

Antioxidant Capacities and Main Reducing Substance Contents in 110 Fruits and Vegetables Eaten in China

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ABSTRACT

The aim of this study was to screen strongly-antioxidant fruits and vegetables and supply practical diet guidance for the public. We used 1,1-diphenyl-2-picrylhydrazyl (DPPH), ferric-reducing antioxidant potential (FRAP), 2,2'-azino-bis-3-ethylbenzthiazoline-6-sulphonic acid (ABTS) and total reducing power (TRP) assays to investigate antioxidant activities in 110 fruits and vegetables. To analyze the correlation between antioxidant capacities and main reducing substance contents, total phenolic, flavonoid and vitamin C contents were assessed. The results showed great variation in antioxidant activity, and fifteen fruits and vegetables possessed the strongest antioxidant capacities: *Toona sinensis*, hawthorn, jujube, lotus root, persimmon, red plum, black plum, chilli pepper, star fruit, strawberry, blueberry, cherry, peach, pomegranate and great burdock. Total phenolic contents showed higher correlation with antioxidant capacity when using FRAP and TRP assays than when using the DPPH or ABTS assay. Phenolics and flavonoids, rather than vitamin C, contributed to antioxidant potential in most fruits and vegetables.

KEYWORDS

Antioxidant Capacity; Fruits; Vegetables; Phenolic; Flavonoid; Vitamin C

1. Introduction

Many epidemiological studies have indicated that the oxidative stress imposed by reactive oxygen species (ROS) plays an important role in many chronic and degenerative diseases, such as cardiovascular diseases, cancer, diabetes mellitus, neurodegenerative diseases and ageing [1,2]. The scavenging of ROS is thought to be an effective measure to depress the level of oxidative stress in organisms for prevention and treatment of some chronic and degenerative diseases [3]. Fruits and vegetables are good sources of natural antioxidants, vitamins and minerals, which play key roles in maintaining nutritional balance and scavenging ROS in the human body. Various studies have demonstrated that intakes of fruits and vegetables rich in antioxidants are inversely associated with

the risk of many chronic diseases, such as cardiovascular diseases and cancer [4-6]. Following cereal foods, fruits and vegetables played the second most important role in the traditional Chinese diet, the Yellow Emperor Canon of Medicine, which was compiled from about 475-221 BC and emphasized that, "fruits are helpful and vegetables are beneficial supplementary food for human health", indicating that Chinese ancestors realized fruits and vegetables had a positive influence on human health and nutritional balance. A great deal of recent research has indicated that fruits and vegetables rich in natural nutrients and secondary metabolites with antioxidant activity, such as phenolic and flavonoid compounds, contributed to overall health and disease prevention [7-9]. Phenolic and flavonoid compounds are considered to have potent antioxidant capacity and ROS-scavenging activity. In recent years, there has been considerable interest in determining

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total phenolic contents and antioxidant capacities of vegetables and fruits [10,11]. Flavonoids, a large family of compounds with a C₆-C₃-C₆ skeleton structure, are the most abundant polyphenols in human diets. Polyphenols are regarded as basic to human health and have broad pharmacological effects on human health, especially in prevention of age-related diseases [12]. Besides phenolic and flavonoid compounds, ascorbic acid (vitamin C) is usually considered to be one of the main reducing substances in fruits and vegetables.

Following development of the economy and improvement of living conditions in China, some chronic and degenerative diseases, such as cardiovascular diseases, cancer, diabetes mellitus, neurodegenerative diseases and ageing, have increased in both cities and countryside. For health promotion and disease prevention, it is necessary for the public to know about the total antioxidant capacities and main reducing substance contents in common fruits and vegetables. In recent years, there has been a great deal of research on the antioxidant capacities of fruits and vegetables in China [3,13]. However, these studies all included small samples and used only one or two assay methods, thus limiting the value of their results. A comparative, multi-method screening of a larger number of fruits and vegetables for antioxidant activity in relation to their phenolic compounds and vitamin C is needed to provide a better understanding of the foods' relative importance as natural antioxidants.

The aim of this study is to systematically evaluate antioxidant capacities with DPPH, ABTS, FRAP and TRP assays and to determine the hydrophilic antioxidant substance content including total phenolic, flavonoid and vitamin C content of 110 fruits and vegetables commonly consumed in China. The study also aims to investigate the correlation between antioxidant capacities and the main reducing substance contents of the foods so as to supply valuable guidance for consumers. Correlation among different antioxidant evaluation methods will also be investigated to obtain the most accurate results.

2. Materials and Methods

2.1. Chemicals and Samples

Gallic acid, ascorbic acid, 2,4,6-Tri(2-pyridyl)-S-triazine (TPTZ), 2,2'-azinobis(3-ethylbenothiazoline-6-sulphonic acid) diammonium salt (ABTS), 1,1-diphenyl-2-picrylhydrazyl (DPPH) and Folin-Ciocalteu's phenol reagent were purchased from Sigma-Aldrich (St. Louis, MO). Potassium persulphate, sodium carbonate, iron (III) chloride 6-hydrate, iron (II) sulphate 7-hydrate, acetic acid and sodium acetate and potassium ferricyanide were obtained from Tianjin Chemical Factory (Tianjin, China). Ethanol, trichloroacetic acid and hydrochloric acid were purchased from Tianjin Guangfu S & T Development Co.,

Ltd. (Tianjin, China). All chemicals used in the experiments were of analytical grade, and distilled water was used.

All 110 fruits and vegetables were collected from the supermarkets in Tianjin, China.

2.2. Sample Preparation and Determination of Moisture Content

The fruit or vegetable was washed with distilled water to remove dirt on their peels, and was given an airing at room temperature for a short time. Then, a precisely weighed amount (about 10.00 g) of edible portions of the samples were cut into small pieces and homogenized with a special grinder with a mixture of 90 ml ethanol-water (50:50, v/v) at 4°C for 4 hr. The mixture was centrifuged at 5000 rpm for 20 min, and then the supernatants were filtered through a 0.2 µm PTFE membrane filter. The sample with final volume 100 ml was collected for the evaluation of antioxidant capacities, total phenolic and flavonoid contents. Another edible portion of each sample was dried in air oven at 95°C for 48 hr until there was no change in weight and then determined moisture content. Samples were extracted and dried in triplicate.

2.3. DPPH Radical-Scavenging Activity Assay

The DPPH radical-scavenging capacity was measured by the method described by Braca *et al.* [14], with a slight modification. Briefly, a 2 ml ethanol solution of DPPH (0.2 mM) was mixed with 2 ml of fruit or vegetable extract in a 10 ml tube and incubated in the dark for 60 min at room temperature before absorbance was measured at 517 nm using a 752N UV-Vis spectrophotometer (Shanghai, China).

The radical-scavenging activity of the extract was calculated as follows:

$$\begin{aligned} & \text{DPPH radical-scavenging (\%)} \\ & = \left[(A_{\text{control}} - A_{\text{sample}} + A_{\text{background}}) / A_{\text{control}} \right] \times 100 \end{aligned}$$

where A_{control} is the absorbance of a mixture of 2 ml DPPH solution and 2 ml 80% ethanol solution, A_{sample} is the absorbance of a mixture of 2 ml DPPH solution and 2 ml extract solution, while $A_{\text{background}}$ is the absorbance of a mixture of the extract and 80% ethanol solution in a volume ratio of 1:1. All samples were tested in triplicate.

2.4. ABTS Radical-Scavenging Activity Assay

The ABTS assay was carried out according to the method established in the literature [15]. Briefly, the ABTS⁺ stock solution was prepared from 7 mM ABTS and 2.45 mM potassium persulphate in a volume ratio of 1:1 and then incubated in the dark for 16 hr at room temperature

and used within 2 days. The ABTS⁺ working solution was prepared by diluting the stock solution with ethanol to an absorbance of 0.70 ± 0.05 at 734 nm. The sample extract (200 μ l) was mixed with 2 ml of the ABTS⁺ working solution. Absorbance of the mixture was measured at 734 nm, and the results were expressed as follows:

$$\text{ABTS}^+ \text{ radical-scavenging (\%)} \\ = \left[\frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}} \right] \times 100$$

where A_{control} is the absorbance of a mixture of 200 μ l water and 2 ml ABTS⁺ working solution, while A_{sample} is the absorbance of a mixture of 200 μ l extracts and 2 ml ABTS⁺ working solution. All samples were tested in triplicate.

