Philippine Journal of Science
149 (3-a): 1045-1057, October 2020
ISSN 0031 - 7683
Date Received: 10 Mar 2020

Phytochemical Content and Antioxidant Capacities of Hydrophilic Extracts of Vegetables Commonly Consumed in the Philippines

Rosaly V. Manaois*, **John Edward I. Zapater**, and **Amelia V. Morales**

Rice Chemistry and Food Science Division, Philippine Rice Research Institute
Maligaya, Science City of Muñoz, Nueva Ecija 3119, Philippines

To provide data on the potential of local plant foods as sources of phytochemicals for human health, this study evaluated the phenolic content and antioxidant capacity of locally cultivated vegetables, both in raw form and in a form that they are usually consumed. Hydrophilic extracts of raw and boiled forms of 47 locally cultivated vegetables were evaluated for their total phenolic content (TPC) and antioxidant capacities using the 2,2-diphenylpicrylhydrazyl (DPPH) and 2,2-azinobis(3-ethylbenzothiazoline-6-sulfonic acid)-diammonium salt (ABTS) assays. Results showed that the TPC of raw vegetables ranged 1.0–79.6 mg gallic acid equivalents (GAE) g^{-1}, with the following vegetables having the highest values among the lot: turmeric > red coral lettuce > sweet potato tops ≥ chili leaves > jute > water spinach 1 > green eggplant > purple eggplant. Antioxidant capacities of raw samples determined by DPPH and ABTS assays ranged 0.6–380.6 µmol Trolox equivalents (TE) g^{-1} and 1.4-322.7 µmol TE g^{-1}, respectively, with the following plants consistently displaying the strongest scavenging values among the lot: turmeric, red coral lettuce, sweet potato tops, jute, chili leaves, lowland water spinach, and purple eggplant. Boiling plant foods had variable effects depending on the material studied. The TPC and antioxidant capacities of the fruit samples eggplant, green pepper, and squash significantly increased ($p < 0.05$) after boiling, while those of chili leaves and squash flower decreased. Boiling generally reduced the antioxidant capacities but turmeric, lowland water spinach, and chili leaves consistently exhibited the highest TPC and antioxidant capacities in either form among the tested samples. Our findings signify that local vegetables may be sources of phenolics and other hydrophilic compounds with antioxidant properties.

Keywords: ABTS radical-cation scavenging activity, antioxidants, DPPH radical scavenging activity, phenolics

INTRODUCTION

Filipinos' consumption of plant foods, particularly vegetables, remains low despite their abundance (FNRI-DOST 2015a; Gonzales *et al.* 2016). Based on the National Nutrition Survey in 2013 (FNRI-DOST 2015b), the mean one-day *per capita* vegetable consumption of Filipinos is 114 g, which is equivalent to only one-half cup of boiled vegetables consumed per day or during the three major meals. This is much lower than the recommended intake, which is three-fourths to one cup of raw or cooked vegetables per meal, based on the new food guide for Filipinos called *Pinggang Pinoy* (FNRI-DOST 2014). Gonzales and colleagues (2016) estimated the daily vegetable intake of Filipino adolescents in public schools in Metro Manila at only 81 g. In a country where chronic

*Corresponding Author: rvmanaois@philrice.gov.ph

diseases such as cardiovascular diseases and cancers have continued to afflict many people (DOH; PSA 2019), prevention through the consumption of low-cost health foods such as vegetables needs to be promoted as this is a better and more sustainable approach than expensive medical treatment.

Little information on the phytochemical content and antioxidant capacities of local vegetables are currently available. In 2005, Garcia and colleagues studied the antioxidant potential of only 12 vegetables using the linoleic acid emulsion and deoxy-D-ribose assays. Rumbaoa *et al.* (2009) focused on different varieties of Philippine sweet potato subjected to steaming, while Baang and co-authors (2015) investigated five different green leafy vegetables – namely, *alugbati* (*Basella rubra* L.), *kulitis* (*Amaranthus tricolor* L.), *ampalayang ligaw* (*Momordica chuchinensis* L.), *kamote* (*Ipomea batatas*), and *saluyot* (*Corchorus olitorius* L.). Sagum and colleagues (2016) evaluated 10 vegetables purchased in the market for their anthocyanidins, flavonoids, polyphenolics, and antioxidative properties. In other countries, similar plant foods have been tested but differences in cultivars, soil, climatic conditions, and agricultural management practices limit their relevance to Filipinos. In addition, the methods used in assessing the antioxidant capacities and components vary. Estimation of the phytochemical content and antioxidant capacities of the vegetables in the form that they are typically eaten is necessary to provide insight into the potential of plant foods as sources of phytochemicals for human health. Thus, identifying local plant foods with relatively high antioxidant levels in both raw and cooked forms is necessary.

This study aimed to evaluate the antioxidant capacities of hydrophilic extracts of 47 various locally-cultivated vegetables in the Philippines. This study also investigated the changes in the levels of total phenolics and antioxidant capacities of the vegetables in their edible boiled forms.

MATERIALS AND METHODS

Test Samples and Chemicals

Forty-seven (47) vegetables were collected in the provinces of Benguet, Bulacan, Isabela, Nueva Ecija, and Mountain Province in Northern and Central Luzon, Philippines from Jun 2015 to Sep 2016. These crops were procured from the farms where they were planted right after harvest or in local markets (Appendix Table I).

Folin-Ciocalteu (FC) phenol reagent, DPPH, ABTS, Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), gallic acid, potassium persulfate, cyanidin-3-glucoside (C3G), chlorogenic acid (CGA), and quercetin were from Sigma Aldrich (St. Louis, MO, USA). All other reagents were of analytical grade.

Sample Processing

Raw samples. The samples were processed within 24 h after procurement. Freshly collected samples were removed of dirt and inedible parts, and the edible portions were weighed. The samples were washed twice with tap water and once with distilled water – prepared as indicated in Appendix Table II – then weighed and dried in an air oven at 40 °C for a minimum of 16 h. After drying, the samples were again weighed, ground to a fine powder, and stored at –20 °C until analyzed.

Cooked samples. Except for the lettuce samples, the washed vegetables were weighed and prepared as specified in Appendix Table II. They were completely submerged in boiling distilled water at previously optimized cooking times per sample (Appendix Table II). These were based on the times when the vegetables were deemed tender for consumption. Timing started after the vegetable was submerged in the boiling water. The cooking water was drained off and the sample was submerged for at least 1 min in sufficient amounts of distilled water (~ 24 °C). The cooked samples were weighed, chopped, oven-dried, powdered, and stored at –20 °C until analyzed.

Antioxidant Extraction

The extraction of hydrophilic antioxidants was done based on the methods of Singh *et al.* (2012) and Khairunnuur *et al.* (2009), with modifications. The powdered sample (0.5 g) was added with methanol (85%, 10 mL) and mixed overnight at 300 rpm. The tubes were centrifuged (3,000 rpm,15 min) and the extracts stored at 4 °C until analyzed.

Phytochemical and Antioxidant Capacity Analysis

TPC analysis. The TPC of the sample extracts were determined based on the method of Singleton and colleagues (1998), with few modifications. Briefly, 0.5 mL of sample extract was mixed with 2.5 mL of FC reagent (1:10). After 15 min, 2 mL of 7.5% Na_2CO_3 solution was added – the contents were mixed thoroughly, left to incubate for 1 h, and then read at 765 nm. A reagent blank (85% methanol) and gallic acid standards (0, 10, 20, 40, 50, 60, 80, and 100 μg L^{-1}) were run with the samples. TPC was expressed as milligrams GAE per gram of sample (mg GAE g^{-1} sample), in a dry weight basis (dwb).

DPPH radical scavenging activity. The DPPH radical scavenging activities of the sample extracts were evaluated using the method of Brand-Williams and co-workers (1995) with modifications. Dilute extract (0.5 mL) was

added with 5 mL of 0.01 mM DPPH solution, mixed, allowed to stand for 1 h, then read at 517 nm. A reagent blank (85% methanol) and Trolox standards (0, 20, 40, 60, 100 160, 200, 240, 280, and 500 µmol L^{-1}) were run with the samples. DPPH radical scavenging activity was expressed as micromoles TE per gram of dry sample (µmol TE g^{-1} sample, dwb).

