 lists physical and chemical properties of *A. setosa* 'No.9', 'CH3' and 'CH4' fruit at 100 DAA. Fresh weight of *A. setosa* 'No.9' was 54±3 g; fruit length was 68±2 mm; and diameter was 46±2 mm. The fresh weight and length of kiwifruit samples were significantly different ($P<0.05$); however, the diameters were not significantly different. *Actinidia setosa* 'No.9' fruit flesh firmness and SSC were 144±5 N and 3.2±0.1 °Brix, 188±6 N and 3.5± 0.1 °Brix for 'CH4'. The fruit flesh color values L, a and b were influenced by the green flesh. The L and a values did not difffer significantly between fruits. The content of quinic acid was highest at the start of fruit development and decreased. The fruit quinic acid content was 1462±35 mg/100 g, malic acid content was 482±24 mg/100 g, and citric acid content was 1116±74 mg/100 g for *A. setosa* 'No.9'.

Table 1. Down length on the branches, leaves and fruit, and yellow rust infection of the leaves *A. setosa* 'No.9', 'CH3' and 'CH4' at 150 DAA.

Characteristics	*A. setosa* 'No.9'	'CH3'	'CH4'
Branch down (μm)	18±1 a[a]	4.5±0.2 b[b]	5±1 b
Leaf down (μm)	5±1 a	3.2 ±0.5 b	2.2±0.3 b
Fruit down (μm)	33±4 a	18.2±0.7 b	17±4 b
Yellow rust infection (%)	14±3 b	77±5 a	92±7 a

[a]Values are means ± standard error.
[b]Means in the same row, followed by the same letter are not significantly different at the 5% level.