2.5. Ferric-Reducing Ability of Plasma (FRAP) Assay

The FRAP assay was determined according to the method described in the literature [16], with a slight modification. The FRAP assay measures ability of antioxidants in the vegetable or fruit extracts to reduce ferric-tripyridyl-triazine (Fe³⁺-TPTZ) complex to the blue-colored, ferrous form (Fe²⁺), which absorbs light at 593 nm. Briefly, sample extract (200 μ l) was mixed with 2.8 ml of ferric-TPTZ reagent (prepared by mixing 300 mM acetate buffer, pH 3.6, and 10 mM TPTZ with 40 mM HCl and 20 mM FeCl₃·6H₂O at a ratio of 10:1:1 (v/v/v)) and incubated at 37°C for 10 min. Six concentrations, of 5, 10, 20, 30, 40 and 50 μ mol/L, were used to prepare the standard curve of FeSO₄. Antioxidant activities are expressed as micromole Fe (II) equivalent per 100 grams fresh weight. Higher values indicate higher reducing power of the sample, and, thus, higher antioxidant activity.

2.6. Total Reducing Power (TRP) Assay

TRP assay of the 110 extracts was determined and expressed as vitamin C equivalence according to the method described in the literature [17], with a slight modification. Briefly, each extract of 1.0 ml was mixed with 2.5 ml phosphate buffer solution (0.2 M, pH 6.6) and 2.5 ml of 1% aqueous potassium ferricyanide, and then incubated at 50°C for 30 min. Then, 2.5 ml of 1% trichloroacetic acid was added to the mixture to stop the reaction, and the mixture was centrifuged at 5000 rpm for 10 min. The supernatant 2.5 ml was mixed with 2.5 ml distilled water and 0.1% FeCl₃ (5 ml), and absorbance was measured at 700 nm with a spectrophotometer. Ascorbic acid was used as a reference owing to its good reducing property. Increased absorbance in 700 nm of the reaction mixture indicated increased reducing power.

2.7. Determination of Total Phenolic Content

Total phenolic content (TPC) was determined according to the literature [3,18]. Briefly, 1 ml of the sample extract or gallic acid standard was added into 2.5 ml of 0.2 M diluted Folin-Ciocalteu reagent. After 6 min, 2 ml of saturated sodium carbonate (about 75 g/L) was added. Absorbance of the mixture was measured at 760 nm after incubation for 2 hr at room temperature. The calibration curve ($y = 7.75x - 0.0082$; $R^2 = 0.9960$) was recorded by using milligram gallic acid equivalents/g dry weight (mg GAE/g DW). All samples were tested in triplicate.

2.8. Determination of Total Flavonoid Content

Total flavonoid content (TFC) was determined according to the reported literature [19], with a slight modification. Briefly, 1 ml of each extract or rutin standard was separately mixed with 0.5 ml of 10% sodium nitrite. After 5 min, 0.5 ml of 10% aluminium nitrate was added and mixed. After 6 min, 3 ml of 4% sodium hydroxide was added and mixed. The final volume was 10 ml with 40% ethanol solution. The reaction mixture was incubated at room temperature for 15 min. Absorbance of the reaction mixture was measured at 510 nm with a UV-visible spectrophotometer. The calibration curve ($y = 0.001x + 0.0024$; $R^2 = 0.9917$) was recorded by using rutin standard solutions in 40% ethanol with concentrations ranging from 2 to 20 μ g/ml. TFC was expressed in terms of milligrams of rutin equivalent per gram of dry mass (mg RE/g DW). Three replications were performed for each to get more accurate results. Results are represented as mean \pm standard deviation (SD).

2.9. Determination of Vitamin C Content

Vitamin C content was determined according to the literature [20,21]. The reaction principle is that the ammonium molybdate as a colouring reagent with vitamin C forms the molybdenum blue in the presence of SO₄²⁻ ions, and the reaction complex has a strong absorption at a wavelength of 730 nm. Briefly, 10 grams of a fruit or vegetable was homogenized with 2% oxalate solution and then filtered to a final volume of 100 ml. Each filtrate 1 ml was separately mixed with a 6% H₂SO₄ solution of 1.5 ml and a 10% ammonium molybdate solution of 2.5 ml in a tube. Finally, 6 ml double-distilled water was added and the reaction tube was sealed. The reaction mixture was dipped in boiling water for 6 min. After being cooled to room temperature, the reaction mixture was measured for absorbance at 730 nm with a UV-visible spectrophotometer. The calibration curve ($y = 10.065x - 0.0574$; $R^2 = 0.9966$) was recorded by using standard vitamin C solution in the range of 2 - 22 μ g/ml. The concentrations were expressed as mg of ascorbic acid equi-

valents per 100 g of fresh weight (mg Vc/100g FW).

2.10. Statistical Analysis

All the experiments were performed in triplicate, and the results were expressed as mean \pm SD. Regression correlation coefficients were calculated to determine the correlation between the antioxidant evaluation method used and the measured contribution to antioxidant capacity of total phenols, total flavonoids and vitamin C. Statistical analysis was performed using SPSS 13.0 and Microsoft Excel 2003.

3. Results and Discussion

3.1. Antioxidant Capacities of 110 Fruits and Vegetables Commonly Consumed in China

DPPH assay is routinely used to evaluate free-radical scavenging potential of foods or other natural compounds and is considered a standard, easy colorimetric method for assessment of antioxidant properties [22]. Results of DPPH assay of 110 fruits and vegetables are shown in **Table 1**. These results indicate that different samples had a wide range of DPPH radical-scavenging activities, $8.59\% \pm 0.69\%$ to $99.86\% \pm 0.46\%$, and the mean DPPH radical-scavenging rate was 58.05% for all 110 samples. Among them, *Toona sinensis* (TS), or Chinese toon, had the highest DPPH radical-scavenging activity ($99.86\% \pm 0.46\%$), followed by hawthorn ($95.72\% \pm 1.10\%$), pomegranate ($94.62\% \pm 1.80\%$) and jujube ($94.43\% \pm 0.36\%$). The other 12 foods that have DPPH radical-scavenging rates above 90% are black plum, chili pepper, star fruit, strawberry, red plum, blueberry, persimmon, cherry, lotus root, red delicious apple, peach and citrus lemon (**Table 1**). Durian had the lowest scavenging rate ($8.59\% \pm 0.69\%$) among the tested samples.

ABTS assay better reflects antioxidant content in a variety of foods than DPPH assay [23]. The results in **Table 1** showed that all samples had some ABTS⁺ radical-scavenging activities, with a wide range of from $7.77\% \pm 0.87\%$ to $98.88\% \pm 1.04\%$, and the mean scavenging rate was 49.89% for all 110 samples. In agreement with the DPPH assay results, TS possessed the strongest ABTS⁺ radical-scavenging activity ($98.88\% \pm 1.04\%$), followed by hawthorn ($96.52\% \pm 0.98\%$), chili pepper ($94.56\% \pm 5.15\%$) and persimmon ($92.78\% \pm 0.69\%$). The other 13 foods that have ABTS⁺ radical-scavenging rates above 90% include jujube, black plum, star fruit, lotus root, strawberry, peach, taro, pomegranate, red plum, great burdock, ginger, cherry and blueberry (**Table 1**). Wax guard had the lowest free-radical scavenging rate ($7.77\% \pm 0.87\%$) among the tested samples. The results of top-ranked antioxidant fruits and vegetables from ABTS assay are very close to those obtained by DPPH assay.

