Composition, enzyme and antioxidant activities of pineapple

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\textbf{ABSTRACT}

Three pineapple cultivars smooth cayenne, Tainung 17, and Tainung 19 were processed into flesh, peel, and stem. Nine samples were analyzed for their proximate compositions and bromelain activity existed in their water extracts. Pineapple fleshes were rich in reducing sugars and soluble fiber whereas peel and stem were rich in crude fiber. Stem showed higher bromelain activity (102–247.3 U/mg). All 18 samples including water and ethanol extracts were quite effective in the scavenging ABTS\textsuperscript{−} and DPPH-radical activities and reducing power as evidenced by their low EC\textsubscript{50} (0.98–15 mg/mL). Water extracts of stem were more effective than their ethanol extracts. The scavenging ABTS\textsuperscript{−}-radical ability was highly related with total phenols and flavonoids. Overall, peel and stem of pineapple showed high amounts of reducing sugars and soluble fiber, and higher bromelain activity and exhibit effective antioxidant activities. These wastes of pineapple would be utilized to develop as a sweet supplement or functional product.

\textbf{INTRODUCTION}

Pineapple [\textit{Ananas comosus} (L.) Merr.] is a subtropical and tropical fruit and its production yield ranked the third in the world after banana and citrus.\textsuperscript{11} Pineapple is a common crop in Taiwan and can be produced all year round. Its flesh can be directly eaten or processed, such as pineapple crisps, canned fruit, dried fruit and concentrated juice. Pineapple is rich in nutrients and minerals, vitamins and dietary fiber as well as effective in antioxidant activities.\textsuperscript{2,6}

Furthermore, pineapple contained stem bromelain and fruit bromelain.\textsuperscript{7} However, most commercial enzyme product is made from pineapple stem since it was a waste. Bromelain could be used to treat osteoarthritis and reduce swelling and inflammation after surgery.\textsuperscript{8–11} In addition, glucosylceramide from pineapple is found to show various effects such as skin moisturizing, improvement of atopic dermatitis, and protection of skin barrier.\textsuperscript{12–14}

The wastes from pineapple industry are inedible peels and stems of pineapples. In the past, these wastes are useless or used as feed or fertilizer. Accordingly, the objective of this study is to find the effects of these wastes for better usage. Three common pineapple cultivars of smooth cayenne, Tainung 17, and Tainung 19 in Taiwan were processed into three parts flesh, peel, and stem. These nine samples were extracted with cold water and ethanol to evaluate their bromelain and antioxidant activities.
MATERIALS AND METHODS

Materials
Three cultivars of smooth cayenne (SC), Tainung 17 (T17), and Tainung 19 (T19) were harvested from a farmer in Chia Yi County, Taiwan, and divided into flesh (F), peel (P), and stem (S). Three parts were further cut into cubes, freeze-dried, passed 0.635 μm sieves, and kept at −4°C before use.

Proximate analysis
The proximate composition of pineapple samples includes ash, fat, fiber, protein, and carbohydrate. Moisture, crude ash, crude fat, crude fiber (insoluble fiber), and crude protein were determined according to the methods of the Association of Official Analytical Chemists (AOAC). The nitrogen conversion factor used for crude protein calculation was 6.25. The total carbohydrate content (g/100 g) was calculated by subtracting the contents of ash, fat, fiber and protein from 100. Reducing sugars in carbohydrate was measured separately using 3,5-dinitrosalicylic acid method due to the fact that this fraction can be utilized in the human body to produce energy.

Extracts preparation
Sample powder (5 g) was added to 50 mL 25°C cold water (W) or 50 mL ethanol (E), and the mixture was shaken at room temperature for 1 hr, and then filtered through Whatman No. 1 filter. The residue was extracted once again as described above. Thus, obtained two extracts were combined and rotary evaporated at 40°C to dryness, freeze-dried and kept at −80°C before use.

Bromelain activity
Enzyme activity was measured according to the methods of Ketnawa et al. and Soares et al. with some modification. Water extract was dissolved in buffer solution (0.2 mol/L Na₂HPO₄, 0.2 mol/L citric acid, pH 7) at the ratio of 10 mg/mL. The mixture (200 µL) was added with 600 µL casein (2 g/100 mL), and the mixture was hold at 45°C for 1 hr, and then the reaction was stopped by adding 800 µL trichloroacetic acid, and the absorbance was measured at 275 nm. One casein digestion unit was defined as the amount of water extract to liberate one μmol of tyrosine and expressed as U/mL. Bromelain activity was calculated by the ratio of enzyme activity (U/mL) and water extract amount (mg/mL) and expressed as U/mg extract.