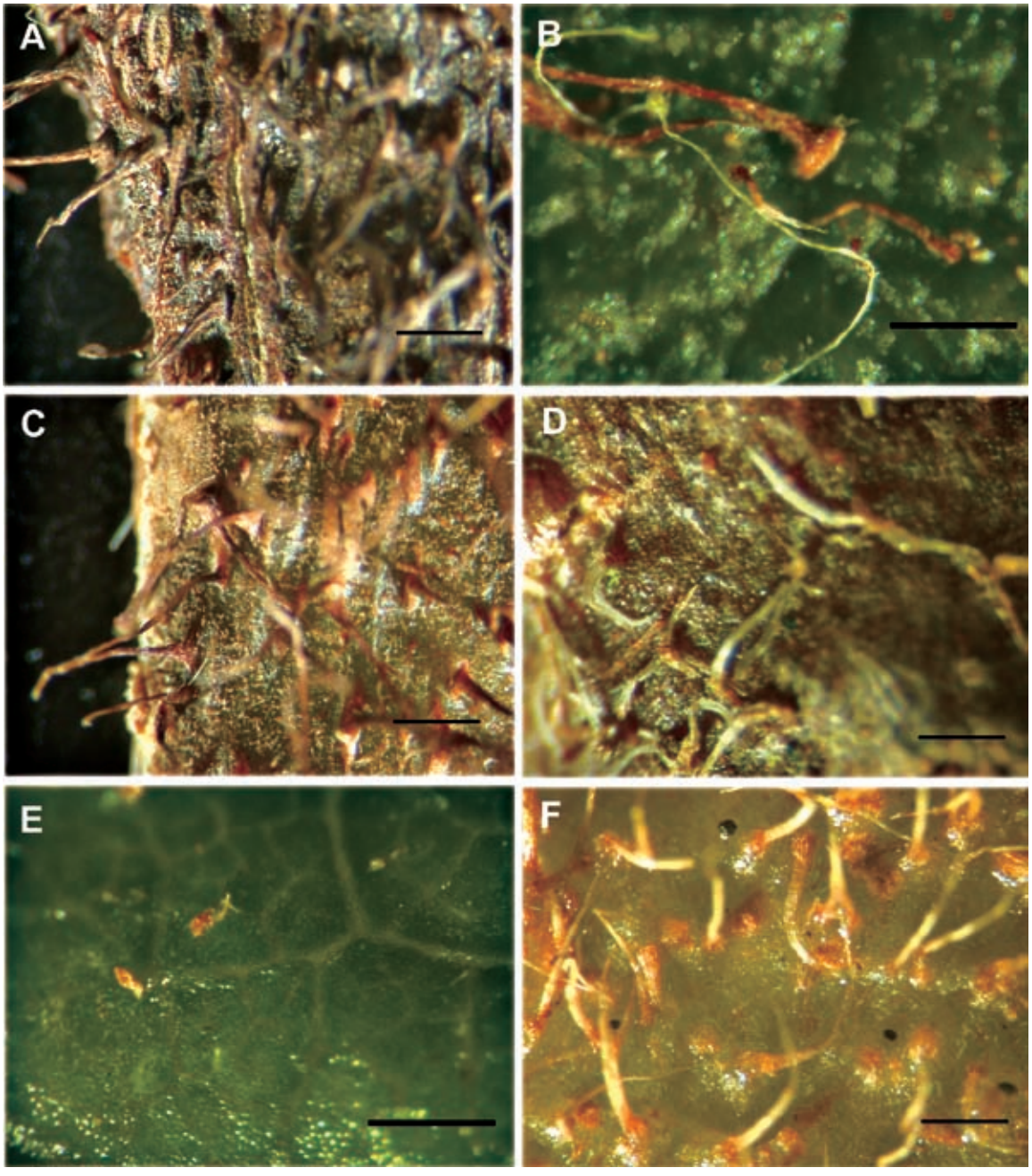

Figure 1. Microscopic observation of kiwifruit sample down at 150 DAA. Branch (A), leaf (B) and fruit (C) of *A. setosa* 'No.9'. Branch (D), leaf (E) and fruit (F) of 'CH4'. (Bars = 10 μm for A, C, D, F and 5 μm for B, E).

Table 2. Properties of the fruit of *A. setosa* 'No.9', 'CH3' and 'CH4' at 100 DAA.

Components	*A. setosa* 'No.9'	'CH3'	'CH4'
Fresh weight (g)	54±3 c[a]	81±5 a[b]	68±3 b
Fruit length (mm)	68±2 b	74±2 a	61.9±0.6 c
Fruit diameter (mm)	46±2 a	47±2 a	45.6±0.8 a
Flesh firmness (N)	144±5 b	136±13 b	188±6 a
SSC (°Brix)	3.2±0.1 b	3.8±0.2 a	3.5±0.1 ab
Titratable acidity (%)	4.6±0.2 a	3.7±0.2 b	2.8±0.2 c
Flesh color (L)	47.2±0.7 a	49±1 a	48±0.2 a
Flesh color (a)	-12.5±0.4 a	-12.2±0.5 a	-12.4±0.5 a
Flesh color (b)	21±0.7 b	22.6±0.4 a	22.5±0.4 a
Quinic acid (mg/100 g)	1462±35 a	1169±49 b	1520±40 a
Malic acid (mg/100 g)	482±24 a	531±63 ab	355±13 b
Citric acid (mg/100 g)	1116±74 ab	1303±173 a	912±119 b

[a]Values are means ± standard error.
[b]Means in the same row, followed by the same letter are not significantly different at the 5% level.

The fruit fresh weight of *A. setosa* 'No.9' was 66±10 g (Table 3). The fruit fresh weights for 'CH3' and 'CH4' at 150 DAA were 102±5 g and 111±4 g, respectively (Figure 2). Kiwifruit sample SSCs achieved harvest standards. *Actinidia setosa* 'No.9' had 6.2±0.1 °Brix. Titratable acidity was calculated for citric acid, and kiwifruit titratable acidity demonstrated significantly different effects ($P<0.05$). All kiwifruits had green flesh with L, a and b values of 45.8±0.9, -11.4±0.3 and 18.9±0.3 for *A. setosa* 'No.9'. Quinic acid, malic acid, and citric acid, were the principal organic acids. Malic acid content for *A. setosa* 'No.9' and 'CH4' was significantly different; however the citric acid contents were not significantly different at maturity.

Effects of maturity on fruit antioxidant components and antioxidant characteristics

Figure 3A shows that the ascorbic acid content of kiwifruit was significantly different at 100 DAA and 150 DAA. *Actinidia setosa* 'No.9' had ascorbic acid content that was higher than 'CH4' and lower than 'CH3'. Ascorbic acid content for *A. setosa* 'No.9', 'CH3', and

Table 3. Properties of the fruit of *A. setosa* 'No.9', 'CH3' and 'CH4' at 150 DAA.