FRAP assay is based on the ability of antioxidants to reduce ferrous III ions to ferrous II ions, and FRAP assay is a simple and widely used method for antioxidant capacity evaluation [3,18]. As indicated in **Table 1**, FRAP values varied from 0.01 ± 0.00 to 12.81 ± 0.92 mmol Fe II/100g FW with the difference being 1281-fold and the average value being 0.386 mmol Fe II/100g FW, based on 110 samples. As **Table 1** shows, TS had the highest antioxidant activity (12.81 ± 0.92 mmol Fe II/100g FW) of all samples analyzed and was ranked first in antioxidant activity by both DPPH and ABTS assays. Following TS, hawthorn fruit had the second-strongest antioxidant activity (4.95 ± 0.28 mmol Fe II/100g FW). In addition, the antioxidant values of jujube and lotus root were higher than 1 mmol Fe II/100g FW. The other ten fruits and vegetables (FRAP values above 0.56 mmol Fe II/100g FW) possessing stronger antioxidant activities as evaluated by FRAP assay were chili pepper, pomegranate, persimmon, black plum, red plum, strawberry, peach, winter Chinese date, great burdock and ginger, in that order. In contrast, milky cucumber, wax gourd, crown daisy, celery, summer squash and haricot bean had the lowest antioxidant activities, with FRAP values of about 0.02 mmol Fe II/100g FW, as **Table 1** shows.

TRP assay is based on the principle of increase in absorbance of reaction mixtures [24], with increase absorbance indicating increased antioxidant activity. Ascorbic acid was used as a standard equivalent antioxidant. As indicated in **Table 1**, TRP values varied from 0.08 to 21.72 mg vitamin C/g FW, with the difference being 271-fold and the mean value being 1.24 mg vitamin C/g FW for 110 samples. TS had the highest TRP value (21.72 ± 1.05 mg vitamin C/g FW), while lettuce (edible stem) had the lowest TRP value (0.08 ± 0.02 mg vitamin C/g FW) among the tested samples. Besides TS, there were 14 other fruits and vegetables (TRP value above 2.02 mg vitamin C/g FW) possessing the higher antioxidant capacities: jujube, hawthorn, lotus root, black plum, great burdock, persimmon, red plum, strawberry, star fruit, chili pepper, *Siraitia grosvenorii*, peach, coriander and pomegranate. These fruits and vegetables possessed top-ranking ferric-reducing power.

Although variance in the antioxidant capacities of various fruits and vegetables was largely due to different evaluation methods, 15 top-ranked antioxidant fruits and vegetables were finally identified, including TS, hawthorn, jujube, lotus root, persimmon, red plum, black plum, chili pepper, strawberry, blueberry, cherry, star fruit, great burdock, peach and pomegranate. They displayed outstanding antioxidant potentials as rated by four evaluation systems. These fruits and vegetables can be important and convenient dietary sources of natural antioxidants for prevention of chronic degenerative diseases caused by oxidative stress. Our research indicated that

Table 1. Antioxidant capacities of 110 fruits and vegetables consumed in China^a.

No.	Common name	DPPH-scavenging rate (%)	ABTS-scavenging rate (%)	FRAP value (mmol Fe(II)/100g)	TRP (mg Vc/g)
1	Apple (golden delicious)	86.33 ± 0.54	85.35 ± 0.68	0.18 ± 0.01	0.78 ± 0.03
2	Apple (Jonagold)	78.36 ± 1.75	75.20 ± 2.55	0.23 ± 0.01	1.02 ± 0.02
3	Apple (qinguan variety)	88.92 ± 0.30	84.86 ± 0.32	0.19 ± 0.01	0.71 ± 0.03
4	Apple (red, delicious)	90.20 ± 2.10	83.14 ± 6.73	0.35 ± 0.03	1.19 ± 0.02
5	Apple (red fuji)	86.37 ± 1.44	83.61 ± 2.21	0.42 ± 0.05	1.37 ± 0.04
6	Banana	70.01 ± 0.57	27.96 ± 0.15	0.20 ± 0.01	0.83 ± 0.03
7	Bitter melon	54.26 ± 2.35	26.22 ± 0.23	0.03 ± 0.01	0.86 ± 0.09
8	Blueberry	92.41 ± 1.80	90.07 ± 0.39	0.46 ± 0.01	1.47 ± 0.11
9	Baby Chinese Cabbage	20.12 ± 0.54	35.85 ± 0.39	0.09 ± 0.01	0.44 ± 0.01
10	Chinese cabbage	39.13 ± 0.63	27.52 ± 0.35	0.06 ± 0.01	0.35 ± 0.04
11	Cabbage	40.91 ± 1.11	22.24 ± 1.03	0.12 ± 0.01	0.43 ± 0.04
12	Cabbage mustard	36.63 ± 1.49	34.85 ± 2.35	0.27 ± 0.01	0.84 ± 0.01
13	Cabbage (Pakchoi)	76.12 ± 3.15	43.77 ± 1.54	0.18 ± 0.02	0.62 ± 0.03
14	Cabbage (small rape)	78.06 ± 1.04	22.35 ± 0.85	0.09 ± 0.04	0.43 ± 0.01
15	Cantaloup	36.51 ± 1.30	19.80 ± 1.86	0.04 ± 0.03	0.23 ± 0.04
16	Carrot	80.64 ± 0.68	34.65 ± 0.54	0.08 ± 0.01	0.73 ± 0.02
17	Cauliflower (white)	88.01 ± 0.38	56.74 ± 1.57	0.11 ± 0.04	0.57 ± 0.03
18	Cauliflower (green)	75.85 ± 0.33	76.52 ± 1.15	0.28 ± 0.02	1.01 ± 0.02
19	Celery	34.26 ± 3.03	28.54 ± 0.62	0.02 ± 0.00	0.22 ± 0.01
20	Cherry	90.92 ± 0.33	90.07 ± 0.40	0.18 ± 0.01	0.80 ± 0.04
21	Cherry-tomato (red)	82.58 ± 0.16	74.56 ± 2.35	0.17 ± 0.02	0.69 ± 0.03
22	Cherry-tomato (yellow)	78.58 ± 0.76	69.62 ± 2.13	0.18 ± 0.00	0.69 ± 0.03
23	Chilli pepper (red)	93.68 ± 1.92	94.56 ± 5.15	0.99 ± 0.02	2.48 ± 0.11
24	Chinese flowering cabbage	32.41 ± 0.99	25.87 ± 3.11	0.12 ± 0.01	0.34 ± 0.01
25	Chinese toon	99.86 ± 0.46	98.88 ± 1.04	12.81 ± 0.92	21.72 ± 1.05
26	Chive	31.65 ± 1.53	19.77 ± 1.73	0.09 ± 0.01	0.46 ± 0.02
27	Citrus	24.36 ± 0.80	24.71 ± 2.66	0.28 ± 0.08	0.58 ± 0.03
28	Citrus limon	90.12 ± 2.10	69.06 ± 1.61	0.24 ± 0.02	1.29 ± 0.05
29	Co-ba	9.41 ± 0.21	19.67 ± 2.24	0.04 ± 0.00	0.15 ± 0.01
30	Coriander	85.41 ± 0.30	62.40 ± 4.61	0.29 ± 0.02	2.05 ± 0.13
31	Cowpea	74.30 ± 0.14	45.32 ± 0.44	0.11 ± 0.02	0.63 ± 0.01
32	Crown daisy	19.96 ± 3.55	18.70 ± 6.04	0.02 ± 0.00	0.28 ± 0.01
33	Cucumber (honey)	20.06 ± 4.18	18.40 ± 0.74	0.04 ± 0.02	0.25 ± 0.01
34	Cucumber (milky)	40.22 ± 0.40	24.23 ± 0.48	0.02 ± 0.01	0.20 ± 0.02
35	Durian	8.59 ± 0.69	42.82 ± 1.44	0.15 ± 0.04	0.53 ± 0.01
36	Eggplant (long)	83.00 ± 0.83	61.59 ± 0.77	0.21 ± 0.03	1.02 ± 0.05