Antioxidant activities
Scavenging ability on 2,2’-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS⁺) radicals was determined following the method of Re et al. The scavenging ability assayed is the ability of the extract to react rapidly with ABTS⁺-radicals and reduce ABTS⁺-radical, and its absorbance was measured at 734 nm. Scavenging ability on 2,2-diphenyl-1-picrylhydrazyl (DPPH) radicals was determined following the method of Shimada et al. The scavenging ability assayed is the ability of the extracts to react rapidly with DPPH-radicals and reduce DPPH-radicals, and its absorbance was measured at 517 nm. The reducing power was measured according to the method of Oyaizu. The reducing power assayed is the ability of the extracts to form a colored complex with ferricyanide and its absorbance was measured at 700 nm. Besides, Trolox and Butylated hydroxyanisole (BHA) were used for comparison.

Effective concentrations (mg extract/mL) at 50% (EC₅₀) is the effective concentration at which ABTS⁺- or DPPH-radicals were scavenged by 50%; the absorbance is 0.5 for reducing power. EC₅₀ was obtained by interpolation from linear regression analysis. EC₅₀ values of antioxidant activities were inversely correlated with their efficacy.

Antioxidant components
Total phenols were measured according to the method of Taga et al. The water or ethanol extract (100 µL, 30 mg/mL) was added to 2 mL of 2 g/100 mL aqueous sodium carbonate solution.
After 2 min, 100 μL of 500 g/L Folin-Ciocalteu reagent was added to the mixture. After 30 min of standing, the absorbance was measured at 750 nm. The content of total phenols was calculated on the basis of the calibration curve of gallic acid and expressed as gallic acid equivalent (mg GAE/g extract).

Flavonoids contents in the free and bound extracts were determined by a colorimetric method of Choi et al. [22] The water or ethanol extract (250 μL, 30 mg/mL) was mixed with 1.25 ml of distilled water and 75 μL of a 5 g/100 mL sodium nitrite solution. After 5 min, 150 μL of a 10 g/100 mL AlCl₃·H₂O was added. After 6 min, 500 μL of 1 mol/L sodium hydroxide and 275 μL of distilled water were added to the mixture. The solution was mixed well and the absorbance was measured at 510 nm. The content of flavonoids was calculated on the basis of the calibration curve of rutin and expressed as rutin equivalent (mg RE/g extract).

Statistical analysis
Each experiment was conducted in triplicate, and the data were analyzed using IBM SPSS Statistics 20 software. The Duncan multiple-range test was used to estimate the variance of each group, and a P value < .05 was considered statistical significance. All data were expressed as mean ± standard error (SE). Pearson correlation coefficients between antioxidant activities and antioxidant components were also analyzed.

RESULTS AND DISCUSSION

Proximate composition and bromelain activity
Nine samples (three cultivars × three parts) were freeze-dried and analyzed for their proximate composition. For each cultivar, moisture contents of flesh and peel were higher than those of stem (Table 1). Obviously, flesh and peel showed better water-holding capacity. Carbohydrate contents and reducing sugar contents were higher in the flesh part. Besides, reducing sugars in pineapple are glucose, fructose and sucrose. [23] The difference between carbohydrate and reducing sugar contents is the content of soluble fiber, which is a bioactive substance. [24]

Contents of soluble fiber in smooth cayenne (SCF, SCP and SCS) were 40.2, 31.5 and 42.3 g/100 g, respectively. Contents of soluble fiber in Tainung 17 (T17F, T17P and T17S) were 33.3, 40.9 and 43.0 g/100 g, respectively. Contents of soluble fiber in Tainung 19 (T19F, T19P and T19S) were 33.9, 42.0 and 22.5 g/100 g, respectively. The sum of soluble fiber content and crude fiber (insoluble fiber) content is dietary fiber content. [24] Crude fiber contents were in the descending order of smooth cayenne, Tainung 17 and Tainung 19. However, peel and stem were rich in crude fiber. It indicates that pineapple is a dietary fiber abundant fruit.

Crude ash contents were 1.84–5.52 g/100 g whereas crude fat contents were 0.32–2.8 g/100 g (Table 1). In three parts, smooth cayenne showed higher crude ash and crude fat contents than Tainung 17 and Tainung 19. Crude protein contents were 2.5–8.1 g/100 g and in the descending order of smooth cayenne, Tainung 17 and Tainung 19. Moreover, flesh contained less amount of crude protein.