ABTS radical cation scavenging activity. The ABTS scavenging activities of the sample extracts were evaluated based on the procedures of Pellegrini *et al.* (2003) and Moore *et al.* (2005), with modifications. Briefly, an ABTS working solution was first prepared by mixing 2.4 mM potassium persulfate and 7 mM aqueous ABTS. The contents were allowed to incubate for 12–16 h. The mixture was diluted to 1:45 and a 0.3-mL aliquot was added with 3 mL of ABTS working solution. The solution was mixed thoroughly and allowed to react for 1 min, after which the absorbance was read at 734 nm against distilled water as blank and Trolox standards (0, 20, 40, 60, 100, 160, 200, 240, 280, 320, 400, 500 µmol/L). ABTS values were expressed in µmol TE g^{-1} sample dwb.

Quantification of Phenolic Compounds

Sample preparation. The raw and cooked samples with the highest levels of TPC, DPPH, and ABTS were frozen overnight (–20 °C) and lyophilized (–108 °C, ≥ 12 h). The lyophilized samples were ground and 0.5 g each was extracted with 10 mL of 85% HPLC-grade methanol, as described above. The extracts were filtered through 0.45-µm cellulose acetate and transferred into 2-mL amber vials prior to analysis.

HPLC analysis. The samples were assessed for their phenolic composition using a Waters Alliance e2695 HPLC system (Milford, MA, 01757, USA) equipped with a Waters 2998 photodiode array detector. Data signals were acquired and processed using the EMPOWER 3 PDA software. Analytical separation of phenolics was carried out using a BRISA LC2 C18 column (250 mm x 4.6 mm x 0.46 µm) (Teknokroma, Barcelona, Spain). Sample (20 µL) was injected by an autosampler and eluted through the column with a gradient mobile phase consisting of solvent A (99:1 of water: acetic acid) and solvent B (48:50:2 of water:acetonitrile: acetic acid) at 1 mL/min. The solvent gradient was programmed as follows: 0% B at 0 min, increasing from 0–18 min to 30%; 18–30 min isocratic elution at 30% B; 30–45 min at 30–100% B; and 45–47 min 100% isocratic elution. The column temperature was 40 ºC and the absorbance was monitored between 220–530 nm. Phenolic quantification was based on the maximum absorbance of specific phenolic components: CGA and quercetin, 320 nm; and C3G, 530 nm.

Statistical Analysis

SAS v. 9.1 was used in the statistical analysis. ANOVA was performed on the antioxidant and TPC values and multiple comparisons were carried out using Tukey's studentized range test. The level of significance used was $p < 0.05$ and measurements were performed in triplicates unless otherwise stated.

RESULTS AND DISCUSSION

TPC

Table 1 summarizes the TPC of raw and boiled vegetables. Lettuce samples were not subjected to boiling as these are usually consumed raw (*e.g.* in salads). The TPC of the raw vegetables ranged from 0.8–79.6 mg GAE g^{-1} sample. Among the vegetables tested, the samples with the highest TPC (22.5–79.6 mg GAE g^{-1} dwb) in their raw forms were the following: turmeric > red coral lettuce > sweet potato tops ≥ chili leaves > jute > water spinach 1 (lowland) > green eggplant > purple eggplant. Green leafy vegetables had higher TPC while fruits, seeds, bulbs, and roots generally belonged to the lower tier among the samples – with the exception of eggplant and turmeric. Phenolics are secondary metabolites produced in plants to protect them from herbivores, pests, and pathogens (Rehman *et al.* 2012); hence, they are found in high concentrations in the leaves and stems of plants (Larbat *et al.* 2014), as observed in this study.

Boiling is one of the most common cooking methods in the Philippines. Phenolics are known to be destroyed upon boiling due to their thermal instability (Tang *et al.* 2015). However, several samples still exhibited high TPC after boiling, as indicated in Table 1. These were turmeric, lowland water spinach, chili leaves, purple eggplant, and the two green pepper varieties. The samples – which consistently had the highest TPC among the test samples, raw or cooked – were turmeric, chili leaves, lowland water spinach, and purple eggplant. This, despite the fact that the edible parts of these samples belong to different types, the forms boiled were similar to others belonging to the same type and were boiled at the same duration. Loss of phenolics could occur depending on cooking time and food size (Hwang *et al.* 2012). Among these four samples, only chili leaves showed a marked decline in TPC after boiling, which was common among leafy vegetables, except for lowland water spinach. Turmeric contains the phenolic compound curcumin, which has been extensively studied and reported to exhibit high antioxidant capacity and various other biological functions and medicinal effects (Tanvir *et al.* 2017). Curcuminoids were found to be heat resistant in hydrothermal treatments with temperatures ranging 50–100 °C for 30 min (Prathapan *et al.* 2009),

Table 1. TPC and antioxidant capacities of raw and boiled vegetables.