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37	Eggplant (round)	84.25 ± 0.84	59.02 ± 0.83	0.10 ± 0.04	0.66 ± 0.03
38	Endive	86.86 ± 0.87	41.06 ± 0.84	0.25 ± 0.02	1.27 ± 0.03
39	Fennel	39.49 ± 1.97	88.97 ± 6.14	0.35 ± 0.02	1.42 ± 0.09
40	Garlic (stem)	71.14 ± 1.75	77.99 ± 0.58	0.14 ± 0.01	0.67 ± 0.04
41	Garlic seedling	28.06 ± 1.91	50.95 ± 5.13	0.16 ± 0.02	0.82 ± 0.02
42	Garlic sprouts	20.71 ± 0.69	60.27 ± 2.67	0.23 ± 0.01	0.65 ± 0.01
43	Ginger	80.56 ± 0.29	90.08 ± 0.71	0.56 ± 0.02	1.38 ± 0.07
44	Grape	77.93 ± 3.21	18.41 ± 0.69	0.07 ± 0.01	0.35 ± 0.04
45	Great burdock	85.22 ± 9.43	90.15 ± 0.85	0.57 ± 0.03	4.73 ± 0.17
46	Green pepper	75.49 ± 0.76	78.51 ± 1.61	0.12 ± 0.03	0.72 ± 0.06
47	Haricot bean	24.90 ± 5.95	22.88 ± 1.50	0.01 ± 0.00	0.24 ± 0.04
48	Hawthorn	95.72 ± 1.10	96.52 ± 0.98	4.95 ± 0.28	6.45 ± 0.21
49	Hotbed chives	81.00 ± 0.45	47.36 ± 1.64	0.05 ± 0.02	0.44 ± 0.02
50	Houttuynia cordata	35.51 ± 0.52	39.70 ± 2.33	0.27 ± 0.01	0.83 ± 0.02
51	Jujube	94.43 ± 0.36	92.48 ± 0.91	1.98 ± 0.04	6.80 ± 0.16
52	Jujube (Chinese date)	80.43 ± 0.10	81.56 ± 5.58	0.64 ± 0.02	1.56 ± 0.02
53	Kidney bean	63.29 ± 3.54	33.18 ± 0.89	0.07 ± 0.01	0.53 ± 0.06
54	Kiwifruit	71.57 ± 0.94	47.83 ± 0.61	0.37 ± 0.02	1.11 ± 0.01
55	Kumquat	22.93 ± 1.87	24.12 ± 1.86	0.06 ± 0.00	0.26 ± 0.02
56	Leeks	80.54 ± 2.70	46.10 ± 3.48	0.20 ± 0.02	0.68 ± 0.03
57	Lettuce (leaf)	39.57 ± 0.77	22.83 ± 0.69	0.04 ± 0.02	0.25 ± 0.02
58	Lettuce (stem)	21.80 ± 0.22	9.30 ± 1.07	0.02 ± 0.01	0.08 ± 0.02
59	Longan	14.76 ± 1.79	36.42 ± 1.11	0.09 ± 0.02	0.49 ± 0.03
60	Loquat	31.99 ± 0.96	30.49 ± 2.88	0.29 ± 0.04	1.02 ± 0.03
61	Lotus root	90.72 ± 0.09	91.14 ± 1.60	1.12 ± 0.01	5.50 ± 0.13
62	Luffa	62.36 ± 1.30	23.92 ± 2.89	0.02 ± 0.00	0.37 ± 0.02
63	Mango	37.93 ± 1.05	39.80 ± 0.70	0.11 ± 0.01	0.67 ± 0.05
64	Mangosteen	37.54 ± 0.43	27.82 ± 0.61	0.11 ± 0.01	0.34 ± 0.03
65	Melon	22.93 ± 0.48	8.78 ± 4.81	0.04 ± 0.00	0.20 ± 0.02
66	Mung bean sprout	17.26 ± 0.79	14.24 ± 2.94	0.04 ± 0.01	0.24 ± 0.03
67	Muskmelon	24.03 ± 0.87	23.15 ± 2.91	0.21 ± 0.01	0.52 ± 0.01
68	Mushroom	14.29 ± 2.89	25.02 ± 1.52	0.09 ± 0.03	0.38 ± 0.01
69	Mushroom (long-rooted)	15.88 ± 1.66	46.22 ± 5.11	0.13 ± 0.01	0.56 ± 0.03
70	Navel orange	82.18 ± 0.72	63.06 ± 2.63	0.25 ± 0.03	0.60 ± 0.02
71	Onion (red peel)	60.84 ± 2.22	43.81 ± 0.55	0.10 ± 0.01	0.91 ± 0.05
72	Onion (yellow peel)	68.03 ± 0.01	72.11 ± 0.68	0.08 ± 0.01	0.62 ± 0.02
73	Orange (var. gong)	55.91 ± 1.02	61.00 ± 0.53	0.16 ± 0.01	0.72 ± 0.06

Continued

74	Orange (var. huangyan)	68.16 ± 0.92	41.89 ± 0.15	0.14 ± 0.02	0.62 ± 0.02
75	Orange (var. honey)	60.29 ± 0.40	50.20 ± 0.09	0.15 ± 0.03	0.36 ± 0.01
76	Papaya	61.77 ± 0.29	47.05 ± 2.22	0.11 ± 0.01	1.39 ± 0.49
77	Pea (sweet broad)	24.26 ± 0.99	35.64 ± 2.87	0.35 ± 0.02	0.95 ± 0.03
78	Peach	90.17 ± 1.23	90.87 ± 1.21	0.68 ± 0.07	2.34 ± 0.10
79	Pear (general)	58.57 ± 2.08	36.97 ± 0.68	0.09 ± 0.01	0.24 ± 0.01
80	Pear (huangguan)	27.09 ± 0.95	19.98 ± 5.54	0.05 ± 0.00	0.30 ± 0.02
81	Pear (red peel)	85.81 ± 1.86	82.18 ± 1.98	0.18 ± 0.03	0.86 ± 0.05
82	Pepino fruit	73.70 ± 0.29	36.61 ± 1.04	0.14 ± 0.01	1.00 ± 0.07
83	Persimmon	92.18 ± 0.15	92.78 ± 0.69	0.86 ± 0.02	4.34 ± 0.01
84	Pineapple	59.58 ± 1.75	21.92 ± 3.98	0.07 ± 0.01	0.74 ± 0.02
85	Pitaya	76.46 ± 2.05	38.69 ± 1.39	0.10 ± 0.01	0.40 ± 0.04
86	Plum (black)	94.21 ± 0.90	91.27 ± 0.76	0.86 ± 0.06	5.26 ± 0.11
87	Plum (red)	92.78 ± 1.90	90.54 ± 0.63	0.84 ± 0.03	3.91 ± 0.34
88	Pomegranate	94.62 ± 1.80	90.75 ± 0.18	0.89 ± 0.05	2.02 ± 0.07
89	Pomelo (red flesh)	27.77 ± 1.83	19.53 ± 1.10	0.28 ± 0.02	0.68 ± 0.01
90	Pomelo(white flesh)	75.32 ± 0.88	69.12 ± 2.55	0.13 ± 0.01	0.61 ± 0.02
91	Potato	36.56 ± 4.22	50.20 ± 0.09	0.09 ± 0.02	0.40 ± 0.01
92	Pumpkin	77.07 ± 2.35	73.06 ± 0.97	0.07 ± 0.01	0.54 ± 0.07
93	Radish (cherry shape)	25.69 ± 0.41	16.27 ± 1.00	0.14 ± 0.01	0.35 ± 0.01
94	Radish (green peel)	61.48 ± 1.22	40.28 ± 0.57	0.11 ± 0.00	0.62 ± 0.02
95	Radish (xinlimei)	18.38 ± 0.39	37.77 ± 1.24	0.11 ± 0.01	0.60 ± 0.01
96	Radish (white peel)	74.92 ± 1.80	46.51 ± 2.77	0.08 ± 0.01	0.46 ± 0.05
97	Rambutan	34.56 ± 0.67	30.99 ± 0.85	0.12 ± 0.01	0.68 ± 0.04
98	Siraitia grosvenorii	63.01 ± 1.88	41.61 ± 1.19	0.29 ± 0.07	2.42 ± 0.13
99	Soybean sprouts	18.45 ± 1.04	19.63 ± 0.99	0.03 ± 0.00	0.31 ± 0.01
100	Spinach	66.26 ± 1.25	88.11 ± 0.39	0.13 ± 0.02	0.69 ± 0.11
101	Star fruit	93.10 ± 0.93	91.16 ± 0.47	0.38 ± 0.01	2.52 ± 0.05
102	Strawberry	92.85 ± 1.90	90.98 ± 1.03	0.72 ± 0.01	3.17 ± 0.09
103	Summer squash	37.58 ± 2.73	14.06 ± 0.59	0.01 ± 0.00	0.28 ± 0.02
104	Swamp cabbage	31.02 ± 2.72	37.34 ± 0.94	0.16 ± 0.01	1.04 ± 0.04
105	Taro	87.26 ± 0.31	90.78 ± 0.45	0.45 ± 0.02	1.16 ± 0.03
106	Tomato (general)	80.79 ± 0.46	41.41 ± 2.32	0.05 ± 0.01	0.29 ± 0.04
107	Watermelon	51.43 ± 1.75	18.96 ± 1.27	0.03 ± 0.00	0.23 ± 0.02
118	Wax guard	12.56 ± 2.61	7.77 ± 0.87	0.02 ± 0.00	0.24 ± 0.08
109	Welsh onion	19.61 ± 1.03	21.64 ± 1.86	0.07 ± 0.01	0.41 ± 0.01
110	Yam	24.27 ± 1.68	27.63 ± 3.18	0.10 ± 0.01	0.48 ± 0.02