Overall, pineapple is a high carbohydrate fruit, rich in sugars and soluble fiber, but contained fewer amounts of ash, fat and protein. However, crude fiber was low in flesh. In addition, Tainung 17 and Tainung 19 contained higher amount of carbohydrate but lower amount of other components. As the waste of pineapple, peel and stem still contained rich components especially the reducing sugars and be utilized as sweet supplement and bioenergy or for other usage.

After 25°C water extraction, nine samples showed different ranges of bromelain activity (Table 1). Stem showed higher bromelain activity (102–247.3 U/mg extract) same as that in Gautam et al. [7] and the stem activities were in the descending order of WT19S, WT17S and WSCS. The activities of flesh and peel were 48–100 U/mg extract with WSCF being the highest. However, peel showed the activity of 56–60 U/mg extract. Therefore, stem and peel could be a rich source of bromelain enzyme.
Table 1. Proximate composition of pineapple and its waste and bromelain activity of their water extracts.

| Proximate composition (g/100 g) | SCF \(^b\) | SCP \(^b\) | SCS \(^b\) | T17F \(^b\) | T17P \(^b\) | T17S \(^b\) | T19F \(^b\) | T19P \(^b\) | T19S \(^b\) |
|---------------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| Moisture \(^a\)                | 16.1 ± 0.3A | 12.04 ± 0.02D | 10.47 ± 0.01 F | 11.4 ± 0.1E | 14.43 ± 0.06B | 6.9 ± 0.1 G | 12.1 ± 0.2D | 13.2 ± 0.1 C | 0.5 ± 0.1 H |
| Dry matter \(^a\)              | 84.0 ± 0.3 H | 87.96 ± 0.02E | 89.53 ± 0.01 C | 88.6 ± 0.1D | 85.57 ± 0.06 G | 93.3 ± 0.1B | 87.9 ± 0.2E | 86.8 ± 0.1 F | 99.6 ± 0.1A |
| Carbohydrate \(^a\)            | 87.4 ± 0.2D | 69.5 ± 0.8 F | 66.7 ± 0.1 G | 94.0 ± 0.6A | 82.0 ± 0.5E | 72.3 ± 0.6 F | 92.5 ± 0.2B | 83.4 ± 0.1DE | 89.1 ± 0.3 C |
| Reducing sugar \(^a\)          | 47.17 ± 0.27 C | 38.1 ± 2.20D | 23.0 ± 1.2 F | 60 ± 2B | 41.16 ± 0.09D | 29 ± 2E | 58.6 ± 0.8B | 41.4 ± 0.65D | 41.6 ± 0.65D |
| Crude fat \(^a\)               | 2.35 ± 0.01 G | 4.06 ± 0.05B | 5.52 ± 0.01A | 1.84 ± 0.02 H | 3.41 ± 0.03D | 2.9 ± 0.1 F | 2.23 ± 0.01 G | 3.84 ± 0.04 C | 3.20 ± 0.01E |
| Crude fiber \(^a\)             | 4.2 ± 0.1D | 19.8 ± 0.9A | 119.0 ± 0.2A | 1.2 ± 0.1E | 8.0 ± 0.9 C | 16.0 ± 0.9B | 1.45 ± 0.04E | 7.1 ± 0.1 C | 4.27 ± 0.03D |
| Crude protein \(^a\)           | 3.5 ± 0.2 C | 3.9 ± 0.4 C | 8.1 ± 0.1A | 2.5 ± 0.5D | 5.11 ± 0.09B | 7.59 ± 0.01A | 3.5 ± 0.2 C | 4.13 ± 0.06 C | 2.5 ± 0.3D |
| Water extract \(^b\)           | WSCF | WSCP | WSCS | WT17F | WT17P | WT17S | WT19F | WT19P | WT19S |
| (W)                             | 100 ± 3 C | 56 ± 4DE | 102 ± 4 C | 54.9 ± 0.6DE | 60.0 ± 0.2D | 161 ± 3B | 48 ± 4E | 56 ± 3DE | 247.3 ± 0.6A |

Moisture and dry matter of raw pineapple samples were presented on the basis of freeze-dried weight; other components were presented on dry weight.

\(^a\)SC, smooth cayenne; T17, Tainung 17; T19, Tainung 19; F, flesh; P, peel; S, stem; W, water extract.