Vegetables	Moisture content (%)[a]	TPC (mg GAE g^{-1} dwb)[b]		%Diff[c]	DPPH radical scavenging activity (µmol TE g^{-1} dwb)[b]		%Diff[a]	ABTS radical cation scavenging activity (µmol TE g^{-1} dwb)[b]		%Diff[c]
		Raw	Boiled		Raw	Boiled		Raw	Boiled	
Leaves										
Bitter gourd	88	7.8 ± 0.3^{lmnop}	2.3 ± 0.2^{nopq}	–70	27.0 ± 1.8^{no}	4.3 ± 0.6^{klm}	–84*	24.0 ± 1.2^{jklm}	7.9 ± 0.5^{nopq}	–67*
Chili	71	37.9 ± 3.45^{c}	22.5 ± 0.4^{c}	–41*	197.3 ± 2.6^{e}	116.9 ± 5.6^{c}	–41*	135.4 ± 2.7^{d}	94.4 ± 3.9^{c}	–30*
Chinese Cabbage	91	9.5 ± 0.5^{jklm}	2.3 ± 0.2^{nopq}	–76*	30.4 ± 0.8^{mno}	10.7 ± 0.8^{jklm}	–65*	32.0 ± 1.0^{i}	7.7 ± 0.5^{opqr}	–76*
Jute	76	31.8 ± 0.0^{d}	8.5 ± 0.3^{fghi}	–73*	239.3 ± 1.3^{d}	52.0 ± 2.5^{e}	–78*	136.8 ± 3.3^{d}	82.7 ± 1.0^{de}	–40*
Lettuce 1	95	12.6 ± 0.5^{hi}	–	–	67.5 ± 4.9^{h}	–	–	46.4 ± 2.9^{h}	–	–
Lettuce 2, red coral	92	55.3 ± 1.3^{b}	–	–	380.6 ± 14.7^{a}	–	–	180.9 ± 3.6^{b}	–	–
Moringa	79	17.8 ± 0.3^{g}	9.2 ± 0.3^{fgh}	–48*	60.6 ± 2.2^{hi}	31.2 ± 0.8^{fg}	–48*	45.4 ± 0.8^{h}	31.6 ± 1.6^{i}	–30*
Mustard	93	10.3 ± 0.2^{ijkl}	4.8 ± 0.2^{jklm}	–53*	36.6 ± 1.4^{klmn}	14.1 ± 0.4^{ijklm}	–62*	28.1 ± 0.9^{ijk}	16.2 ± 1.0^{jkl}	–42*
Spinach	83	6.8 ± 0.1^{nopq}	2.3 ± 0.1^{nopq}	–66*	21.8 ± 1.0^{opqr}	8.8 ± 0.6^{jklm}	–60*	16.1 ± 0.9^{opq}	15.9 ± 1.3^{jkl}	–1
String beans	87	7.2 ± 0.5^{mnop}	4.6 ± 0.2^{klmn}	–36*	14.5 ± 0.7^{pqrst}	16.2 ± 1.5^{ghijklm}	+12	27.7 ± 0.7^{ijkl}	11.8 ± 0.6^{lmno}	-58*
Sweet potato Tops	88	38.3 ± 1.2^{c}	9.5 ± 0.4^{fg}	–75*	254.9 ± 4.5^{c}	48.8 ± 4.1^{e}	–81*	162.8 ± 4.2^{c}	33.2 ± 1.2^{i}	-80*
Water spinach 1	90	28.4 ± 2.2^{e}	30.7 ± 1.7^{b}	+8	170.8 ± 5.0^{f}	193.6 ± 26.0^{b}	+13	101.1 ± 0.7^{e}	114.7 ± 4.1^{b}	+14*
Water spinach 2	88	3.5 ± 0.1^{rst}	5.9 ± 0.2^{ijk}	+66*	55.8 ± 0.3^{ijj}	56.6 ± 4.1^{e}	+2	30.2 ± 0.4^{ij}	22.7 ± 0.9^{j}	–25*
Fruit										
Bitter gourd	94	2.5 ± 0.1^{stu}	2.4 ± 0.0^{nopq}	–4	6.2 ± 0.2^{stuv}	8.0 ± 0.2^{jklm}	+28*	2.2 ± 0.3^{q}	3.9 ± 0.1^{pqr}	+76*
Bottle gourd	95	2.3 ± 0.1^{stu}	1.6 ± 0.1^{pq}	–32*	14.2 ± 0.5^{qrst}	9.4 ± 1.0^{jklm}	–34*	4.6 ± 0.1^{rs}	3.8 ± 0.5^{pqr}	+16
Chili	74	10.3 ± 0.3^{ijk}	10.5 ± 0.1^{f}	+2	23.3 ± 0.8^{opq}	29.7 ± 0.7^{ghi}	+28*	22.8 ± 0.2^{klmn}	21.8 ± 0.2^{jk}	–5*
Eggplant 1	91	22.5 ± 1.8^{f}	21.1 ± 1.3^{cd}	–6	191.8 ± 6.5^{e}	178.5 ± 12.8^{b}	–7	82.2 ± 5.6^{f}	85.0 ± 6.6^{d}	+3
Eggplant 2	93	24.5 ± 0.5^{f}	8.4 ± 0.6^{fgh}	–66*	141.3 ± 1.47^{g}	30.9 ± 0.7^{fgh}	–78	28.9 ± 2.4^{ijk}	36.0 ± 3.6^{hi}	+24*
Green pepper 1	91	9.1 ± 0.0^{jklmn}	16.0 ± 0.3^{e}	+76*	40.8 ± 0.3^{kl}	81.0 ± 0.6^{d}	+98*	30.7 ± 1.8^{i}	53.1 ± 0.7^{f}	+73*
Green pepper 2	90	8.3 ± 0.3^{klmno}	19.9 ± 0.4^{d}	+141*	31.1 ± 0.9^{lmno}	114.6 ± 1.2^{c}	+268*	21.6 ± 0.3^{lmno}	77.6 ± 3.0^{e}	+260*
Okra	91	5.8 ± 0.3^{opqr}	4.3 ± 0.1^{klmno}	–26	37.9 ± 1.4^{klm}	23.3 ± 1.5^{ghij}	–39*	22.6 ± 0.7^{klmn}	17.5 ± 0.4^{jkl}	–22*
Papaya	92	1.3 ± 0.0^{tu}	1.4 ± 0.1^{pq}	+6	4.4 ± 0.1^{tuv}	2.5 ± 0.2^{lm}	–42*	4.2 ± 0.2^{rs}	3.7 ± 0.1^{pqr}	–11*
Sponge gourd	94	2.0 ± 0.0^{tu}	1.5 ± 0.1^{pq}	–25	5.2 ± 0.0^{stuv}	3.0 ± 0.1^{lm}	–42*	5.1 ± 0.2^{rs}	0.6 ± 0.1^{qr}	–88*
Squash 1	81	1.1 ± 0.0^{tu}	1.3 ± 0.1^{pq}	+13	1.2 ± 0.0^{v}	3.3 ± 0.0^{lm}	+165*	2.1 ± 0.0^{s}	2.2 ± 0.1^{pqr}	+7*
Squash 2	79	0.8 ± 0.0^{u}	0.7 ± 0.0^{pq}	–8	0.6 ± 0.0^{v}	1.1 ± 0.0^{lm}	+91*	1.4 ± 0.1^{s}	1.4 ± 0.1^{pqr}	–1
Squash 3	77	1.0 ± 0.0^{u}	1.0 ± 0.0^{pq}	+9	0.8 ± 0.03^{v}	1.0 ± 0.0^{lm}	+19	2.4 ± 0.4^{s}	1.4 ± 0.0^{pqr}	–42
Tomato	94	4.6 ± 0.2^{qrs}	5.3 ± 0.0^{ijk}	+15*	15.0 ± 0.3^{prqs}	16.6 ± 0.2^{ghijkl}	+11*	12.2 ± 0.4^{pq}	15.6 ± 0.7^{jkl}	+28*
Seeds										
Mungbean	11	1.0 ± 0.0^{tu}	0.8 ± 0.0^{pq}	–22*	1.7 ± 0.1^{v}	1.1 ± 0.1^{lm}	–37*	1.6 ± 0.1^{s}	1.2 ± 0.4^{pqr}	–24
Peanut	43	3.0 ± 0.2^{stu}	2.5 ± 0.1^{nop}	–17*	12.2 ± 0.3^{rstu}	8.6 ± 0.3^{jklm}	–29*	12.6 ± 0.8^{pq}	8.2 ± 0.2^{mnop}	–35*
Pods										
Cowpea	88	6.3 ± 0.3^{opq}	5.2 ± 0.3^{ijk}	–17*	24.7 ± 1.9^{op}	28.3 ± 0.6^{ghi}	+15*	20.5 ± 0.7^{mno}	19.6 ± 0.6^{ijk}	–42
String beans	91	5.6 ± 0.2^{pqr}	4.2 ± 0.3^{l}	–25*	24.5 ± 1.9^{opq}	15.7 ± 1.4^{gijklmn}	–36*	17.1 ± 0.3^{nop}	15.1 ± 0.5^{klmn}	–12*
Winged bean	93	6.3 ± 0.2^{opq}	5.0 ± 0.3^{jkl}	–21*	27.5 ± 0.3^{no}	14.8 ± 0.4^{hijklm}	–46*	20.7 ± 0.4^{mno}	15.5 ± 0.9^{jklm}	–25*
Bulbs and roots										
Garlic	64	1.3 ± 0.0^{tu}	1.2 ± 0.0p^{q}	–8*	2.3 ± 0.2^{uv}	1.8 ± 0.1^{lm}	–22*	1.8 ± 0.1^{s}	1.4 ± 0.0^{pqr}	–23*
Ginger	85	7.2 ± 0.2^{mnop}	7.2 ± 0.6^{hij}	–1	38.1 ± 1.3^{klm}	20.2 ± 1.2^{ghijk}	–47*	50.6 ± 3.6^{gh}	43.2 ± 2.9^{gh}	–15
Radish	95	1.4 ± 0.1^{tu}	1.4 ± 0.1^{pq}	+1	4.5 ± 0.2^{tuv}	3.4 ± 0.3^{lm}	–25*	3.2 ± 0.2^{s}	1.8 ± 0.2^{pqr}	–44*
Red onion	89	2.4 ± 0.0^{stu}	2.2 ± 0.1^{opq}	–7*	4.3 ± 0.2^{uv}	4.2 ± 0.2^{klm}	–1	4.0 ± 0.4^{rs}	3.7 ± 0.3^{pqr}	–8
Sweet potato 1	65	1.6 ± 0.1^{tu}	2.9 ± 0.3^{lmnop}	+81*	6.5 ± 0.4^{stuv}	22.0 ± 2.6^{ghij}	+239*	3.8 ± 0.1^{rs}	6.1 ± 0.6^{opqr}	+58*
Sweet potato 2	70	1.7 ± 0.2^{tu}	1.4 ± 0.0^{pq}	–20*	10.0 ± 0.3^{stuv}	8.2 ± 0.2^{jklm}	–20*	4.4 ± 0.2^{rs}	3.8 ± 0.2^{pqr}	–14*
Taro Corm	78	4.6 ± 0.3^{qrs}	2.6 ± 0.2^{mnop}	–45*	43.4 ± 0.6^{k}	16.3 ± 1.2^{ghijklm}	–62*	23.6 ± 0.5^{klm}	11.9 ± 1.4^{kmno}	–50*
Turmeric	91	79.6 ± 1.0^{a}	76.3 ± 3.9^{a}	–4	303.2 ± 9.0^{b}	295.7 ± 92.1^{a}	–2	322.7 ± 7.2^{a}	324.0 ± 9.6^{a}	–0.
Flower										
Banana Blossom	90	9.1 ± 0.2^{jklmn}	8.0 ± 0.2^{ghi}	–12*	46.0 ± 1.6^{ijk}	46.4 ± 2.5^{ef}	+1	56.5 ± 1.9^{g}	47.4 ± 2.1^{fg}	–16*
Squash	94	11.3 ± 0.2^{ij}	8.5 ± 0.2^{fgh}	–25*	28.9 ± 1.0^{mno}	11.2 ± 0.2^{jklm}	–61*	18.5 ± 0.3^{mnop}	11.9 ± 0.3^{lmno}	–36*
Other plant parts										
Bamboo shoot	94	14.4 ± 0.4^{h}	5.9 ± 0.3^{ijk}	–59*	5.4 ± 0.2^{stuv}	2.3 ± 0.1^{m}	–58*	2.5 ± 0.2^{s}	1.1 ± 0.1^{pqr}	–55*
Corn	55	1.3 ± 0.0^{tu}	0.1 ± 0.0^{q}	–91	3.0 ± 0.1^{uv}	2.8 ± 0.2^{lm}	–6	2.6 ± 0.2^{s}	2.9 ± 0.2^{pqr}	+14
Mushroom 1	53	2.1 ± 0.1^{stu}	0.7 ± 0.0^{q}	–57*	3.1 ± 0.3^{uv}	1.1 ± 0.1^{m}	–66*	2.2 ± 0.0^{s}	0.8 ± 0.0^{r}	–62*
Mushroom 2	92	2.9 ± 0.2^{stu}	0.9 ± 0.0^{pq}	–77*	5.6 ± 0.4^{stuv}	0.4 ± 0.0^{lm}	–92*	5.7 ± 0.4^{rs}	0.4 ± 0.1^{qr}	–85*
Taro stalk	93	2.8 ± 0.1^{stu}	2.7 ± 0.1^{m}	–2	10.4 ± 0.7^{stuv}	11.0 ± 0.6^{jklm}	+5	10.1 ± 0.4^{qr}	8.2 ± 0.5^{mnop}	–19*

