IRJIEST 7 (2021) 20-27
Available online at irjiest.batstate-u.edu.ph
International Research Journal on Innovations in Engineering, Science and Technology

Physicochemical and antioxidant properties of selected Philippine indigenous berries

Liezl M. Atienza[a,*], Dianne Jane A. Sunico[a,c], Loraine B. Ancheta[b], James Ryan D. Aranzado[a], Carmella Jhoy G. Mercado[a,d], Aimee Sheree A. Barrion[a]
[a]*Institute of Human Nutrition and Food, College of Human Ecology, University of the Philippines Los Baños (UPLB)*
[b]*Institute of Food Science and Technology, College of Agriculture and Food Science, UPLB*
[c]*Department of Science and Technology-Science Education Institute*
[d]*Laguna State Polytechnic University Los Baños*

ABSTRACT

There are many underutilized berries indigenous to the Philippines with various chemical and nutritional properties that are yet to be explored and up to date, studies on these are still limited. Among which are locally known as bignay (*Antidesma bunius* (Linn.) Spreng.), duhat (*Syzygium cumini* (L.) Skeels), and lipote (*Syzygium spolycephaloides* (C.B. Rob.) Merr.). Hence, to gain more understanding on the potential of the selected Philippine indigenous berries as functional food, analyses of some of their physicochemical and antioxidant properties were undertaken. The results from this investigation can serve as baseline data to support functional food product/nutraceutical development and/or in vitro and in vivo studies and promote the utilization of these Philippine indigenous berries. The primary objective of this study was to evaluate some physicochemical properties, including color, pH, water activity, total soluble solids, total sugars, proximate composition, as well as antioxidant properties such as antioxidant activity, total phenolic content, and total flavonoid content of the selected Philippine indigenous berries, bignay "kalabaw", bignay "common", duhat, and lipote. The physicochemical properties were evaluated using a chromameter for color values, pH pen for pH values, water activity meter for water activity, refractometer for total soluble solids, phenol-sulfuric acid method for total sugars, and AOAC international guidelines were followed for the proximate analysis. For the antioxidant properties, antioxidant activity was determined through DPPH free radical scavenging activity and TEAC-ABTS assays while the total phenolic and total flavonoid contents were analyzed using the Folin-Ciocalteu method and aluminum chloride colorimetric assay, respectively. Results of the present study showed that the selected Philippine indigenous berries, bignay cultivars, "kalabaw" and "common", duhat, and lipote, are good sources of energy and have significant levels of macronutrients such as from fat, protein, and carbohydrate as well as phenolic compounds as compared to other varieties of berries that are widely grown across many other countries. Each Philippine indigenous berry evaluated in the present study has its own unique characteristics and advantage, especially when it comes to the antioxidant properties. Hence, the selected Philippine indigenous berries are another good source of natural antioxidants with various significant health benefits and high value for commercialization and as functional food. The results warrant further in vitro and/or in vivo tests of these berries' functional properties and its health and nutritional benefits.

Keywords: physicochemical, antioxidant, Philippine, indigenous, berries

1. Introduction

Due to the elevated concern in malnutrition, chronic diseases, and the existence of global epidemics and even raised consciousness about human health, consumers have acknowledged the significance of foods providing not just basic nutrition but are also accompanied with other health benefits. Known as functional foods, these foods are rich sources of bioactive components that help enhance human biological defense mechanisms, prevent and recover from specific diseases, control physical and mental disorders, and slow down aging processes [1]. Fruits, containing a wide array of phytochemicals and other nutrients, are promoted as functional foods [2].

As a tropical country, the Philippines is home to a wide variety of wild edible fruits that are often underutilized. Among these fruits are the Philippine indigenous berries which are recognized to have promising health benefits due to its abundance in essential nutrients and functional compounds having antioxidant properties [3]. These include bignay (*Antidesma bunius* (L.) Spreng), duhat (*Syzygium cumini* (L.) Skeels), and lipote (*Syzygium polycephaloides* (C. B. Rob.) Merr.). Recent scientific findings report that these berries have high potential to be developed into food supplements and nutraceuticals [4,5] and are non-toxic even when taken in large amounts [5].