Components	*A. setosa* 'No.9'	'CH3'	'CH4'
Fresh weight (g)	66±10 b[a]	102±5 a[b]	111±4 a
Fruit length (mm)	73±1 b	83±1.7 a	71.7±0.9 b
Fruit diameter (mm)	44±0.8 c	49±1 b	53±1 a
Flesh firmness (N)	73±7 c	171±7 b	197±8 a
SSC (°Brix)	6.2±0.1 c	8.9±0.5 a	7.5±0.2 b
Titratable acidity (%)	2.2±0.0 c	3.7±0.2 a	2.8±0.2 b
Flesh color (L)	45.8±0.9 b	49.2±0.9 a	47.4±1 ab
Flesh color (a)	-11.4±0.3 a	-12.9±0.4 b	-12.2±0.3 ab
Flesh color (b)	18.9±0.3 b	22.0±0.4 a	22.0±0.5 a
Quinic acid (mg/100 g)	1384±46 a	1023±50 b	1430±38 a
Malic acid (mg/100 g)	565±9 a	471±63 a	228±2 b
Citric acid (mg/100 g)	1463±46 ab	1655±46 a	1361±45 b

[a]Values are means ± standard error.
[b]Means in the same row, followed by the same letter are not significantly different at the 5% level.

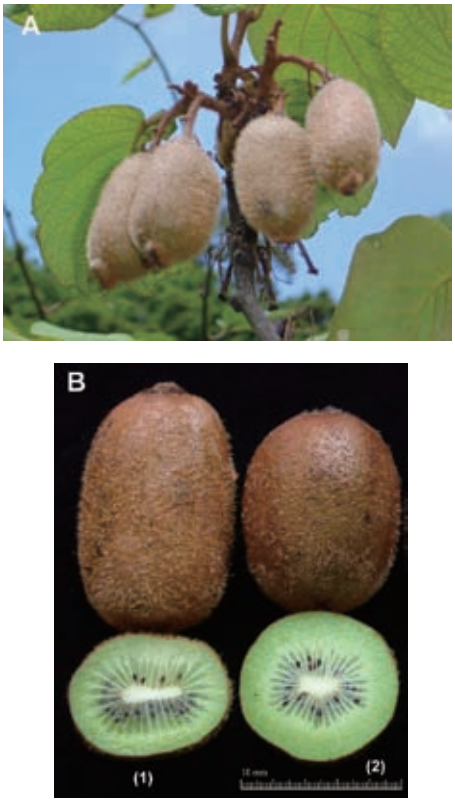

Figure 2. The fruit shape of *A. setosa* 'No.9' (A), 'CH3' (B1) and 'CH4' (B2) at 150 DAA.

'CH4' was 83±6 mg/100 g, 119±6.0 mg/100 g, and 56± 3 mg/100 g, respectively. The kiwifruit had significantly higher phenolic content at the start of fruit development, but this decreased as the fruit matured. Fruit total phenolic compound contents of *A. setosa* 'No.9' were 0.5±0.0 mg/ g and 0.4±0.1 mg/g at 100 and 150 DAA, respectively (Figure 3B). Total phenol content in *A. setosa* 'No.9' was significantly higher than in 'CH3' ($P<0.05$) at maturity.

Figure 4A presents the POD activity for *A. setosa* 'No.9', 'CH3' and 'CH4'. *Actinidia setosa* 'No.9' and 'CH4' activities did not differ significantly at either 100 or 150 DAA fruit POD. The POD activity of 'CH3' was higher than that of the other two cultivars at both 100 DAA and at maturity. All three fruits displayed lower POD activity (5 fold) at 150 DAA than at 100 DAA. Fruit PPO activity for *A. setosa* 'No.9' was not significantly different at 100 DAA and 150 DAA (Figure 4B). The PPO activity for *A. setosa* 'No.9' and 'CH4' was 0.01±0.0 and 0.02±0.0 ΔA_{420}/min/g.fw, respectively.