[a]Moisture content of fresh samples
[b]Means ± SD (n = 3). Mean values with the same lowercase letter within a column are not significantly different at $p < 0.05$.
[c]Differences with * indicate statistical significance between the TPC values of raw and boiled forms by t-test ($p < 0.05$).

which could explain the results of this study (Table 1). In purple eggplant, leaching of phenolics into the cooking water might have been prevented, as the vegetable was boiled whole, hence the TPC retention. This was not observed in the other eggplant variety tested. Boiling was shown to exert different effects on the antioxidant properties of different varieties of eggplant (Lo Scalzo *et al.* 2016). In addition, physical characteristics (*e.g.* size and shape) of the samples and amount of water used for boiling could account for the differences observed. For different varieties of plants belonging to the same species, harvest season and planting location may also influence the levels of phenolics, which could be the subject of future studies.

Boiling of the vegetables to the form they are edible generally caused a reduction in their TPC, with reductions ranging from 1.2–91.4% (Table 1). This result is consistent with previous reports on different crops (Azizah *et al.* 2009; Singh *et al.* 2015). When vegetables are boiled, antioxidant compounds break down and then leach into the cooking water, resulting in decreased antioxidant activity (Sultana *et al.* 2008). Notable declines in TPC were observed in leafy vegetables, such as Chinese cabbage (75.6%), sweet potato tops (75.2%), jute (73.2%), spinach (66.5%), mustard (52.9%), and moringa leaves (48.3%). These results contradict the findings of Hossain and co-workers (2017), who reported significant enhancement of TPC in boiled samples of amaranth and different varieties of spinach grown in India. It can be noted that boiling treatment conditions employed in this study and the cultivars tested were different. Variations in the effects of boiling in the different varieties of the same species of plants can also be observed. In this study, the levels of phenolics in lowland water spinach were not significantly affected by boiling, while improvement in TPC was recorded in the other variety. Along with the leafy vegetables, plant parts with soft tissues such as bamboo shoots and mushrooms also had > 50% reduction in TPC after boiling, which could be due to relative ease of breaking down the cellular matrix, causing thermal degradation or leaching of phenolics into the boiling water. Decreases in TPC in other plant foods were also observed in seeds, pods, and flowers, but to a lesser extent.

Samples with increased TPC after boiling were the two green pepper samples, sweet potato (white-fleshed), and tomato (Table 1). The enhancement in TPC could either be due to the formation of simpler phenolic compounds from complex ones (Singh *et al.* 2014), deactivation of polyphenolic oxidase and improvement of extractability of phenolics (Shaimaa *et al.* 2016), or the liberation of phenolics during hydrolysis of the glycoside bonds in pectin or cellulose networks where phenolic compounds are usually contained (Padmini *et al.* 2015).

DPPH Radical Scavenging Activity

The DPPH activities of the plant extracts are presented in Table 1. The DPPH values of the raw samples varied widely at 0.6–380.6 μmol TE g^{-1}. The vegetables with the highest DPPH values (141.3–380.6 μmol TE g^{-1}) were red coral lettuce > turmeric > sweet potato tops > jute > chili leaves ≥ purple eggplant > water spinach 1 > green eggplant.

In the boiled form, the DPPH values of the samples ranged 0.4–295.7 μmol TE g^{-1} (Table 1). The boiled vegetables with the highest DPPH scavenging activities (46.4–295.7 μmol TE g^{-1}) were turmeric, lowland water spinach, purple eggplant, chili leaves, the two green pepper varieties, upland water spinach, jute, and banana blossom. Generally, boiling reduced the DPPH values of the vegetables, with oyster mushroom losing as much as 92%. Leafy vegetables were among the most antioxidant-rich samples, but most of these vegetables significantly lost > 40% of their DPPH antioxidant power after boiling. Minimal heat processing may be necessary to prevent loss of components that exhibit antioxidant activities, particularly in leafy vegetables.

String bean leaves and other non-leafy vegetables – such as banana blossom, purple eggplant, red onion, and taro stalk – retained their DPPH antioxidant capacities after boiling (Table 1). This signifies that the antioxidants may still be present even after boiling. For purple eggplant, which was boiled whole, retention of antioxidant capacity may be due to minimal leaching of antioxidants into the boiling water, which can also be observed in the change in its TPC content (Table 1). In red onion, boiling for 1 min resulted in retained antioxidant capacity. Kosewski and colleagues (2018) reported that red onion boiled for 10 min, the conventional method used in Polish cooking, had reduced DPPH activity by as much as 71%. Nine vegetables had significantly improved ($p < 0.05$) DPPH activities after boiling to their edible forms, with as much as 239% enhancement, as shown in Table 1. These were bitter gourd, chili fruit, cowpea, the two green pepper samples, squash fruits 1 and 2, white-fleshed sweet potato, and tomato. A possible reason for the increase was the liberation of antioxidant components from the cell wall of plants in general (Sun *et al.* 2014) or the formation of other compounds with high antioxidant capacity, notably the aglycones. This results from the breaking of glucosides of flavonoids, a group of polyphenolics, particularly in cowpea (Xu and Chang 2008); Maillard reaction products, especially in peppers (Wangcharoen and Morasuk 2009); and CGA and several forms of di-caffeoylquinic acid in sweet potatoes (Bellail *et al.* 2012). Furthermore, deactivation of peroxidases, which have pro-oxidant properties, could have also contributed to improved antioxidant capacities of the boiled samples (Gazzani *et al.* 1998; Xu and Chang 2008).

ABTS Radical Cation Scavenging Activity

Raw samples had ABTS activities ranging from 1.4–322.7 µmol TE g^{-1} (Table 1). Turmeric, red coral lettuce, sweet potato tops, jute, chili leaves, lowland water spinach, and purple eggplant had the highest ABTS antioxidant capacities among the test samples. These vegetables also exhibited the highest ABTS activities among the lot after boiling. In terms of plant part types, leafy vegetables were generally stronger ABTS radical scavengers than the rest of the samples – raw or boiled – with the exception of turmeric, eggplants, ginger, green peppers, and banana blossom.

Of the 46 boiled samples, 27 had significantly reduced ABTS values ($p < 0.05$), with decreases by as much as 88% (sponge gourd) (Table 1). Bitter gourd, green pepper, squash, and tomato had significantly increased ABTS activities after boiling. These trends in ABTS measurements were noted as generally similar to the results of the DPPH assay. These results signify that phenolic compounds present in the vegetables have the ability to scavenge both ABTS and DPPH radicals *in vitro*, as also shown by the strong positive correlations ($r = 0.9126^{**}$ and $r = 0.9323^{**}$, $p < 0.01$) between DPPH and ABTS values for both extracts of raw and cooked samples, respectively (Appendix Figure I). Tiveron and co-workers (2012) also reported a positive correlation ($r = 0.71$) between ABTS and DPPH values of 23 vegetables consumed in Brazil. However, except for banana blossom, ginger, and turmeric, all hydrophilic extracts were more effective in DPPH radical scavenging than ABTS. Although ABTS and DPPH follow the same electron donation mechanism (Rubalya Valantina and Neelamegam 2015), different antioxidant compounds vary in their reaction and quenching action against various radicals, as previously reported (Wang M *et al.* 1998; Wang W *et al.* 2008). In a study by Noreen and colleagues (2017), extracts and fractions of the medicinal plant *Coronopus didymus* were shown to be better scavengers of ABTS radical than DPPH. The same action was displayed by ethanolic extracts of the stem and leaf of *Grewia carpinifolia* (Adebiyi *et al.* 2017) and some leafy vegetables consumed in Africa (Obeng *et al.* 2020). In the latter, no correlation between the ABTS and DPPH methods was also noted (Obeng *et al.* 2020). These contradict the results of this study, which tested a wide range of samples – with phenolic compounds having varying complexity, polarity, and chemical properties under a different solvent system. Some other factors that could have contributed to this distinction in the observed DPPH and ABTS relationship are stereoselectivity of the radicals used, and solubility and redox potential of the antioxidants and radicals (Apak *et al.* 2007; Amensour *et al.* 2010; Noreen *et al.* 2017).