Antidesma bunius (Linn.) Spreng, or traditionally known as bignay, is an indigenous tree widely grown in different parts of the Philippines. Its fruits can be processed into wine, jams, and jellies but can also be eaten raw. The two most widespread varieties of bignay in the country are "kalabaw" and 'common' cultivars. The "kalabaw" cultivar is generally larger in size and in percent edible portion as compared to the 'common' cultivar, however, the bignay 'common' cultivar is higher in abundance [6]. Still, both may exhibit distinct nutritional properties and beneficial health effects. In the recent findings of [6] and [7], both cultivars of fully-ripe

*Corresponding author
Email address: lmatienza@up.edu.ph

bignay are excellent sources of antioxidants and may be helpful in the management of dyslipidemia, especially the "kalabaw" cultivar in this area [4]. Moreover, bignay fruits have been previously reported to have anti-microbial [8], anti-diabetic [9], antiradical, antiplatelet, anticoagulant, anti-dysenteric, anticancer, and antihypertensive activities [10,11].

Syzygium cumini (L.) Skeels, locally called duhat, is an evergreen tree from the myrtle family and is native to the tropics [12]. It is found throughout the country and is one of the most popular summer fruits [13]. The ripe fruits are usually consumed raw by adding salt or sugar but can also be processed into drinks, preserves, wines, and syrup. It is high in vitamin C and contains iron, calcium, magnesium, sodium, potassium, copper, thiamine, riboflavin, nicotinic acid, and anthocyanin [14, 15]. Also found to be rich in polyphenolic compounds, duhat is considered to have a wide range of pharmacological activities such as anticancer, anti-inflammatory, cardioprotective, hepatoprotective, antidiabetic, antioxidant, anti-diarrhoeal, anti-microbial, lipid peroxidation inhibitory, antipyretic, antihistamine, antiplaque, anti-fertility, gastroprotective, and anti-viral [16]. Moreover, in the recent study of [17], the Philippine duhat may have a potential use in obese and dyslipidemic patients.

Syzygium polycephaloides (C.B. Rob.) Merr., commonly known as lipote, is a fruit bearing-tree also belonging to the same plant genus as duhat (*S. cumini* (L.) Skeels). It is considered rare and endemic to the Philippines which can only be found in areas such as Southern Luzon, Bicol, and Eastern Visayas. It was even included in the list of "Rare and vanishing fruit trees and shrubs in the Philippines" of Dr. Domingo Madulid, Philippine botanist [18]. Its fruit is eaten fresh, juiced, or made into wine. Being a deep colored fruit like bignay and duhat, it is considered to be a good source of phenolic compounds and antioxidants [19]. It was stated by [20] that the antioxidant activity of lipote fruit was comparable to that of Vitamin E. Interestingly, a recent study of [21] showed that lipote fruits, especially in the unripe stage, had a very appreciable amount of total phenols and percent antioxidant activity.

Up to date, studies on the nutritional and health-promoting properties of Philippine indigenous berries are still limited. Hence, to gain more understanding on the potential of the selected Philippine indigenous berries as functional food, analyses of some of their proximate composition and antioxidant properties were undertaken. The results from this investigation can serve as baseline data to support functional food product/nutraceutical development and/or *in vitro* and *in vivo* studies and promote the utilization of these Philippine indigenous berries.

The primary objective of this study was to evaluate some physicochemical properties, including color, pH, water activity, total soluble solids, total sugars, proximate composition, as well as antioxidant properties such as antioxidant activity, total phenolic content, and total flavonoid content of the selected Philippine indigenous berries, bignay "kalabaw", bignay "common", duhat, and lipote.