^aValues are means of 3 replicates ± standard deviation; n = 3.

TS, a popular tree vegetable originally from China, had the strongest antioxidant activities among the tested fruits and vegetables. Other recent research has shown that TS is rich in flavonoids and gallic acid, which play an important role in its antioxidant activity and make it an ideal dietary vegetable for natural antioxidants [25,26]. Our previous research also indicated that the older leaves as well as the edible, tender leaves of TS have significant antioxidant potential and are suitable natural alternatives to synthetic antioxidants [27]. Therefore, TS can be considered a good source of natural antioxidants with a health-promoting function.

3.2. Correlation among Different Evaluation Methods

Because multiple reaction characteristics and mechanisms likely are involved, each antioxidant assay procedure provides only an estimate of antioxidant capacity, and is subjective to its conditions and reagents. Therefore, the use of different methods (DPPH, ABTS, FRAP and TRP) helps to fully elucidate a full profile of the antioxidant capacities of many samples. Correlation analysis was used to explore the relationship among the varying

antioxidant capacities identified by different evaluation methods for all 110 fruits and vegetables. Among the methods used for quantifying antioxidant activities, the correlation by squared regression coefficient (R^2) between DPPH and ABTS, FRAP and TRP was 0.5815, 0.0786 and 0.1569, respectively (Figure 1). The R^2 values between ABTS and FRAP and TRP were 0.1228 and 0.2307, respectively, while the R^2 value between TRP and FRAP was 0.8861 (Figure 1). Results showed that correlations among different assay methods varied greatly. Among them, we found the R^2 values between DPPH and ABTS and that between FRAP and TRP had higher positive correlations, while the R^2 values between DPPH and FRAP or TRP and that between ABTS and FRAP or TRP had lower positive correlations. This suggests that different antioxidant evaluation assays, with different mechanisms and reaction characteristics, have great variation when assaying the same sample. Furthermore, if three samples possessing the strongest free-radical scavenging abilities (TS, hawthorn and jujube) were removed, the R^2 value of left 107 samples would increase significantly (e.g. the R^2 value between DPPH and FRAP would change from 0.0786 to 0.2654). This indicates that the strongest antioxidant samples skewed the relation-

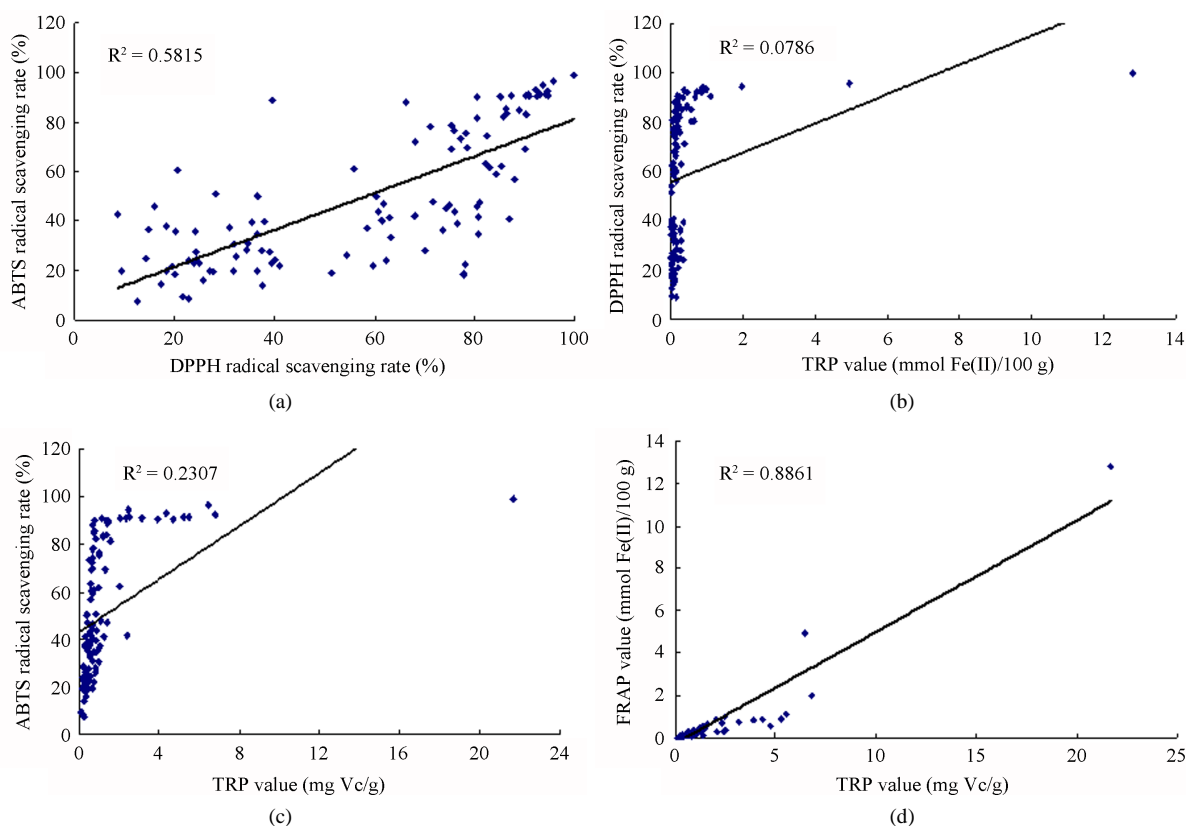


Figure 1. Correlation between antioxidant capacities measured by the DPPH, ABTS, FRAP and TRP assays. (a) Correlation between antioxidant capacities measured by DPPH and ABTS assays. (b) Correlation between antioxidant capacities measured by DPPH and FRAP assays. (c) Correlation between antioxidant capacities measured by ABTS and TRP assays. (d) Correlation between antioxidant capacities measured by FRAP and TRP assays.

ships among the antioxidant evaluation methods, and the same conclusion has been obtained by other researchers [3,28].