Relationship of TPC and Antioxidant Capacities

Analyses yielded significant correlations ($p < 0.05$) for the TPC of the samples against their antioxidant capacities (DPPH and ABTS), both in raw (Figure 1A) and cooked forms (Figure 1B), with r values ranging 0.74–0.98. These results suggest that phenolics significantly influence the hydrophilic antioxidant capacities of the assayed vegetables, supporting previous reports on some raw and boiled plant foodstuff (Takebayashi *et al.* 2013; Preti *et al.* 2017).

Although the antioxidant capacities generally decreased after boiling, slightly higher correlations between TPC and antioxidant capacities were obtained in boiled samples than in raw ones (Figures 1A and 1B). In addition to phenolics, the antioxidant capacity of the

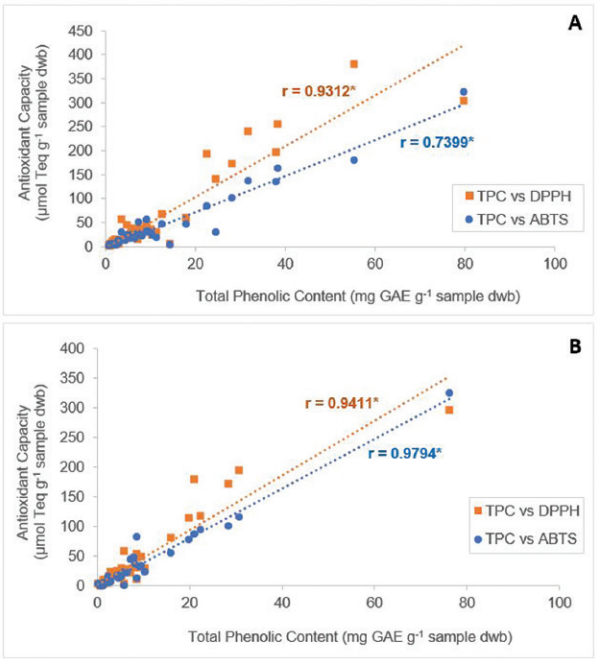


Figure 1. Correlations ($p < 0.05$) of TPC versus antioxidant capacities of raw (A) and boiled (B) vegetables.

hydrophilic extracts of the vegetables can be due to various other compounds present such as ascorbic acid, a heat-labile antioxidant compound. Moist-heat cooking methods, *e.g.* boiling, have been found to greatly reduce ascorbic acid (Hwang *et al.* 2012), while phenolic content is either decreased or increased depending on the structure of the vegetable and type of phenolic compounds present (Gunathilake *et al.* 2018). Reduction in ascorbic acid reached up to 66.5% after boiling for 15 min in red peppers (*Capsicum annuum* L.) (Hwang *et al.* 2012) and 85.75% in squash boiled for 5 min (Agamy 2016). In these studies, however, TPC also decreased significantly after boiling, contrary to the results of this present study for the same vegetables. Nevertheless,

boiling was found to more adversely affect ascorbic acid levels than phenolics in several green vegetables common in the Mediterranean diet (Vinha *et al.* 2015). Boiling could have exerted the same effect on the antioxidants in the samples of this present study.

It must be highlighted, though, that the vegetables used in this study were subjected to different boiling times, as the *in vitro* analyses of the antioxidant capacities and TPC were done on the extracts of edible forms of the vegetables. Our purpose is to give an estimation of the antioxidants that could be available when these vegetables are consumed. A more thorough investigation on the effect of boiling, as well as other cooking methods commonly employed in the country, should be studied in future work to determine which method could best preserve the antioxidants in local vegetables.

Quantification of Phenolic Compounds of Selected Samples

Identification and quantification of primary phenolic compounds were conducted in the samples, which had high TPC and exhibited high radical scavenging activities – namely, red coral lettuce, lowland water spinach, and chili leaves (Table 2). Turmeric, which generally displayed the highest TPC and antioxidant capacities either in raw or boiled form, was not assayed due to a limited amount of sample procured and unavailability of HPLC standards for curcuminoids or other phenolic compounds known to be abundant in turmeric. Results of the chromatographic analysis showed that CGA was present in all the measured vegetables, with levels ranging 1.16–12.78 mg g^{-1} and 0.74–3.06 mg g^{-1} in raw and cooked forms, respectively. Red coral lettuce had the highest CGA level among the three vegetables. CGAs are among the abundant phenolic compounds in plants, many of which are important components of the human diet (Liang and Kitts 2016). Predictably, red coral lettuce was also the only sample with C3G (0.37 mg g^{-1}) because C3G is a natural pigment found in plants. In addition to these compounds, other compounds reported in red coral lettuce are caffeoylmalic acid (Becker *et al.* 2014), derivatives of cyanidin-3-O-malonyl-glucopyranoside (Mulabagal *et al.* 2010), caffeic acid derivatives, quercetin 3-O-rhammoside and rutinoside, and luteolin 4-O-glucoside (Aires *et al.* 2013). These compounds could have accounted for the measured TPC (55.3 mg GAE g^{-1}; Table 1) in this study.

Quercetin was detected only in chili leaves, either raw (0.03 mg g^{-1}) or boiled (0.01 mg g^{-1}) (Table 2). Its CGA level dropped by 51.5% after boiling. CGA had possibly undergone isomerization into 4-O-caffeoylquinic acid and 5-O-caffeoylquinic acid during boiling (Kan *et al.* 2014). CGA might have also washed out with the boiling water (Sukrasno and Kusmardiyani 2014) or had hydrolyzed into caffeic acid (Miglio *et al.* 2008). Water spinach 1 (lowland), however, had raised CGA level after boiling by up to 37%, which could be attributed to the deactivation of polyphenol oxidase, an enzyme that can cause degradation of CGA (Lo Scalzo *et al.* 2010).

CONCLUSION AND RECOMMENDATIONS

Vegetables commonly consumed in the Philippines vary widely in terms of phenolic content and antioxidant capacities. Boiling can significantly affect the phenolic content and antioxidant capacities of up to 92% and 88%, respectively; this suggests that the vegetables, particularly the green leafy ones, must be subjected to minimal heating to prevent the loss of antioxidants. As this study focused on antioxidant properties of hydrophilic extracts only, it is worthwhile to evaluate the lipophilic antioxidants present in the samples and any changes after boiling to estimate antioxidant intake from these vegetables. Additionally, *in vivo* antioxidant capacity analysis of the vegetables is warranted to give a complete antioxidant profile of the samples and to provide a basis for future epidemiological studies. Such information will be useful in nutritional research and could serve as valuable inputs in crafting policies on nutrition in the country.

Table 2. Levels of phenolic compounds in raw and cooked vegetables.

Vegetable	Content (mg g^{-1} sample, dwb)[a,b]					
	Cyanidin-3-glucoside		Chlorogenic acid		Quercetin	
	Raw	Cooked	Raw	Cooked	Raw	Cooked
Red coral lettuce	0.37 ± 0.03	–	12.78 ± 0.31[a]	–	ND	–
Water spinach 1	ND	ND	1.95 ± 0.39[b]	3.06 ± 0.42[a]	ND	ND
Chili leaves	ND	ND	1.16 ± 0.06[c]	0.74 ± 0.01[b]	0.03 ± 0.01	0.01 ± 0.00

[a]Means ± SD (n = 3). Mean values with the same letter within a column are not significantly different at $p < 0.05$.
[b]ND – not detected

ACKNOWLEDGMENTS

The authors are grateful to the staff of the Palayamanan Plus and FutureRice Farm at Philippine Rice Research Institute for the vegetables. Appreciation is extended to Mr. John Paulo A. Samin and Mr. Henry F. Mamucod for their technical support. Ms. Charisma Love Gado-Gonzales is also thanked for her editorial assistance. This study was supported by the United Nations University and Kirin Holdings Co., Inc., Tokyo, Japan.