\(^b\)Each value is expressed as mean ± SE (n = 3). Means with the same uppercase letter within a row do not differ significantly (P < 0.05).

\(^c\)Bromelain activity (U/mg extract); the ratio of enzyme activity (U/mL) and extract amount (mg/mL). Enzyme activity (U/mL); the amount of extract to liberate one µmol of tyrosine.
**Extraction yield**

Generally, the yields of water extract were higher than those of ethanol extract (Table 2). Water extract was abbreviated as W; ethanol extract as E; smooth cayenne as SC; Tainung 17 as T17; Taivhung 19 as T19; flesh as F; peel as P; and stem as S. The higher yields of water extracts might be due to more water-soluble substances in nine samples of pineapple samples. However, for SCS, the yield of water extract was lower than that of ethanol. For water extract, flesh showed much higher yield than peel and stem. For ethanol extract, flesh and peel showed comparable yields and their yields were higher than those of stem.

**EC₅₀ in antioxidant activities**

The antioxidant activities of water, and ethanol extracts from pineapple including scavenging ability on ABTS⁺- and DPPH-radicals, and reducing power were assayed and the results were converted into EC₅₀ (mg extracts per mL) in Table 3 for comparison of their efficacy. EC₅₀, the effective concentration at which ABTS⁺- or DPPH-radicals or were scavenged by 50%; the absorbance was 0.5 for reducing power. EC₅₀ was obtained by interpolation from linear regression analysis. However, at 1.25 mg/mL, the scavenging ABTS⁺-radical ability of Trolox was 99.6%; the scavenging DPPH-radical ability of BHA was 95.4%; and the reducing power of Trolox was 2.44 (absorbance at 700 nm).

All 18 pineapple samples were quite effective in the scavenging ABTS⁺-radical ability as evidence by their low EC₅₀ (0.98–7.0 mg/mL). Similarly, all samples were effective in the scavenging DPPH-radical ability as evidence by their low EC₅₀ (0.72–15 mg/mL) except WT19F. Moreover, all samples were effective in reducing power as evidence by their low EC₅₀ (2.1–13 mg/mL) except WT19S.

In the scavenging ABTS⁺-radical ability, ethanol extracts of flesh and peel were more effective than their water extracts whereas water extracts of stem were more effective than their ethanol extracts. For three parts, stem was more effective than peel except ET19S, and peel was in turn more effective than flesh. However, three pineapple cultivars were comparable in scavenging ABTS⁺-radicals.

In the scavenging DPPH-radical ability, ethanol extracts were more effective than water extracts. For three parts, flesh seemed to be less effective whereas peel and stem were comparable. However, the T19 cultivar was slightly less effective. In reducing power, ethanol extracts were more effective than water extracts. For three parts, stem was more effective than peel and peel was in turn more effective than flesh except WT19S. However, three varieties are comparable except WT19F and WT19S. Overall, three pineapple cultivars showed effective antioxidant activities.

### Table 2. Yield of water and ethanol extracts from pineapple and its waste.

| Sample | Water extract  | Ethanol extract |
|--------|----------------|-----------------|
| SCF    | a70.3 ± 0.88 b | b34.9 ± 0.3A    |
| SCP    | a41.8 ± 0.2E   | B30 ± 1B        |
| SCS    | b8.9 ± 0.8 G   | a14.9 ± 0.5E    |
| T17F   | a80 ± 2A       | b27 ± 2 CD      |
| T17P   | a56 ± 1D       | b27.7 ± 0.68C   |
| T17S   | a21 ± 1 F      | b9.6 ± 0.2 F    |
| T19F   | a80 ± 3A       | b24.5 ± 0.7D    |
| T19P   | a60.94 ± 0.03 C| b25.3 ± 0.2 CD  |
| T19S   | a6.6 ± 0.5 G   | b2.47 ± 0.09 G  |

n SC, smooth cayenne; T17, Tainung 17; T19, Tainung 19; F, flesh; P, peel; S, stem.