2. Materials and methods

2.1. Chemicals

All chemicals used in this study were of HPLC- or analytical-grade and were purchased from Sigma-Aldrich Corporation, Singapore.

2.2. Plant collection and sample preparation

Fully ripe bignay (*A. bunius* (L.) Spreng), both 'common' and 'kalabaw' varieties, and lipote (*S. polycephaloides* (C.B. Rob.) Merr.) fruits were harvested in Laguna province, Philippines. Fully ripe duhat (*S. cumini* (L.) Skeels) fruits, on the other hand, were gathered in a local town in Batangas, Philippines. The identity of bignay, duhat, and lipote were authenticated by a curator at the Botanical Herbarium, Museum of Natural History, UPLB. The collected fruits were washed with water and pulped using the fruit pulping machine at the Institute of Food Science and Technology, UPLB. The obtained flesh, including the peels, were freeze-dried using a freeze dryer fabricated for the Department of Science and Technology (DOST) by Gecar Machine Solutions, Inc. (Quezon, Philippines) and ground using a multi-functional high-speed disintegrator (Getra® Model IC-04A, Jakarta, Indonesia). The resulting powder was then sieved with a commercially available fine-mesh (10 mm) sieve, packed in clean metalized bags, and stored at -20 ºC until use.

2.3. Physicochemical properties

2.3.1. Color

Colorimetric measurements of each freeze-dried bignay, lipote, and duhat fruit samples were performed using a hand-held chromameter. The instrument was previously calibrated using a standard white tile and psychrometric color terms L (lightness) and b (yellowness-to-blueness) were taken in triplicates.

2.3.2. pH

The pH values were determined using a calibrated pen-type pH pen at 26 °C using three standard buffers (J.T. Baker standard buffers pH 4, pH 7, pH 10). Five grams of each freeze-dried bignay, lipote, and duhat fruit samples were placed in a beaker with 45 ml distilled water and stirred. The pH pen electrode was immersed in the solution and pH readings were done in triplicates.

2.3.3. Water activity

Water activity of freeze-dried berry samples was determined using a water activity meter at 26 °C. Analysis was done in triplicates

2.3.4. Total soluble solids

The total soluble solids (TSS) was obtained by mixing an amount of freeze-dried berry samples with distilled water in 1:1 ratio. A drop of the supernatant is then placed onto the prism of a refractometer to read the measurement at 20 °C. Analysis was done in triplicates and results were expressed as °Brix.

2.3.5. Total sugar content

Total sugar (TS) contents, or also known as total carbohydrates content (TCC), were determined using the phenol-sulfuric acid method by [22]. The freeze-dried bignay, duhat, and lipote fruits were extracted using 80% ethanol in a water bath shaker at 85 ± 5 °C for 30 minutes. The extraction step was done for at least three times and the obtained residues were diluted as needed. The extracted samples were immediately added with 5% phenol and sulfuric acid followed by incubation for 10 minutes at 85 ± 5 °C in a static water bath. Absorbance was read at 490 nm at room temperature using a UV-Vis spectrophotometer. A glucose stock solution was prepared and used as standard. The TS values were calculated using the formula below:

$$TS = \frac{cV}{m} \tag{1}$$

where, TS refers to the total sugar contents, c is the concentration (μg/mL) of glucose established from the calibration curve, V is the volume (mL) of the extract solution, and m is the weight (g) of extract.

2.3.6. Proximate composition

The moisture, crude protein, crude fat, crude fiber, ash, and nitrogen free extract (NFE) contents of freeze-dried bignay, duhat, and lipote fruits were determined according to the [23]. Moisture content was determined by drying the sample in a hot air oven at 105 ± 5 °C until constant weight. Crude protein was determined using the Kjeldahl method. The crude fat content was measured using the Soxhlet apparatus and hexane as solvent. Crude fiber was determined using acid and base hydrolysis. Ash was determined by direct incineration in a muffle furnace at 550 °C - 600 °C. All the tests were carried out in triplicates.