NOTES ON APPENDICES

The complete appendices section of the study is accessible at http://philjournsci.dost.gov.ph

REFERENCES

ADEBIYI OE, OLAYEMI FO, NING-HUA T, GUANG-ZHI Z. 2017. *In vitro* antioxidant activity, total phenolic and flavonoid contents of ethanol extract of stem and leaf of *Grewia carpinifolia*. Beni-Seuf Univ J Appl Sci 6(1): 10–14.

AGAMY NF. 2016. Effect of boiling and microwave cooking on some antioxidant compounds in highly consumed vegetables in Egypt. Cent Eur Res J 2: 76–84.

AIRES A, MARQUES E, CARVALHO R, ROSA EAS, SAAVEDRA MJ. 2013. Evaluation of biological value and appraisal of polyphenols and glucosinolates from organic baby-leaf salads as antioxidants and antimicrobials against important human pathogenic bacteria. Molecules 18(4): 4651–4668.

AMENSOUR M, SENDRA E, PEREZ-ALVAREZ JA, SKALI-SENHAJI N, ABRINI J, FERNANDEZ-LOPEZ J. 2010. Antioxidant activity and chemical content of methanol and ethanol extracts from leaves of rockose (*Cistus ladaniferus*). Plant Food Hum Nutr 65(2): 170–178.

APAK R, GÜÇLÜ K, DEMIRATA B, ÖZYÜREK M, ÇELIK SE, BEKTAŞOĞLU B, BERKER KI, ÖZYURT D. 2007. Comparative evaluation of various total antioxidant capacity assays applied to phenolic compounds with the CUPRAC assay. Molecules 12(7): 1496–1547.

AZIZAH AH, WEE KC, AZIZAH O, AZIZAH M. 2009. Effect of boiling and stir frying on total phenolics, carotenoids and radical scavenging activity of pumpkin (*Cucurbita moschato*). Int Food Res J 16(1): 45–51.

BAANG RP, DEL ROSARIO RM, PALMES ND. 2015. Phytochemical profiles and antioxidant activity of selected indigenous vegetables in Northern Mindanao, Philippines. World Acad Sci Eng Technol 9(8): 828–833.

BELLAIL AA, SHALTAOUT OE, YOUSSEF MM, EL GAMAL AMA. 2012. Effect of home-cooking methods on phenolic composition and antioxidant activity of sweet potato (*Ipomoea batatas* (L.) Lam.) cultivars grown in Egypt. Food Nutr Sci 3: 490–499.

BECKER C, KLAERING H-P, KROH LW, KRUMBEIN A. 2014. Cool-cultivated red leaf lettuce accumulates cyanidin-3-O-(6''-O-malonyl)-glucoside and caffeoylmalic acid. J Food Chem 146: 404–411.

BRAND-WILLIAMS W, CUVELIER ME, BERSET C. 1995. Use of a free radical method to evaluate antioxidant activity. LWT-Food Sci Technol 28(1): 25–30.

[DOH] Department of Health. n/d. What are the Leading Causes of Mortality in the Philippines? Retrieved on 18 Jun 2020 from https://www.doh.gov.ph/node/1058

[FNRI-DOST] Food and Nutrition Research Institute – Department of Science and Technology. 2014. Pinggang Pinoy Food Guide. Taguig City, Philippines.

[FNRI-DOST] Food and Nutrition Research Institute – Department of Science and Technology. 2015a. Analysis of the Nutritional Status and Dietary Diversity of Filipino Households: Focus on the Fisherfolks. Taguig City, Philippines.

[FNRI-DOST] Food and Nutrition Research Institute-Department of Science and Technology. 2015b. Philippine Nutrition Facts and Figures 2013: Food Consumption Survey. Taguig City, Philippines.

GARCIA VV, MAGPANTAY TO, ESCOBIN LD. 2005. Antioxidant potential of selected Philippine vegetables and fruits. Philipp Agric Sci 88(1): 78–83.

GAZZANI G, PAPETTI A, MASSOLINI G, DAGLIA M. 1998. Anti- and prooxidant activity of water-soluble components of some common diet vegetables and the effect of thermal treatment. J Agric Food Chem 46(10): 4118–4122.

GONZALES JT, RAAIJ JV, NARCISO ZV. 2016. Consumption pattern for fruits and vegetables of some Filipino adolescents in selected public schools in the city of Manila. J Nutr Disorders Therapy 6(4): 1000202. DOI: 10.4172/2161-0509.1000202

GUNATHILAKE KDPP, RANAWEERA KKDS, RUPASINGHE HPV. 2018. Effect of different cooking methods on polyphenols, carotenoids and antioxidant activities of selected edible leaves. Antioxidants (Basel) 7(9): 117. DOI: 10.3390/antiox7090117

HOSSAIN A, KHATUN MA, ISLAM M, HUQUE R. 2017. Enhancement of antioxidant quality of green leafy vegetables upon different cooking method. Prev Nutr Food Sci 22(3): 216–222

HWANG IG, SHIN YJ, LEE S, LEE J, YOO SM. 2012. Effects of different cooking methods on the antioxidant properties of red pepper (*Capsicum annuum* L.). Prev Nutr Food Sci 17(4): 286–292.

KAN S, CHEUNG MWM, ZHOU Y, HO WS. 2014. Effects of boiling on chlorogenic acid and the liver protective effects of its main products against CCl4-induced toxicity *in vitro*. J Food Sci 79(2): C147–C154.

KHAIRUNNUUR FA, ZULHAIRI A, AZRINA A, MOKLAS MAM, KHAIRULLIZAM S, ZAMREE MS, SHAHIDAN MA. 2009. Nutritional composition, *in vitro* antioxidant activity and *Artemia salina* L. lethality of pulp and seed of *Tamarindus indica* L. leaves. Malays J Nutr 15(1): 65–75.

KOSEWSKI G, GÓRNA I, BOLESŁAWSKA I, KOWALÓWKA M, WIĘCKOWSKA B, GŁÓWKA AK, MORAWSKA A, JAKUBOWSKI K, DOBRZYŃSKA M, MISZCZUK P, PRZYSŁAWSKI J. 2018. Comparison of antioxidative properties of raw vegetables and thermally processed ones using the conventional and sous-vide methods. Food Chem 240: 1092–1096.

LARBAT R, PARIS C, LE BOT J, ADAMOWICZ S. 2014. Phenolic characterization and variability in leaves, stems and roots of Micro-Tom and patio tomatoes, in response to nitrogen limitation. Plant Sci 224: 62–73.

LIANG N, KITTS DD. 2016. Role of chlorogenic acids in controlling oxidative and inflammatory stress conditions. Nutrients 8(1): 16. DOI:10.3390/nu8010016

LO SCALZO R, FIBIANI M, FRANCESE G, D'ALESSANDRO A, ROTINO G, CONTE P, MENNELLA G. 2016. Cooking influence on physicochemical fruit characteristics of eggplant (*Solanum melongena* L.). Food Chem 194: 835–842.

LO SCALZO R, FIBIANI M, MENNELA G, ROTINO GL, DAL SASSO M, CULICI M, SPALLINO A, BRAGA PC. 2010. Thermal treatment of eggplant (*Solanum melongena* L.) increases the antioxidant content and the inhibitory effect on human neutrophil burst. J Agric Food Chem 58(6): 3371–3379.

MIGLIO C, CHIAVARO E, VISCONTI A, FOGLIANO V, PELLEGRINNI N. 2008. Effects of different cooking methods on nutritional and physicochemical characteristics of selected vegetables. J Agric Food Chem 56(1): 139–147.

MOORE J, HAO Z, ZHOU K, LUTHER M, COSTA J, YU L. 2005. Carotenoid, tocopherol, phenolic acid and antioxidant property of Maryland-grown soft wheat. J Agric Food Chem 53(17): 6649–6657.

MULABAGAL V, NGOUAJIO M, NAIR A, ZHANG Y, GOTTUMUKKALA DL, NAIR MG. 2010. *In vitro* evaluation of red and green lettuce (*Lactuca sativa*) for functional food properties. J Food Chem 118(2): 300–306.

NOREEN H, SEMMAR N, FARMAN M, MCCULLAGH JSO. 2017. Measurement of total phenolic content and antioxidant activity of aerial parts of medicinal plant *Coronopus didymus.* Asian Pac J Trop Med 10(8): 792–801.