The free radical scavenging activity of fruit extracts of *A. setosa* 'No.9', 'CH3', and 'CH4' were tested using the DPPH technique (Table 4). Free radical scavenging activities for all kiwifruit samples were >90%. The fruit DPPH activities of *A. setosa* 'No.9', 'CH3' and 'CH 4' were 95.3±0.3%, 95.3±0.1% and 95.6±0.3% at 100 DAA, respectively. However, DPPH activities of *A. setosa* 'No.9' had stronger radical scavenging ability than did 'CH3' at maturity. *Actinidia setosa* 'No.9' 11±2% and 'CH4' 10± 1% had higher ferrous ion chelating capability than 'CH3' 6±1% at 100 DAA (Table 4).

DISCUSSION

In today's business environment, a continuous supply of novel products is essential to retaining a competitive advantage (Jaeger et al., 2003). Thus new product development is the key to survival and has driven the industry to initiate large breeding programmes to formalise the development of new cultivars (Jaeger et al., 2003). Stec et al. (1989) found that parameters such as aroma intensity and acceptability, sweetness, acidity, and ripe fruit flavour were significantly affected by the firmness of the fruit.

The *A. setosa* only grows at elevations >1,500 m in Taiwan. The relatively high insect and disease-resistant characteristics of *A. setosa* are attributable to the length of the down on its branches, leaves, and fruit. For *A. setosa* 'No.9' these lengths are longer than on either 'CH3' or 'CH4', and both suffer a high rate of yellow rust infection. yellow rust spore reproduction is attributable to the temperature, water, and other environmental conditions on kiwifruit leaves. The strong disease-resistance of *A. setosa* is attributable to the long down on its leaves.

The largest fruit, *A. setosa* 'No.9', had a mature fresh weight of 66±10 g; fruit length was 73±1 mm, and diameter was 44±0.8 mm. Fruit Fresh weights for *A. setosa* grown at an experimental farm by the Department of Horticulture at National Taiwan University (altitude 2,300 m) and the On Ma Mountain Peaceful Township in Taichung County (altitude 2,000 m), Taiwan, were 24.3±

Table 4. % Scavenging of the DPPH radical by extracts of *A. setosa* 'No. 9', 'CH3' and 'CH4' at 100 DAA and 150 DAA, and Fe^{2+} chelation (%) of kiwifruit samples at 100 DAA.

Characteristics	100 DAA			150 DAA		
	A. setosa 'No.9'	'CH3'	'CH4'	*A. setosa* 'No.9'	'CH3'	'CH4'
DPPH effect (%)	95.3±0.3 a[a]	95.3±0.1 a[b]	95.6±0.3 a	96.1±0.2 a	93±1 b	95±1 ab
Iron (Fe^{2+}) chelation (%)	11±2 a	6±1 b	10±1 a	-[c]	-	-

[a]Values are means ± standard error.
[b]Means in the same row, followed by the same letter are not significantly different at the 5% level.
[c]No data.

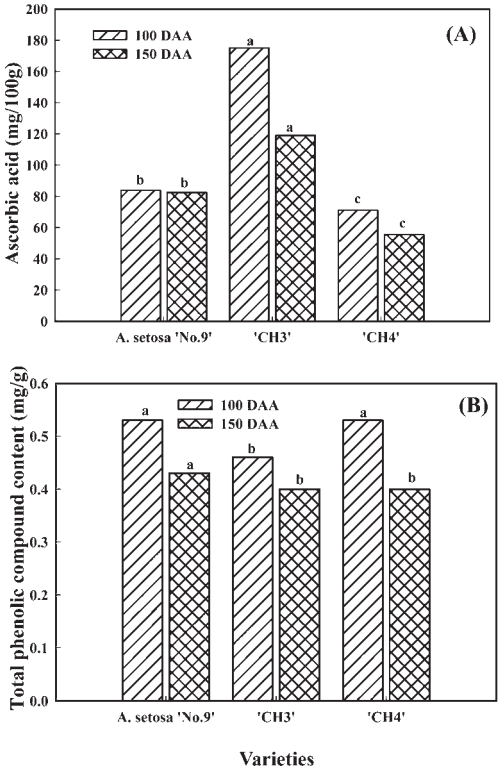

Figure 3. The fruit ascorbic acid (A) and total phenolic compound content (B) of *A. setosa* 'No.9', 'CH3' and 'CH4' at 100 DAA and 150 DAA. Columns labelled with different letters are significantly different from one another for different varieties ($P<0.05$).