2.4. Antioxidant properties

2.4.1. DPPH free radical scavenging activity

DPPH (2,2-diphenyl-1-picrylhydrazyl radical) free radical scavenging activity and ABTS [(2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid)] assays were conducted to determine the antioxidant activity of the selected Philippine indigenous berries.

In this assay, 100 g of each sample were weighed and placed in a test tube wrapped in aluminum foil. Each tube was added with 5 mL methanol solution (50%) and mixed intermittently using a vortex mixer for 10 minutes. Solutions were transferred into another tube using a filter paper. One milliliter aliquot was obtained from each filtered solution, mixed with 4 mL distilled water and followed by 1 mL DPPH solution, and stood for 30 minutes in a dark room [24], as cited by [8]. Spectrophotometric measurements were done at 517 nm using Labtronics microprocessor UV-Vis spectrophotometer. All analyses were done in triplicates. The DPPH free-radical scavenging activity was computed using the formula below.

$$DPPH\ scavenging\ activity\ (\%) = \frac{absorbance\ of\ control - absorbance\ of\ sample}{absorbance\ of\ control} \times 100 \tag{2}$$

2.4.2. TEAC-ABTS

The method used by [25] was followed in this analysis wherein an ABTS radical cation solution was prepared by dissolving 0.25 M ABTS and 3.45 M potassium persulfate in 50% methanol. The solution was kept in a dark environment for 12–16 hours at 4 °C. Dilutions were made until the absorbance reading reached 0.70 ± 0.05 at 732 nm. On the other hand, a series of methanolic solutions of Trolox (2–40 μg/mL) was prepared as standard and methanol served as blank. The samples/standards were added in the ABTS radical cation solution in separate tubes and incubated for 15 minutes in a dark environment at room temperature. Absorbance was read subsequently using a UV/Vis spectrophotometer. All analyses were done in triplicates. Results were expressed as mg Trolox equivalents per g sample (mg TE/g) calculated using the formula:

$$TE = \frac{cV}{m} \tag{3}$$

where TE refers to Trolox equivalents, c is the concentration (μg/mL) of Trolox established from the calibration curve, V is the volume (mL) of the extract solution, and m is the weight (g) of extract.

2.4.3. Total phenolic content

Total phenolic content was measured using the Folin-Ciocalteu method followed by [26] in triplicates. The sample extracts were prepared by mixing 50 mg of each dried sample and 5 mL absolute methanol using a vortex mixer for 30 minutes followed by centrifugation for 10 minutes at 300 rpm. A series of gallic acid solutions (0, 100, 200, 400, 600, 800 μg/ml) was prepared to serve as standard. A 200-μL sample aliquot/standard was mixed with 2.8 mL distilled water, 1 mL of 2 M sodium carbonate solution, and 200 μL of Folin-Ciocalteu reagent in a test tube, consecutively. The tubes were placed in boiling water for 15 minutes and cooled to room temperature for color development. The absorbance was read at 710 nm using Labtronics microprocessor UV-Vis spectrophotometer. Data on TPC were expressed as mg gallic acid equivalents (GAE) per gram dry matter of sample.

2.4.4. Total flavonoids content

The total flavonoid content was spectrometrically analyzed in triplicates using the aluminum chloride colorimetric assay. A series of quercetin solutions (0, 100, 200, 400, 600, 800 μg/ml) was prepared to serve as standard. A 200-μL previously extracted sample aliquot/standard was transferred into test tubes and subsequently mixed with 2 mL distilled water and 0.3 ml 5% sodium nitrite solution. The solutions were stood for 1 minute for color development and then added with 1 mL of 1 M sodium hydroxide. The absorbance was read at 510 nm spectrophotometer using the Labtronics microprocessor UV-Vis spectrophotometer. Results were expressed as mg of quercetin equivalents/ 100 g of dry mass [27,28].