OBENG E, KPODO FM, TETTEY CO, ESSUMAN EK, ADZINYO OA. 2020. Antioxidant, total phenols and proximate constituents of four tropical leafy vegetables. Sci African 7, e00227. DOI: 10.1016/j.sciaf.2019.e00227

PADMINI T, KARPAGAVALLI B, VIJAYALASHMI R, JESUPRIYA PS. 2015. Changes in antioxidants during heat-processing of green-leafy vegetables. Int J Agric Food Sci 15(4): 115–120.

PELLEGRINI N, DEL RIO D, COLOMBI B, BIANCHI M, BRIGHENTI F. 2003. Application of the 2,2-azinobis(3-ethylbenzothiazoline-6-sulfonic acid) radical cation scavenging assay to a flow injection system for the evaluation of antioxidant activity of some pure compounds and beverages. J Agric Food Chem 51(1): 260–264.

PRATHAPAN A, LUKHMAN M, ARUMUGHAN C, SUNDARESAN A, RAGHU KG. 2009. Effect of heat treatment on curcuminoid, colour value and total polyphenols of fresh turmeric rhizome. Int J Food Sci Tech, 44(7): 1438–1444.

PRETI R, RAPA M, VINCI G. 2017. Effect of steaming and boiling on the antioxidant properties and biogenic amines content in green bean (*Phaseolus vulgaris*) varieties of different colours. J Food Qual. p. 1–8. DOI:10.1155/2017/5329070

[PSA] Philippine Statistics Authority. 2019. Registered Deaths in the Philippines, 2017. Retrieved on 18 Jun 2020 from https://psa.gov.ph/vital-statistics/id/138794

REHMAN F, KHAN FA, BADRUDDIN S. 2012. Role of Phenolics in Plant Defense Against Insect Herbivory. In: Chemistry of Phytopotentials: Health, Energy and Environmental Perspectives. Srivastava MM, Khemani LD, Srivastava S eds. Berlin: Springer-Verlag. 309p.

RUBALYA VALANTINA RR, NEELAMEGAM P. 2015. Selective ABTS and DPPH- radical scavenging

activity of peroxide from vegetable oils. Int Food Res J 22(1): 289–294.

RUMBAOA RG, CORNAGO DF, GERONIMO IM. 2009. Phenolic content and antioxidant capacity of Philippine sweet potato (*Ipomoea batatas*) varieties. Food Chem 113(4): 1133–1138.

SAGUM RS, MALLILIN AC, BAQUIRAN AFP, ALCANTARA JDS. 2016. Phytochemical, antioxidant activity of pigmented rice, vegetables and fruits in the Philippines. 42nd FNRI Seminar Series Book of Abstracts, Food and Nutrition Research Institute, Department of Science and Technology, Taguig City, Philippines.

SHAIMAA GA, MAHMOUD MS, MAHAMED MR, EMAM AA. 2016. Effect of heat treatment on phenolic and flavonoid compounds and antioxidant activities of some Egyptian sweet and chili pepper. Nat Prod Chem Res 4(3): 1–6.

SINGH DR, SINGH S, SALIM KM, SRIVASTAVA RC. 2012. Estimation of phytochemicals and antioxidant activity of underutilized fruits of Andaman Islands (India). Int J Food Sci Nutr 63(4): 446–452.

SINGH DR, SINGH S, BANU VS. 2014. Phytochemical composition, antioxidant activity and sensory evaluation of potential underutilized fruit soursop (*Annona muricata* L.) in Bay Islands. J Andaman Sci Assoc 19(1): 30–37.

SINGH S, SWAIN S, SINGH DR, SALIM KM, NAYAK D, ROY SD. 2015. Changes in phytochemical anti-nutrients and antioxidant activity in leafy vegetables by microwave-boiling with normal and 5% NaCl solution. Food Chem 176: 244–253.

SINGLETON VL, ORTHOFER R, LAMUELA-RAVENTOS RM. 1998. Analysis of total phenols and other oxidative substrates and antioxidants by means of Folin-Ciocalteu reagent. Methods Enzymol 299: 152–178.

SUKRASNO YMS, KUSMARDIYANI S. 2014. Influence of cooking methods on chlorogenic acid content of potato peels (*Solanum tuberosum* L.). Int J Pharmacogn Phytochem Res 6(3): 488–491.

SULTANA B, ANWAR F, IQBAL S. 2008. Effect of different cooking methods on the antioxidant activity of some vegetables from Pakistan. Int J Food Sci Technol 43(3): 560–567.

SUN L, BAI X, ZHUANG Y. 2014. Effect of different cooking methods on total phenolic contents and antioxidant activities of four Boletus mushrooms. J Food Sci Technol 51(11): 3362–3368.

TAKEBAYASHI J, OKI T, WATANABE J, YAMASAKI K, CHEN J, SATO-FURUKAWA M, TSUBOTA-UTSUGI M, TAKU K, GOTO K, MATSUMOTO T, ISHIMI Y. 2013. Hydrophilic antioxidant capacities of vegetables and fruits commonly consumed in Japan and estimated daily intake of hydrophilic antioxidants from these foods. J Food Comp Anal 29(1): 25–31.

TANG Y, CAI W, XU B. 2015. Profiles of phenolics carotenoids, and antioxidative capacities of thermal processed white, yellow, orange, and purple sweet potatoes grown in Guilin, China. Food Sci Hum Wellness 4(1): 123–132.

TANVIR EM, HOSSEN MS, HOSSAIN MF, AFROZ R, GAN SH, KHALIL MI, KARIM N. 2017. Antioxidant properties of popular turmeric (*Curcuma longa*) varieties from Bangladesh. J Food Qual 2017(3): 1–8. DOI: https://doi.org/10.1155/2017/8471785

TIVERON AP, MELO PS, BERGAMASCHI KB, VIEIRA TMFS, REGITANO-D'ARCE MAB, ALENCAR SM. 2012. Antioxidant activity of Brazilian vegetables and its relation with phenolic composition. Int J Mol Sci 13(7): 8943–8957.

VINHA AF, ALVES RC, BARREIRA SV, COSTA AS, OLIVEIRA MB. 2015. Impact of boiling on phytochemicals and antioxidant activity of green vegetables consumed in the Mediterranean diet. Food Func 6(4): 1157–1163.

WANG M, LI J, RANGARAJAN M, SHAO Y, LA VOIE EJ, HUANG T, HO C. 1998. Antioxidative phenolic compounds from Sage (*Salvia officinalis*). J Agric Food Chem 46(12): 4869–4873.

WANG W, WU N, ZU YG, FU YJ. 2008. Antioxidative activity of *Rosmarinus officinalis* L. essential oil compared to its main components. Food Chem 108(3): 1019–1022.

WANGCHAROEN W, MORASUK W. 2009. Antioxidant capacity changes of bird chili (*Capsicum frutescens* Linn.) during hot air drying. Kasetsart J Nat Sci 43(1): 12–20.

XU B, CHANG SKC. 2008. Effect of soaking, boiling and steaming on total phenolic content and antioxidant activities of cool season food legumes. Food Chem 110(1): 1–13.

Appendix Table I. Vegetable samples used in the experiment.