Each value is expressed as mean ± SE (n = 3). Means with the same uppercase letter within a column do not differ significantly (P < 0.05). Means with the same lowercase letter within a row do not differ significantly (P < 0.05).
Table 3. EC<sub>50</sub> value of water and ethanol extracts from pineapple in antioxidant activities.

| Extracts  | Scavenging ability on ABTS<sup>+</sup> radicals (mg/mL) | Scavenging ability on DPPH radicals (mg/mL) | Reducing power (mg/mL) |
|-----------|--------------------------------------------------------|-----------------------------------------------|-----------------------|
| WSCF      | 5.6 ± 0.28                                             | 4.9 ± 0.3B                                    | 12.1 ± 0.5A           |
| ESCF      | 4.75 ± 0.06 C                                         | 1.33 ± 0.04DE                                 | 5.4 ± 0.2 C           |
| WSCP      | 2.90 ± 0.08DEF                                        | 1.19 ± 0.02DE                                 | 4.87 ± 0.07 C         |
| ESCP      | 2.35 ± 0.03EF                                         | 0.93 ± 0.01 F                                 | 2.51 ± 0.07EFG        |
| WSCS      | 0.98 ± 0.02 H                                         | 2.1 ± 0.2DE                                   | 3.61 ± 0.02D          |
| ECS       | 2.1 ± 0.1FG                                            | 0.66±0.01 G                                   | 2.86 ± 0.04DEFG       |
| WT17F     | 7.0 ± 0.3A                                             | 3.4 ± 0.2 C                                   | 8.29 ± 0.05B          |
| ET17F     | 3.15 ± 0.05DE                                         | 1.21 ± 0.01DE                                 | 5.5 ± 0.2 C           |
| WT17P     | 3.53 ± 0.05D                                          | 1.19 ± 0.03DE                                 | 4.92 ± 0.02 C         |
| ET17P     | 2.78 ± 0.06DEF                                        | 0.82 ± 0.01 F                                 | 3.39 ± 0.05DE         |
| ET17S     | 1.33 ± 0.03 GH                                        | 2.48±<0.01 CD                                 | 13 ± 1A               |
| ET17S     | 2.05 ± 0.04 FG                                        | 0.81 ± 0.04 F                                 | 2.07 ± 0.03 G         |
| WT9F      | 6.8 ± 0.4A                                            | > 20                                          | 12.5 ± 0.2A           |
| ET9F      | 3.36 ± 0.08D                                          | 1.19 ± 0.01DE                                 | 5.40 ± 0.04 C         |
| WT9P      | 3.2 ± 0.10D                                           | 1.15 ± 0.03DE                                 | 5.27 ± 0.06 C         |
| ET9P      | 2.20 ± 0.04 F                                         | 0.88 ± 0.01 F                                 | 3.11 ± 0.08DEF        |
| ET9S      | 1.14 ± 0.01 H                                         | 15 ± 1A                                       | > 20                  |
| ET9S      | 3.07 ± 0.07DE                                         | 0.72 ± 0.02 F                                 | 2.19 ± 0.03 FG        |

<sup>a</sup> W, water extract; E, ethanol extract; SC, smooth cayenne; T17, Tainung 17; T19, Tainung 19; F, flesh; P, peel; S, stem.

<sup>b</sup> EC<sub>50</sub>, the effective concentration at which ABTS<sup>+</sup>- or DPPH-radicals or were scavenged by 50%; the absorbance was 0.5 for reducing power. EC<sub>50</sub> was obtained by interpolation from linear regression analysis.

<sup>c</sup> Each value is expressed as mean ± SE (n = 3). Means with the same uppercase letter within a row do not differ significantly (P < 0.05).

Table 4. Contents of total phenols and flavonoids of water and ethanol extracts from pineapple and its waste.

| Sample  | Total phenols content (µg GAE/mg) | Flavonoids content (µg RE/mg) |
|---------|----------------------------------|-----------------------------|
|         | Water extract    | Ethanol extract  | Water extract    | Ethanol extract  |
| SCF     | 15.5 ± 1.6 F  | 21.4 ± 0.3F    | 6.1 ± 0.3E      | 7.8 ± 0.2D      |
| SCP     | 19 ± 1DE       | 24.1 ± 0.8DE   | 12.3 ± 0.3D     | 12.2 ± 0.4B     |
| SCS     | 30 ± 1A        | 32.7 ± 0.8B    | 18.6 ± 0.3B     | 14.6 ± 0.5A     |
| T17F    | 13.6 ± 0.9E<sup>b</sup> | 20.8 ± 0.2 F  | 5.88 ± 0.06E    | 10.6 ± 0.3 C    |
| T17P    | 20.5 ± 0.8D    | 24.3 ± 0.7DE   | 12.2 ± 0.2D     | 13.9 ± 0.5B     |
| T17S    | 28.5 ± 0.27AB  | 27.4 ± 0.4 C   | 17.3 ± 0.2 C    | 12.7 ± 0.5B     |
| T19F    | 11.0 ± 0.3G    | 21.3 ± 0.4F    | 5.64 ± 0.01E    | 10.7 ± 0.4 C    |
| T19P    | 17.4 ± 0.3DE   | 25.7 ± 0.4D    | 12.0 ± 0.2D     | 14.4 ± 0.6A     |
| T19S    | 27.3 ± 0.4BC   | 36 ± 1A        | 23.5 ± 0.3A     | 15.0 ± 0.5A     |