2.5. Statistical analysis

Analyses were performed in triplicates and their results were expressed as mean ± standard deviation (SD). The data for antioxidant properties were subjected to one-way analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) test at $p<0.05$ for post-hoc mean comparisons using R version 3.5.3 statistical software.

3. Results and discussion

3.1. Physicochemical properties of selected Philippine indigenous berries

Table 1 shows the physicochemical properties of freeze-dried bignay, duhat, and lipote fruits. Parameters measured include color values (L, a, b), pH, water activity, total soluble solids (TSS), and total sugars. Results showed that freeze-dried lipote had the highest color value for lightness (L*), redness (a*), and yellowness (b*) while the negative b-value for the two bignay cultivars implies an inclination towards the blue color [29].

Table 1. Physicochemical properties of selected Philippine indigenous berries (±SD).

Parameter	Bignay "kalabaw"	Bignay "common"	Duhat	Lipote
Color values				
L*	21.55 ± 0.81	14.30 ± 0.00	16.80 ± 0.00	28.51 ± 0.00
a*	15.43 ± 1.31	20.71 ± 0.00	14.64 ± 0.00	27.53 ± 0.00
b*	-1.34 ± 0.42	-1.46 ± 0.00	5.14 ± 0.00	5.46 ± 0.00
pH	4.40 ± 0.00	4.13 ± 0.12	4.80 ± 0.06	4.07 ± 0.06
Water activity at 26°C	0.332 ± 0.002	0.246 ± 0.003	0.283 ± 0.005	0.196±0.007
TSS (°Brix)	6.17 ± 0.29	6.60 ± 0.17	6.00 ± 0.00	5.83 ± 0.29
Total sugars (g/100g)	5.12 ± 26.10	3.28 ± 26.97	5.07 ± 113.12	1.74 ± 3.81

The pH values for the selected indigenous berries ranged from 4.07 to 4.80 wherein highest pH value was found in duhat, and therefore with least acidity, and the lowest pH value in lipote, hence a quite higher acidity compared to the other Philippine berries. The pH values for bignay, duhat, and lipote were relatively higher as compared to the pH of blueberry, blackberry, and strawberry ranging from pH 3.13 to 3.50 [30]. Fruit acidity, as measured by titratable acidity and/or pH, is an important component of fruit organoleptic quality and is associated with the sour taste [31]. In general, consumers prefer less acidic foods due to its decreased sour taste [32].

The water activity obtained at 26 °C was the highest for freeze- dried bignay 'kalabaw' and the lowest for lipote ranging from 0.332 ± 0.002 to 0.196 ± 0.007. These values indicate high stability of the selected indigenous berries against microbiological spoilage during storage [33]. Moisture content and water activity are equally employed to describe water content of food although water activity correlates better with flow factor than moisture content especially foods in fine/powdered form [34].

In addition to fruit color and acidity, the total soluble solids and sugar content are important characteristics for fruits since consumers have a preference towards a sweeter taste [35]. The total soluble solids content presented ranged from 5.83 ± 0.29 to 6.60 ± 0.17 °Brix with bignay 'common' having the highest value. The total soluble solids content of the selected Philippine indigenous berries were lower as compared to black berry and strawberry (7.83 °Brix, 10.17 ° Brix, respectively) but higher than in blueberry (5.33 °Brix) [30].

Moreover, the total sugar content (g/100 g) presented for the selected Philippine indigenous berries ranged from 1.74 ± 3.81 to 5.12 ± 26.10 with bignay "kalabaw" having the highest value and lipote with the lowest value. These values were also lower as compared to the sugar content of organic strawberry (16.52 g/100g) and blueberry (7.91 g/100g) in a study conducted in Serbia. Sugar content is one of the essential parameters considered in the evaluation of the nutritional fruit quality and nutritive value of berries [36].