No.	Sample	Scientific name	Common name (Filipino)	Variety/ description	Source (municipality/city, province)	Harvest season[a]
Leaves						
1	Bitter gourd	*Momordica charantia*	*Ampalaya*	Farmer's variety	Muñoz, NE	2016 WS
2	Chili	*Capsicum frutescens*	*Talbos ng sili*	Farmer's variety	Muñoz, NE	2016 WS
3	Chinese cabbage	*Brassica rapa*	*Petsay*	Pavito F1	Muñoz, NE	2015 WS
4	Jute	*Corchorus olitorius*	*Saluyot*	Farmer's variety	Muñoz, NE	2015 WS
5	Lettuce 1	*Lactuca sativa*	*Letsugas*	Korean	Muñoz, NE	2016 DS
6	Lettuce 2, red coral	*Lactuca sativa*	*Letsugas*	Lollo Rosso	Muñoz, NE	2016 DS
7	Moringa	*Moringa oleifera*	*Malunggay*	Farmer's variety	Muñoz, NE	2016 DS
8	Mustard	*Brassica juncea*	*Mustasa*	Monteverde	Muñoz, NE	2015 WS
9	Spinach	*Spinacia oleracea*	*Alugbati*	Green amaranth	Muñoz, NE	2015 DS
10	String beans	*Vigna unguiculata* subs. *sesquipedalis*	*Talbos ng Sitaw*	Farmer's variety	Muñoz, NE	2016 DS
11	Sweet potato	*Ipomoea batatas*	*Talbos ng Kamote*	Farmer's variety	Muñoz, NE	2016 DS
12	Water spinach 1	*Ipomoea aquatica*	*Kangkong*	Lowland	Muñoz, NE	2016 WS
13	Water spinach 2	*Ipomoea aquatica*	*Kangkong*	Upland	Muñoz, NE	2015 WS
Fruit						
14	Bitter gourd	*Momordica charantia*	*Ampalaya*	Farmer's variety	Sagada, Mt. Province	2015 WS
15	Bottle gourd	*Lagenaria siceraria*	*Upo*	Farmer's variety	San Rafael, Bulacan	2015 WS
16	Chili	*Capsicum frutescens*	*Siling labuyo*	Farmer's variety	Bontoc, Mt. Province	2015 WS
17	Eggplant 1, purple,	*Solanum melongena*	*Talong na haba*	Morena	Muñoz, NE	2015 WS
18	Eggplant 2, green	*Solanum melongena*	*Talong na bilog*	Round	Muñoz, NE	2016 DS
19	Green pepper 1	*Capsicum annuum*	*Siling panigang*	Django	Muñoz, NE	2016 DS
20	Green pepper 2	*Capsicum annuum*	*Siling panigang*	Korean	Muñoz, NE	2016 DS
21	Okra	*Abelmoschus esculentus*	*Okra*	Smooth green	Muñoz, NE	2015 WS
22	Papaya, unripe	*Carica papaya*	*Papaya*	Green	San Jose, NE	2016 WS
23	Sponge gourd	*Luffa acutangula*	*Patola*	Farmer's variety	San Jose, NE	2016 DS
24	Squash 1	*Cucurbita maxima*	*Kalabasa*	Suprema	Muñoz, NE	2016 DS
25	Squash 2	*Cucurbita maxima*	*Kalabasa*	Farmer's variety	Muñoz, NE	2015 WS
26	Squash 3	*Cucurbita maxima*	*Kalabasa*	Farmer's variety	Sagada, Mt. Province	2016 DS
27	Tomato	*Solanum lycopersicum*	*Kamatis*	Diamante max	Muñoz, NE	2016 DS
Seeds						
28	Mungbean	*Phaseolus aureus*	*Munggo*	Farmer's variety	Isabela	2016 DS
329	Peanut	*Arachis hypogaea*	*Mani*	Farmer's variety	Muñoz, NE	2016 WS
Pods						
30	Cowpea	*Vigna unguiculata*	*Sitaw na turo*	Sumilang	Muñoz, NE	2015 WS
31	String beans	*Vigna unguiculata* subs. *sesquipedalis*	*Sitaw na haba*	Negrostar	Muñoz, NE	2015 WS
32	Winged bean	*Psophocarpus tetragonolobus*	*Sigarilyas*	Farmer's variety	Muñoz, NE	2016 DS

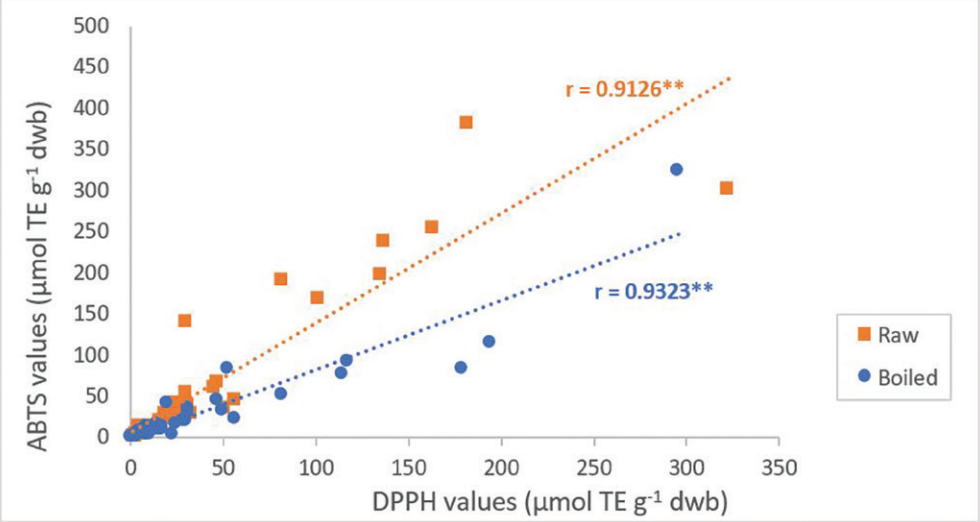
No.	Sample	Scientific name	Common name (Filipino)	Variety/ description	Source (municipality/city, province)	Harvest season[a]
Bulbs and roots						
33	Garlic, bulb	*Allium sativum*	*Bawang*	Farmer's variety	Muñoz, NE	2016 DS
34	Ginger, rhizome	*Zingiber officinale*	*Luya*	Farmer's variety	Muñoz, NE	2016 DS
35	Radish, root	*Raphanus sativus*	*Labanos*	Farmer's variety	Baguio City	2016 WS
36	Red onion, bulb	*Allium cepa*	*Sibuyas*	Red Pinoy	Bongabon, NE	2015 DS
37	Sweet potato 1, tuber	*Ipomoea batatas*	*Kamote*	White fleshed	Sagada, Mt. Province	2015 WS
38	Sweet potato 2, tuber	*Ipomoea batatas*	*Kamote*	Orange fleshed	Muñoz, NE	2016 DS
39	Taro, corm	*Colocasia esculenta*	*Gabi*	Farmer's variety	Muñoz, NE	2015 WS
40	Turmeric, rhizome	*Cucurma longa*	*Luyang dilaw*	Farmer's variety	Muñoz, NE	2016 WS
Flower						
41	Banana	*Musa* spp.	*Puso ng saging*	Farmer's variety	Muñoz, NE	2016 WS
42	Squash	*Cucurbita maxima*	*Bulaklak ng kalabasa*	Suprema	Muñoz, NE	2016 DS
Other plant parts						
43	Bamboo, shoot	*Bambusa vulgaris*	*Labong*	Farmer's variety	Muñoz, NE	2016 WS
44	Corn, kernels	*Zea mays*	*Mais*	Farmer's variety	Muñoz, NE	2016 DS
45	Mushroom 1, cap and stalk	*Calocybe indica*	*Kabute*	Milky	Muñoz, NE	2015 WS
46	Mushroom 2, cap and stalk	*Pleurotus ostreatus*	*Kabute*	Oyster	Muñoz, NE	2015 WS
47	Taro, stalk	*Colocasia esculenta*	*Gabi*	Farmer's variety	Muñoz, NE	2015 WS

[a]DS – dry season; WS – wet season; NE – Nueva Ecija

Appendix Table II. Sample form and boiling information.

Vegetable, part used	Edible form prepared and boiled	Ratio of vegetable to cooking water (g/L)	Boiling time (min)
Moringa leaves	Stem and petiole removed	170:1	1
Onion bulb	Cut into four equal parts, about 0.5–1-in^3	200:1	1
Bitter gourd leaves	Tender tops	70:1	2
Squash flower	Sepals and stamen removed	750:1	3
Other leafy vegetables	Tender tops	130:1	3
Water spinach 1 & 2	Tender leaves and stalks	130:1	3
Mushroom	Cap and tender stem	375:1	3
Pods	Tips removed	100:1	4
String beans	Cut into 4-in lengths	310:1	4
All root and tubers	Cut into about 0.5–1-in^3 cubes	310:1	5
Taro corm	Cut into about 0.5–1-in^3 cubes	330:1	5
Taro stalk	Cut into 3-in length	330:1	5
Fruits			
Bitter gourd, bottle gourd, sponge gourd	Cut into about 0.5–1 in^3	720:1	5

Vegetable, part used	Edible form prepared and boiled	Ratio of vegetable to cooking water (g/L)	Boiling time (min)
Tomato	Cut into eight equal sizes (about 0.5–1 in^3)	540:1	5
Chili, green pepper, okra	Whole	180:1	5
Eggplant (purple)	Whole (about 6-in long)	180:1	5
Eggplant (green)	Whole (about 3-in diameter)	180:1	5
Papaya, squash	Cut into about 0.5–1 in^3	360:1	5
Garlic	Cloves	220:1	5
Rhizomes	Cut into about 0.5–1 in^3	375:1	5
Banana blossom	Cut into four pieces (about 3 in long)	150:1	7
Bamboo shoot	Strips (as purchased)	210:1	8
Corn	In cob	270:1	30
Peanut	Shelled	75:1	30
Mungbean seeds	Whole	100:1	40



Appendix Figure I. Correlations ($p < 0.001$) between the results of the DPPH and ABTS antioxidant assays in extracts of raw (n = 47) and boiled (n = 46) vegetables.