3.3. Total Phenolic and Flavonoid Content of 110 Fruits and Vegetables

The total phenolic content (TPC) of 110 fruits and vegetables was determined using the Folin-Ciocalteu method, which is a simple and widely used method [3,18]. As shown in **Table 2**, TPC varied from 0.93 ± 0.10 to 96.37 ± 7.32 mg GAE/g DW, with the difference being 103-fold and the average value being 6.02 mg GAE/g DW for 110 fruits and vegetables. TS (96.37 ± 7.32 mg GAE/g) had the highest TPC value, followed by hawthorn, great burdock, red plum, black plum, lotus root, jujube and cabbage mustard. Grape had the lowest TPC value (0.93 ± 0.10 mg GAE/g) among the tested fruits and vegetables. Most of the highest-antioxidant fruits and vegetables also had the highest TPC values, such as TS, hawthorn, black plum, red plum, lotus root and jujube. However, pomegranate (4.79 ± 0.15 mg GAE/g) and persimmon (5.59 ± 0.18 mg GAE/g) had only medium TPC values; their potent antioxidant capacities may be due to other types of antioxidant substances.

Total flavonoid content (TFC) of 110 fruits and vegetables was determined using the reported method of Zhi-shen *et al.* [19], with minor modifications. As shown in **Table 2**, TFC varied from 0.19 ± 0.04 to 24.34 ± 1.39 mg RE/g DW, and the mean value of 110 fruits and vegetables was 1.866 mg RE/g DW. TS (24.34 ± 1.39 mg RE/g DW) had the highest TFC value, followed by hawthorn (15.71 ± 0.26 mg RE/g DW) and lotus root (8.53 ± 0.36 mg RE/g DW). Chinese cabbage had the lowest TFC value (0.19 ± 0.04 mg RE/g DW) among the tested fruits and vegetables. Following TS, hawthorn and lotus root, the eight fruits and vegetables with the highest TFC values were peach, black plum, great burdock, jujube, star fruit, blueberry, pomegranate and red plum. However, despite their lower antioxidant potential, fennel, Houttuynia cordata, coriander and swamp cabbage actually had higher TFC values (**Table 2**). This illustrates that there is not always a positive correlation between antioxidant potential and flavonoid content.

3.4. Correlation between Antioxidant Capacities and TPC and TFC

A great deal of research has shown a significant relationship between antioxidant activity and TPC in selected herbs, vegetables and fruits. Phenolic compounds have been found to make a major contribution to antioxidant activity [7,28,29]. However, results were based on statistical analysis of small samples. The current study systematically investigated antioxidant capacity and TPC of

110 fruits and vegetables. Statistical results of such a large sample revealed that correlation between antioxidant activity and TPC by different systems of assay showed large variations, with R^2 values ranging from 0.0740 to 0.9026 (**Figure 2**). Correlations between TPC and antioxidant activities as shown by FRAP and TRP assays are much higher than those shown by DPPH and ABTS assays (**Table 2**). This means that phenolic compounds are the main antioxidant components of fruits and vegetables identified by the FRAP and TRP systems of assay. Correlations between antioxidant capacity and TFC in 110 fruits and vegetables are in agreement with those of TPC (R^2 values ranging from 0.1391 to 0.8186, data not shown). We found some fruits and vegetables had higher TFC but lower antioxidant activity (**Tables 1 and 2**). This conclusion is similar to others' research [30, 31]. Even so, we found phenolic and flavonoid compounds had a decisive influence on antioxidant potency in most of the fruits and vegetables tested, which agrees with other previous reports [9,13,18].

3.5. Vitamin C Content and Its Relationship with Antioxidant Activity

Vitamin C content in 110 fruits and vegetables fell into a very wide range, between 1.13 and 345.78 mg vitamin C/100g FW (**Table 2**). Correlation analysis between vitamin C content and antioxidant activity was conducted for the purpose of investigating contribution of vitamin C to antioxidant potential. We found the correlation coefficients between vitamin C content and antioxidant capacity of the 110 samples were very low as measured by all four assays (R^2 values ranging from 0.0127 to 0.0726, data not shown). The correlation between vitamin C content and FRAP value was the lowest, but the other three correlations were not much higher. This suggests that vitamin C has only a weak contribution, compared with those of TPC and TFC, to antioxidant capacity in most of the fruits and vegetables tested. In recent research on this problem, some authors have reported a positive correlation between vitamin C content and antioxidant activity [31], while others have found no correlation [32]. We think vitamin C content plays a more important role in nutrition than in the antioxidant activity of fruits and vegetables. However, in some fruits and vegetables, vitamin C content might play a relatively important role in antioxidant power [13,33].

4. Conclusion

Antioxidant capacities of 110 fruits and vegetables displayed a very large range, and phenolic and flavonoid content, rather than vitamin C content, played a key role in antioxidant potential. Comparative assessments using four antioxidant evaluation methods strongly suggest that

Table 2. Humidity (%) and the main reducing substance contents in 110 fruits and vegetables in China^a.

No.	Common name	TPC ^b (mean ± SD, GAE mg/g)	TFC ^c (mean ± SD, µg RE/g)	Vitamin C ^d (mg/100g FW)	Moisture g/100g
1	Apple (golden delicious)	1.91 ± 0.01	0.45 ± 0.07	5.67 ± 0.16	86.87 ± 0.59
2	Apple (Jonagold)	2.14 ± 0.36	0.58 ± 0.06	6.84 ± 1.20	88.55 ± 0.19
3	Apple (qinguan variety)	3.75 ± 0.18	0.94 ± 0.05	7.42 ± 0.61	84.57 ± 0.73
4	Apple (red, delicious)	3.34 ± 0.06	0.88 ± 0.09	8.72 ± 0.03	85.83 ± 0.32
5	Apple (red fuji)	3.21 ± 1.11	0.86 ± 0.03	9.71 ± 1.42	86.08 ± 0.08
6	Banana	1.00 ± 0.13	0.69 ± 0.05	9.44 ± 0.69	73.86 ± 0.30
7	Bitter melon	4.45 ± 0.92	1.78 ± 0.26	85.50 ± 0.07	94.11 ± 0.08
8	Blueberry	6.53 ± 0.50	4.51 ± 0.10	3.97 ± 0.26	85.35 ± 0.42
9	Baby Chinese Cabbage	3.14 ± 0.16	0.25 ± 0.04	11.78 ± 0.22	94.03 ± 0.30
10	Chinese cabbage	2.05 ± 0.13	0.19 ± 0.04	8.11 ± 0.02	95.60 ± 0.04
11	Cabbage	3.08 ± 0.08	0.52 ± 0.12	13.99 ± 0.08	93.15 ± 0.18
12	Cabbage mustard	13.67 ± 0.51	2.08 ± 0.18	11.26 ± 0.03	93.67 ± 0.39
13	Cabbage (Pakchoi)	3.71 ± 0.69	1.47 ± 0.19	26.32 ± 0.01	95.01 ± 0.22
14	Cabbage (small rape)	3.78 ± 0.15	0.76 ± 0.11	14.10 ± 0.16	95.82 ± 0.35
15	Cantaloup	1.13 ± 0.10	0.56 ± 0.10	38.76 ± 0.32	91.50 ± 2.52
16	Carrot	2.20 ± 0.15	0.62 ± 0.04	27.08 ± 0.34	92.56 ± 0.04
17	Cauliflower (white)	7.07 ± 0.47	1.15 ± 0.10	30.84 ± 0.02	86.12 ± 1.39
18	Cauliflower (green)	2.84 ± 0.04	1.83 ± 0.62	58.42 ± 0.13	86.12 ± 1.39
19	Celery	3.90 ± 0.79	0.36 ± 0.14	1.98 ± 0.01	96.00 ± 1.41
20	Cherry	8.85 ± 0.06	1.99 ± 0.03	8.08 ± 0.72	81.04 ± 0.82
21	Cherry-tomato (red)	5.17 ± 0.25	0.48 ± 0.19	18.78 ± 0.07	93.75 ± 0.67
22	Cherry-tomato (yellow)	6.56 ± 0.84	2.16 ± 0.11	21.98 ± 0.29	95.72 ± 3.71
23	Chilli pepper (red)	6.07 ± 1.16	1.31 ± 0.18	133.27 ± 1.04	74.76 ± 1.32
24	Chinese flowering cabbage	5.84 ± 0.08	1.11 ± 0.06	12.86 ± 0.06	94.90 ± 0.47
25	Chinese toon	96.37 ± 7.32	24.34 ± 1.39	6.45 ± 0.11	79.82 ± 0.38
26	Chive	5.18 ± 0.18	0.86 ± 0.36	15.38 ± 0.25	94.16 ± 0.47
27	Citrus	3.69 ± 0.01	0.70 ± 0.31	26.33 ± 0.81	83.53 ± 0.05
28	Citrus limon	6.57 ± 0.14	3.24 ± 0.37	11.79 ± 0.21	89.85 ± 0.34
29	Co-ba	6.85 ± 0.36	1.58 ± 0.08	7.86 ± 0.01	95.35 ± 0.01
30	Coriander	9.17 ± 0.49	3.84 ± 0.38	9.30 ± 0.09	91.61 ± 0.21
31	Cowpea	3.58 ± 0.30	1.47 ± 0.25	8.97 ± 0.05	90.71 ± 0.26
32	Crown daisy	6.94 ± 0.40	1.23 ± 0.11	2.38 ± 0.01	95.69 ± 0.10
33	Cucumber (honey)	7.40 ± 0.57	2.26 ± 1.79	11.86 ± 0.04	96.46 ± 0.01
34	Cucumber (milky)	2.01 ± 0.14	0.62 ± 0.06	10.80 ± 0.11	94.83 ± 0.18
35	Durian	1.82 ± 0.04	0.36 ± 0.05	8.67 ± 1.08	70.77 ± 2.72
36	Eggplant (long)	6.61 ± 0.28	2.36 ± 0.04	5.98 ± 0.05	94.24 ± 0.08