Among the selected Philippine indigenous berries, duhat obtained the highest percent moisture (20.16%), crude fat (4.50%), and crude protein (7.10%) but with the lowest crude ash (3.38%) and percent NFE (62.22%) as shown in Table 2. Meanwhile, freeze-dried lipote contained the highest percent crude fiber of 3.83% and the lowest caloric value of 314.64 kcal per 100g sample from fat, protein, and carbohydrate. The caloric values presented ranged from 314.64 to 326.56 kcal (for bignay 'small') which is relatively higher than other usually consumed dried fruit such as raisins having 299 kcal per 100 grams sample [37] and other known high-calorie fruits such as banana (73.43 to 148.80 kcal/100g) and avocado (167 kcal/100g) [38,39] making freeze dried berries a good energy source [40].

Table 2. Proximate composition and caloric value of selected Philippine indigenous berries.

Composition	Bignay "kalabaw"	Bignay "common"	Duhat	Lipote
Moisture, %	11.86	11.02	20.16	11.25
Crude ash, %	6.62	5.86	3.38	6.27
Crude fat, %	0.00	0.00	4.50	0.00
Crude fiber, %	0.83	1.49	2.64	3.82
Crude protein, %	5.01	4.93	7.10	4.34
Nitrogen-free extract, %	75.67	76.71	62.22	74.32
Caloric value (kcal/100g)	322.72	326.56	317.78	314.64

Note: Caloric values were calculated based on the obtained percent crude protein, crude fat, and NFE.

3.2. Antioxidant properties of selected Philippine indigenous berries

Aside from its ability to retain the overall quality of food even after drying, freeze-drying is said to be an effective method to preserve antioxidant properties of fruits as well as other food materials and increase the extraction efficiency of phenolic compounds [41,42]. The very low temperature and absence of liquid water during drying retard most biochemical and microbiological deteriorations while retaining the primary structure and anthocyanin and antioxidant properties [43].

Some antioxidant properties including DPPH free radical scavenging activity, TEAC-ABTS values, total phenolic content (TPC), and total flavonoid content (TFC) of freeze-dried bignay "kalabaw", bignay "common", duhat, and lipote fruit have been evaluated. Methanol was used in the extraction of the samples since methanolic extracts have been reported to contain most of the phytochemical constituents as compared to ethyl acetate and hexane extracts [19].

3.2.1. Antioxidant activity

DPPH assay is one of the most widely used methods for screening the antioxidant activity of plant extracts by investigating the free radical-scavenging activities of the present bioactive compounds [44,45]. The DPPH reagent (2,2 -diphenyl-1-picrylhydrazyl) is relatively stable and can be reduced principally by more reactive reducing components such as phenolic substances [46].

Figure 1 shows that among the selected Philippine indigenous berries, duhat obtained the highest DPPH scavenging activity (96.07 ± 0.86%) followed by lipote (84.43 ± 2.81%), bignay "kalabaw" (79.02 ± 0.26%), and bignay "common" (76.40 ± 2.77%), respectively. Results varied significantly with each type of berry at $p \leq 0.05$. This implies that duhat might have higher antioxidative compounds such as flavonoids and polyphenols relative to bignay and lipote [47]. Nonetheless, the DPPH free radical -scavenging activity of the selected Philippine indigenous berries were comparable or even higher than other freeze-dried berries such as wild berry (85%), blueberry (49%), and cherry laurel (35%) [48,49,41]. It was mentioned by [50] that fruits with a DPPH free radical scavenging activity of 87% and above are considered to have an excellent scavenging effect against DPPH radical.

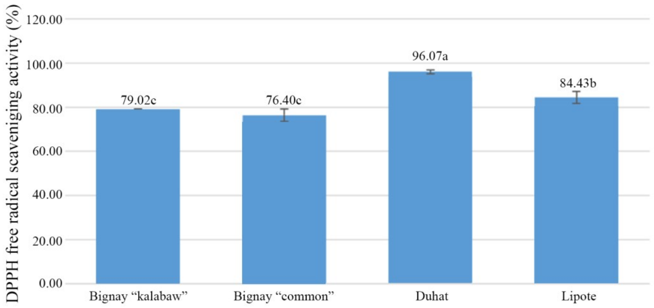

Figure 1. DPPH free radical scavenging activity (%) of freeze-dried bignay "kalabaw", bignay "common", duhat, and lipote fruits. Different lowercase letters denote a significant difference (P ≤0.05; Tukey's test). Error bars indicate standard deviation.