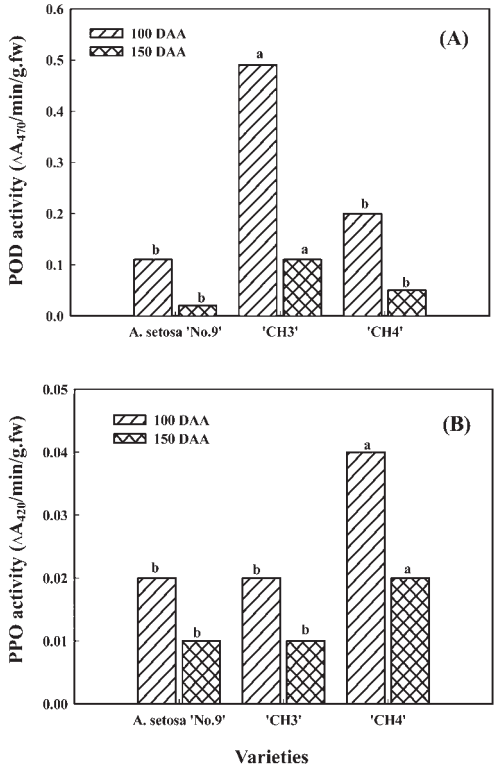

Figure 4. The fruit POD (A) and PPO (B) activity of *A. setosa* 'No.9', 'CH3' and 'CH4' at 100 DAA and 150 DAA. Columns labelled with different letters are significantly different from one another for different varieties ($P<0.05$).

0.3 g and 22±1 g, respectively. The SSC and flesh firmness of kiwifruit were utilized as an index of maturation and harvesting time. In this study, *A. setosa* 'No.9', 'CH3' and 'CH4' all attained the harvest standard at 150 DAA. Generally, starch content rapidly decreases and SSC rapidly increases at maturity. Chlorophyll degradation is characteristic of fruit ripening (Martinez et al., 2001); however, flesh color is attributable to the chlorophyll content. Average ascorbic acid for *A. setosa* 'No.9' was 83±3 mg/100 g, and the highest was 104±6 mg/100 g for 'CH3' at 150 DAA. Fruit ascorbic acid content differs according to habitat, harvest temperature, amounts of sunshine and rainfall, cultivation management, and measuring techniques (Gonzalez Rodriguez et al., 1993). Ascorbic acid increases rapidly during mid-season when seeds enlarge and fruit growth slows (Okuse and Ryugo, 1981). Gonzalez Rodriguez et al. (1993) determined that quinic acid concentrations exceeded those of the other acids at the start of fruit growth and then decreased as fruit matured.

Kiwifruit has more ascorbic acid than fruits such as cashew apples (Assuncao and Mercadante, 2003), bananas, papayas, longan, lychees, and rambutan (Wall, 2006). The ascorbic acid content of 'Abbott' and 'Monty' were 159.20 mg/100 g and 164.05 mg/100 g, respectively (Chou and Nee, 2005). The current recommended dietary allowance (RDA) for ascorbic acid for adult nonsmoking men and women is 60 mg/day, based on a mean requirement of 46 mg/day to prevent scurvy (Carr and Frei, 1999). More attention has been paid to the antioxidants contained in fruits because epidemiological studies have revealed high fruit intake to be associated with reduced mortality and morbidity of cardiovascular disease and some types of cancer, and one of the possible mechanisms involves the antioxidant activity present in the fruits (Lampe, 1999; Guo and Yang, 2001).

Total phenolic content of kiwifruit, oranges, apples, and pears was 0.22, 0.51, 0.48 and 0.12 g/100 g of fresh weight (Cai et al., 2004). In this study, total phenolic content was significantly different between 100 and 150 DAA. Kiwifruit total phenolic content was highest at the initial growth period. The PPO activity varied significantly, likely depending on the fruit species, cultivar, stage of maturity, analytical methods, and experimental extraction conditions (Nicolas et al., 1994). Kiwifruit POD and PPO activity were both low at 100 and 150 DAA. The PPO activity for *Psidium guajava* 'Shui-Jing Bar' and 'Li-Tzy Bar' was 3 and 2 ΔA_{420}/min/g.fw at maturity, respectively (Hang, 2002). The POD activity for *Psidium guajava* 'Shui-Jing Bar' and 'Li-Tzy Bar' was 0.8 and 1.1 ΔA_{470}/min/g.fw at maturity, respectively (Hang, 2002).