Continued

37	Eggplant (round)	4.57 ± 0.19	2.82 ± 0.11	5.87 ± 0.07	94.56 ± 0.13
38	Endive	9.33 ± 0.01	2.68 ± 0.17	1.64 ± 0.02	91.59 ± 0.06
39	Fennel	10.83 ± 0.09	4.09 ± 0.22	1.72 ± 0.10	91.04 ± 0.34
40	Garlic (stem)	1.41 ± 0.47	1.74 ± 0.11	65.63 ± 0.79	64.73 ± 0.40
41	Garlic seedling	4.16 ± 0.01	1.39 ± 0.08	26.68 ± 0.18	89.53 ± 0.51
42	Garlic sprouts	5.07 ± 0.11	1.03 ± 0.06	29.30 ± 0.16	87.93 ± 0.36
43	Ginger	10.05 ± 2.49	1.78 ± 0.15	9.01 ± 0.02	93.23 ± 0.18
44	Grape	0.93 ± 0.10	0.54 ± 0.08	8.34 ± 1.02	86.20 ± 0.24
45	Great burdock	19.43 ± 1.30	5.78 ± 0.29	7.89 ± 0.79	80.30 ± 0.20
46	Green pepper	4.72 ± 0.39	0.63 ± 0.14	22.84 ± 0.14	93.27 ± 0.24
47	Haricot bean	2.06 ± 0.42	0.32 ± 0.07	17.28 ± 0.15	93.31 ± 0.20
48	Hawthorn	31.35 ± 0.73	15.71 ± 0.26	58.64 ± 0.87	75.90 ± 0.53
49	Hotbed chives	8.24 ± 0.31	0.99 ± 0.05	7.10 ± 0.04	92.09 ± 0.08
50	Houttuynia cordata	4.14 ± 0.02	3.07 ± 0.28	7.92 ± 0.05	78.76 ± 0.56
51	Jujube	15.21 ± 0.32	5.03 ± 0.96	243.56 ± 0.65	73.46 ± 2.14
52	Jujube (Chinese date)	4.55 ± 0.29	2.76 ± 0.11	345.78 ± 0.86	80.89 ± 0.82
53	Kidney bean	2.39 ± 0.16	1.11 ± 0.11	1.28 ± 0.14	91.97 ± 0.10
54	Kiwifruit	3.18 ± 0.17	0.78 ± 0.16	47.30 ± 0.40	85.86 ± 0.48
55	Kumquat	2.70 ± 0.13	0.61 ± 0.15	5.81 ± 0.94	74.92 ± 1.54
56	Leeks	4.94 ± 0.01	1.69 ± 0.11	1.53 ± 0.13	92.42 ± 0.49
57	Lettuce (leaf)	5.83 ± 0.18	1.63 ± 0.19	2.90 ± 0.01	93.72 ± 0.46
58	Lettuce (stem)	1.80 ± 0.15	0.43 ± 0.22	2.96 ± 0.01	95.68 ± 0.10
59	Longan	2.51 ± 0.05	1.24 ± 0.17	4.85 ± 0.41	78.28 ± 1.71
60	Loquat	5.78 ± 0.08	1.38 ± 0.06	4.52 ± 0.68	85.07 ± 4.51
61	Lotus root	15.46 ± 1.45	8.53 ± 0.36	20.32 ± 0.11	77.75 ± 0.40
62	Luffa	10.09 ± 6.23	0.91 ± 0.06	2.40 ± 0.04	95.48 ± 0.04
63	Mango	4.17 ± 0.09	0.67 ± 0.09	6.64 ± 0.18	90.12 ± 0.43
64	Mangosteen	1.19 ± 0.01	0.41 ± 0.03	6.22 ± 0.59	79.52 ± 0.25
65	Melon	1.99 ± 0.22	0.67 ± 0.05	4.27 ± 0.25	91.76 ± 0.65
66	Mung bean sprout	3.69 ± 0.15	0.51 ± 0.04	1.13 ± 0.06	95.23 ± 0.30
67	Muskmelon	3.89 ± 0.20	0.44 ± 0.02	3.04 ± 0.22	93.83 ± 0.31
68	Mushroom	4.45 ± 0.02	0.76 ± 0.06	1.50 ± 0.01	89.42 ± 0.71
69	Mushroom (long-rooted)	5.10 ± 0.08	0.89 ± 0.06	2.76 ± 0.02	89.98 ± 0.14
70	Navel orange	2.69 ± 0.37	0.30 ± 0.15	38.36 ± 0.74	86.91 ± 0.44
71	Onion (red peel)	4.69 ± 1.00	1.97 ± 0.01	8.99 ± 0.51	90.71 ± 0.10
72	Onion (yellow peel)	3.15 ± 0.68	0.73 ± 0.04	8.84 ± 0.23	88.31 ± 0.15
73	Orange (var. gong)	2.66 ± 0.12	0.56 ± 0.06	23.99 ± 0.36	89.16 ± 0.08