TEAC-ABTS values for freeze-dried bignay "kalabaw", bignay "common", duhat, and lipote fruits were presented in mg trolox equivalents per gram sample as seen on Figure 2. It can be noted that freeze-dried duhat (77.87 mg TE/g) also had the highest TEAC-ABTS value as compared to lipote, bignay "kalabaw", and bignay "small", in descending order. The TEAC-ABTS value for freeze-dried duhat also has a huge difference when compared to mulberry with a TEAC-ABTS value of 20-25 mg TE/g dried sample [51].

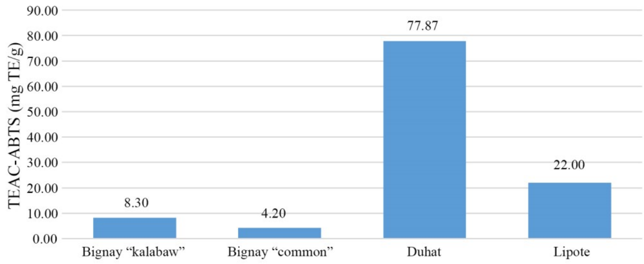

Figure 2. TEAC-ABTS (mg TE/g) of freeze-dried bignay "kalabaw"[7], bignay "common"[6], duhat, and lipote [21] fruits.

3.2.2. Total phenolic and total flavonoid contents

In terms of the total phenolic and flavonoid contents of the selected Philippine indigenous berries, lipote was found to have the highest phenol and flavonoid contents (24.35 ± 0.06 mg GAE/g dried sample and 5.49 ± 0.03 mg QE/g dried sample, respectively) with duhat having the lowest values for both bioactives (12.52 ± 0.02 mg GAE/g dried sample and 1.83 ± 0.02 mg QE/g dried sample) as illustrated in Figures 3 and 4. Results varied significantly with each berry at $p \leq 0.05$ except for the total flavonoid content of the two bignay cultivars.

Still, current findings showed higher values in the total phenolic and flavonoid contents reported by [46] for the methanolic extract of dried plum, a fruit also extensively known to contain copious amounts of antioxidants and other phytochemicals, which only had a phenolic content of 6.26 ± 14.08 mg GAE/g extract and flavonoid content of 0.36 ± 0.47 mg QE/g extract. Additionally, the TPC of the selected Philippine indigenous berries were still higher compared to freeze-dried blueberry (4.26 mg GAE/g) and cherry laurel (10.57 mg GAE/g) [48,49,41].

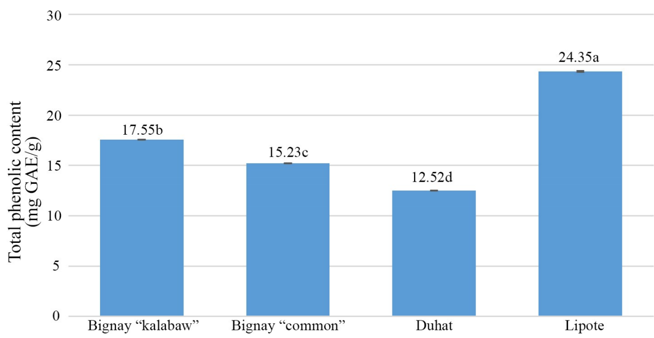

Figure 3. Total phenolic content (mg GAE/g) of freeze-dried bignay "kalabaw", bignay "common", duhat, and lipote fruits. Different lowercase letters denote a significant difference (P ≤0.05; Tukey's test). Error bars indicate standard deviation.