The DPPH is a stable free radical. Antioxidants,

when interacting with DPPH, either_transfer electrons or hydrogen atoms to the DPPH radical, thereby neutralizing it (Naik et al., 2003). Free radical DPPH scavenging activities were all >90% for *A. setosa* 'No.9', 'CH3' and 'CH4' at 100 DAA and 150 DAA. The antioxidant defence system of the body is composed of a mixture of antioxidants. Fruit are good sources of antioxidants that may be more effective and economical than supplements in protecting the body against oxidative damage under different conditions (Leong and Shui, 2002). Mature fruit does not have ferrous ion chelating capability. The radical scavenging and chelating activities are beneficial antioxidative effects against radical-associated health problems, such as cancer and coronary heart disease (Yu et al., 2004).

In summary, the relatively high insect and disease-resistant characteristics of *A. setosa* 'No.9' can be attributed to the adult plant, leaves, and the length of the down on the fruit. Anthesis early and matures early for *A. setosa* 'No.9'; however, the fruit has a long flat shape. Fruit fresh weight was 66±10 g, SSC was 6.2±0.1 °Brix. Flesh firmness was 73±7 N. Ascorbic acid content was 83 ±3 mg/100 g. Total phenolic compound content was 0.4 ±0.1 mg/g, and PPO activity was 0.01±0.0 ΔA_{420}/min/g.fw. Thus, *A. setosa* 'No.9' has significant potential for commercial production.

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臺灣羊桃之物化特性與抗氧化特性

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臺灣羊桃 (*Actinidia setosa*) 分佈於臺灣高海拔 1,500 m 地區，而最大果之‘鞍馬 9 號’選拔自臺灣國立中興大學。本研究主要目的，即探討‘鞍馬 9 號’果實之物化特性與抗氧化特性，且與‘中興 3 號’及‘中興 4 號’比較。實驗中分析之項目包括果實鮮重、果長、果徑、可溶性固形物含量、抗壞血酸含量、檸檬酸含量、葉綠素含量、總酚類化合物含量、過氧化酶、多酚氧化酶、DPPH 及螯合鐵離子等。*A. setosa* 與 *A. deliciosa* 開花期分別為 4 月下旬及 5 月下旬，而成熟期則分別為 9 月下旬及 10 月下旬。*A. setosa* 成熟植株之枝條、葉片及果實表面佈滿絨毛，因而具有抵抗病蟲害能力。‘鞍馬 9 號’葉片銹病率 14±3%，而‘中興 3 號’及‘中興 4 號’分別為 77±5% 及 92±7%。‘鞍馬 9 號’果實為扁長形且絨毛長度為 33±4 μm，而‘中興 3 號’18.2±0.7 μm 及‘中興 4 號’17±4 μm。有機栽培之‘鞍馬 9 號’成熟果鮮重 66±10 g、可溶性固形物含量 6.2±0.1 ° Brix 及可滴定酸度 2.2±0.0%。開花後 150 天之‘鞍馬 9 號’抗壞血酸 83±6 mg/100 g、蘋果酸 565±9 mg/100 g 及總酚類化合物含量 0.4±0.1 mg/g 皆較‘中興 4 號’高，且前者之過氧化酶及多酚氧化酶活性分別為 0.02±0.0 ΔA470/min/g.fw 與 0.01±0.0 ΔA420/min/g.fw。‘鞍馬 9 號’、‘中興 3 號’及‘中興 4 號’之 DPPH 能力分別為 96.1±0.2%、93±1% 及 95±1%。實驗結果指出‘鞍馬 9 號’具有商業品種潛力且可當育種材料。

關鍵詞：‘鞍馬 9 號’；抗壞血酸含量；‘中興 3 號’；‘中興 4 號’；DPPH 自由基；可溶性固形物含量。