<sup>a</sup> SCF, smooth cayenne flesh; SCP, smooth cayenne peel; SCS, smooth cayenne stem; T17F, Tainung 17 flesh; T17P, Tainung 17 peel; T17S, Tainung 17 stem; T19F, Tainung 19 flesh; T19P, Tainung 19 peel; T19S, Tainung 19 stem.

<sup>b</sup> Each value is expressed as mean ± SE (n = 3). Means with the same uppercase letters within a column do not differ significantly (P < 0.05).

Total phenols and flavonoids
Generally, contents of total phenols and flavonoids in ethanol extracts were higher those in water extracts (Table 4). This seems that phenolic compounds are more soluble in ethanol. In ethanol extracts, contents of total phenols and flavonoids were 20.8–36 µg GAE/mg and 7.8–15.0 µg RE/mg, respectively, whereas in water extracts contents of total phenols and flavonoids were 11.0–30 µg GAE/mg and 5.64–23.5 µg RE/mg, respectively. For two extracts, total phenols and flavonoids contents were in the descending order of stem, peel and flesh.

Correlation between antioxidant activities and antioxidant components
Correlation between antioxidant activities and antioxidant components of 18 pineapple samples were studied. Among antioxidant activities, a significant correlation (R = 0.775; P < .01) was observed
between reducing power and the scavenging DPPH-radical ability (Table 5). Moreover, the scavenging 
ABTS\textsuperscript{+}-radical ability was significantly negatively correlated with total phenols (R = \(-0.895\); \(P < .01\)) and flavonoids (R = \(-0.727\); \(P < .01\)). Although these were negatively correlations, \(EC_{50}\) values of antioxidant activities were inversely correlated with their efficacy. In other words, the scavenging 
ABTS\textsuperscript{+}-radical ability was highly related with total phenols and flavonoids. However, a significance 
correlation (R = 0.691; \(P < .01\)) was observed between total phenols and flavonoids.

Significance correlation of both the scavenging ABTS\textsuperscript{+} and DPPH-radical abilities with total 
phenols and flavonoids was found in Lu et al.\textsuperscript{[4]} Furthermore, both the scavenging ABTS\textsuperscript{+} and 
DPPH-radical abilities were significantly correlated. However, the correlation between scavenging 
ABTS\textsuperscript{+} and DPPH-radical abilities was not found in this study. In this study, correlation of reducing 
power with total phenols and flavonoids was not found. This is mighty be due to reducing power was 
correlated with ascorbic acid.\textsuperscript{[4]}

**CONCLUSION**

Nine samples were analyzed for their proximate compositions and bromelain activity of their water 
extracts. Pineapple samples were rich in reducing sugars and soluble fiber and contained fewer amounts 
of ash, fat and protein. However, peel and stem were rich in crude fiber. Stem showed higher bromelain 
activity and stem and peel could be a rich source of bromelain enzyme. All pineapple samples including 
water and ethanol extracts were quite effective in the scavenging ABTS\textsuperscript{+} and DPPH-radical activities 
and reducing power. In antioxidant activities, water extracts of stem were more effective than their 
ethanol extracts. Three pineapple cultivars and three parts showed effective antioxidant activities. 
Besides, the scavenging ABTS\textsuperscript{+}-radical ability was highly related with total phenols and flavonoids. Overall, peel and stem of pineapple showed high amounts of reducing sugars and soluble fiber, and 
higher bromelain activity. Furthermore, peel and stem exhibit effective antioxidant activities. These 
wastes of pineapple would be utilized to develop as a sweet supplement or functional product.

**Acknowledgments**

We would like to acknowledge the financial support of Chia-Ta Biotechnology Co., Tainan, Taiwan, ROC.

**Funding**

This work was supported by the Chia-Ta Biotechnology Co., Tainan, Taiwan, ROC [grant no. Chia-Tai 2019-001].

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