Continued

74	Orange (var. huangyan)	3.40 ± 0.26	0.63 ± 0.10	24.42 ± 0.88	89.87 ± 0.29
75	Orange (var. honey)	1.95 ± 0.27	0.77 ± 0.14	25.87 ± 0.64	87.40 ± 0.26
76	Papaya	6.30 ± 0.05	2.28 ± 0.36	47.85 ± 0.57	89.97 ± 0.24
77	Pea (sweet broad)	7.72 ± 0.05	2.34 ± 0.24	13.08 ± 0.09	89.34 ± 0.56
78	Peach	8.06 ± 1.43	6.72 ± 0.77	4.65 ± 0.45	85.87 ± 1.65
79	Pear (general)	1.13 ± 0.09	0.32 ± 0.04	4.09 ± 0.26	85.95 ± 0.25
80	Pear (huangguan)	1.93 ± 0.04	0.92 ± 0.05	3.72 ± 0.45	88.18 ± 0.33
81	Pear (red peel)	1.38 ± 0.01	1.06 ± 0.06	3.89 ± 0.52	87.07 ± 0.26
82	Pepino fruit	6.04 ± 1.25	1.27 ± 0.15	2.32 ± 0.07	93.19 ± 0.09
83	Persimmon	5.59 ± 0.10	1.09 ± 0.07	7.73 ± 0.73	83.66 ± 0.97
84	Pineapple	2.00 ± 0.03	0.99 ± 0.17	7.68 ± 0.33	85.31 ± 0.20
85	Pitaya	1.21 ± 0.14	1.49 ± 0.18	1.50 ± 0.03	85.72 ± 1.32
86	Plum (black)	17.44 ± 0.81	6.71 ± 0.29	3.51 ± 0.21	88.47 ± 0.19
87	Plum (red)	18.35 ± 1.66	2.83 ± 0.06	4.06 ± 0.17	85.13 ± 0.29
88	Pomegranate	4.79 ± 0.15	3.01 ± 0.34	5.48 ± 0.45	81.03 ± 0.29
89	Pomelo (red flesh)	3.86 ± 0.03	0.60 ± 0.16	4.93 ± 0.83	87.13 ± 0.55
90	Pomelo(white flesh)	2.03 ± 0.05	0.52 ± 0.14	3.58 ± 0.48	87.99 ± 0.05
91	Potato	1.32 ± 0.06	0.92 ± 0.12	3.86 ± 0.08	78.61 ± 1.04
92	Pumpkin	2.29 ± 0.12	0.58 ± 0.11	8.90 ± 0.05	87.34 ± 0.48
93	Radish (cherry shape)	8.72 ± 0.20	0.64 ± 0.27	11.08 ± 0.07	95.49 ± 0.12
94	Radish (green peel)	3.19 ± 0.25	1.02 ± 0.07	6.84 ± 0.12	92.19 ± 0.12
95	Radish (xinlimei)	4.24 ± 0.82	0.37 ± 0.02	9.88 ± 0.18	89.28 ± 0.36
96	Radish (white peel)	3.74 ± 0.06	0.70 ± 0.16	10.09 ± 0.28	95.33 ± 0.01
97	Rambutan	1.71 ± 0.07	0.58 ± 0.28	40.01 ± 0.62	79.35 ± 0.78
98	Siraitia grosvenorii	2.05 ± 0.02	1.08 ± 0.18	2.98 ± 0.09	75.21 ± 1.40
99	Soybean sprouts	3.58 ± 0.17	0.38 ± 0.02	6.62 ± 0.02	90.98 ± 0.23
100	Spinach	5.85 ± 0.36	1.63 ± 0.44	8.84 ± 0.08	91.90 ± 1.22
101	Star fruit	10.00 ± 0.01	4.57 ± 0.21	42.68 ± 0.43	88.62 ± 0.16
102	Strawberry	9.23 ± 0.40	2.68 ± 0.18	36.96 ± 0.55	90.32 ± 0.31
103	Summer squash	1.49 ± 0.10	0.43 ± 0.10	9.85 ± 0.06	95.87 ± 0.40
104	Swamp cabbage	7.68 ± 0.13	3.31 ± 0.14	7.62 ± 0.27	91.11 ± 0.18
105	Taro	8.56 ± 0.06	2.76 ± 0.08	1.27 ± 0.07	88.11 ± 0.86
106	Tomato (general)	6.23 ± 0.12	0.38 ± 0.05	22.46 ± 0.04	94.89 ± 0.22
107	Watermelon	1.00 ± 0.17	0.64 ± 0.05	7.50 ± 0.89	91.72 ± 0.77
118	Wax guard	2.69 ± 0.60	0.27 ± 0.10	5.80 ± 0.08	97.06 ± 0.38
109	Welsh onion	2.61 ± 0.26	0.33 ± 0.06	4.13 ± 0.15	88.34 ± 0.43
110	Yam	1.48 ± 0.13	1.48 ± 0.05	2.25 ± 0.15	83.13 ± 0.32

^aValues are means of 3 replicates ± standard deviation; n = 3; ^bTotal phenolics (mg gallic acid/g DW); ^cTotal flavonoids (mg rutin/g DW); ^dVitamin C (mg ascorbic acid/100g FW).

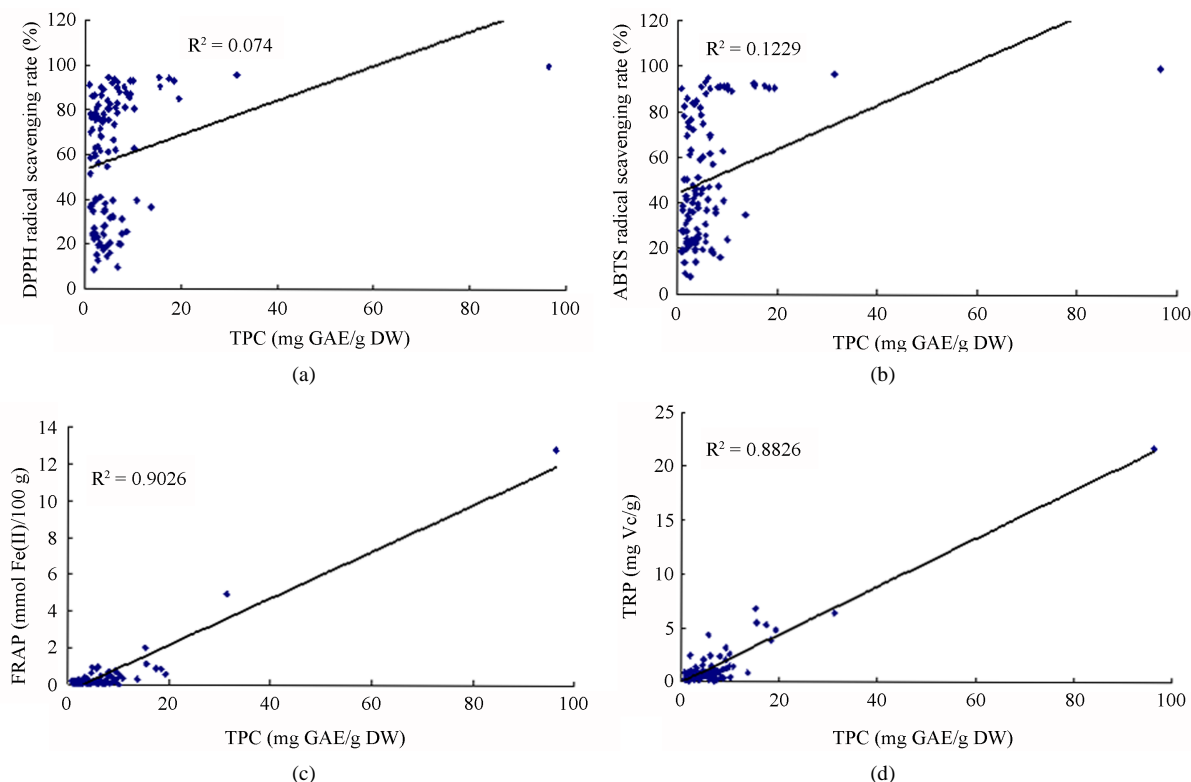


Figure 2. Relationship between antioxidant capacities and TPC (mg gallic acid equivalents/g dry weight) of 110 fruits and vegetables in China. (a) Relationship between antioxidant capacities measured by DPPH assay and total phenolic contents (TPC) recorded by milligram gallic acid equivalents/g dry weight (mg GAE·g⁻¹ DW). (b) Relationship between antioxidant capacities measured by ABTS assay and TPC recorded by mg GAE·g⁻¹ DW. (c) Relationship between antioxidant capacities measured by FRAP assay and TPC recorded by mg GAE·g⁻¹ DW. (d) Relationship between antioxidant capacities measured by TRP assay and TPC recorded by mg GAE·g⁻¹ DW.

not all of the adopted methods are highly related. TPC content showed higher correlation with antioxidant capacity when using FRAP and TRP assays than when using the DPPH or ABTS assay. We identified 15 fruits and vegetables possessing the strongest antioxidant capacities, including Chinese toon, hawthorn, jujube, lotus root, persimmon, red plum, black plum, chili pepper, star fruit, strawberry, blueberry, cherry, peach, pomegranate and great burdock. They can be important dietary sources of natural antioxidants for prevention of chronic degenerative diseases caused by oxidative stress. The highest antioxidant activity and total phenolic content were found in Chinese toon, which is beneficial for development of foods to protect against oxidative stress.

Conflict of Interest Statement

The authors declare that there are no conflicts of interest.

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