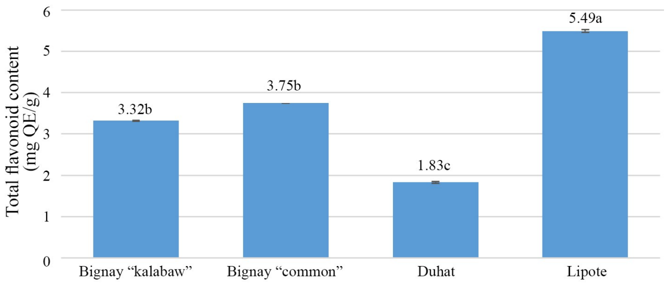

Figure 4. Total flavonoid content (mg GAE/g) of freeze-dried bignay "kalabaw", bignay "common", duhat, and lipote fruits. Different lowercase letters denote a significant difference (P ≤0.05; Tukey's test). Error bars indicate standard deviation.

4. Conclusions

The findings of the present study showed that the selected Philippine indigenous berries, bignay cultivars, "kalabaw" and "common", duhat, and lipote, are good sources of energy and have significant levels of macro nutrients such as fat, protein, and carbohydrate. They also have higher antioxidant activity and total phenolic and flavonoid contents as compared to other varieties of berries that are widely grown across many other countries. Each Philippine indigenous berry evaluated in this study has their own unique characteristics and advantage, especially when it comes to their antioxidant properties. They have great potential to be considered as a functional food, functional food ingredient, or source of useful phytomedicines. Therefore, consumption and commercialization of these berries is encouraged for its health benefits. Further exploratory studies, *in vitro* and/or *in vivo*, on the functional properties of these berries and its specific effects on health and nutrition is recommended.

References

[1] Rincón-León F. Functional foods. In: Caballero B, editor. Encyclopedia of food sciences and nutrition. 2nd ed. San Diego, United States: Academic Press; 2003. p. 2827-32. Available from: https://doi.org/10.1016/B0-12-227055-X/01328-6

[2] Serafini M, Peluso I. Functional foods for health: the interrelated antioxidant and anti-inflammatory role of fruits, vegetables, herbs, spices and cocoa in humans. Current pharmaceutical design. 2016 Dec 1;22(44):6701-15.

[3] Gueco L, Yanos L, Biguelme M. Antioxidant properties of some indigenous and introduced fruit and nut species in the Philippines. Philippine Journal of Crop Science. 2017;42 (1):122-3.

[4] Crieta BR, Tuaño AP, Torio MA, Villanueva JC, Gaban PJ, Castillo-Israel KA. In vitro lipid-lowering properties of the fruits of two bignay [Antidesma bunius (L.) Spreng] cultivars as affected by maturity stage and thermal processing. Food Chemistry: Molecular Sciences. 2021 Jul 30;2:100020.

[5] Estacio MA, Atienza L, Gapasin R, Maniwang JR, Aranzado JR, Mercado CJ, Anville Dela Cruz M, Fernandez ND, Sunico DJ, Israel KA, Bainto L, Ilagan J. Acute oral toxicity test of selected philippine indigenous berries as potential food supplements. Current Developments in Nutrition. 2020 May 29;4(Supplement_2):684. Available from: https://doi.org/10.1093/cdn/nzaa050_007

[6] Castillo-Israel KA, Sartagoda KJ, Illano MC, Flandez LE, Compendio MC, Morales DB. Antioxidant properties of Philippine Bignay (Antidesma bunius (Linn.) Spreng cv. 'Common') flesh and seeds as affected by fruit maturity and heat treatment. Food Research. 2020 Aug 11;4(6):1980-7. Available from: https://doi.org/10.26656/fr.2017.4(6).215

[7] Sartagoda KJ, Ilano MC, Flandez LE, Castillo-Israel KA. Evaluation of the antioxidant activity of bignay (Antidesma bunius (Linn.) Spreng var. Kalabaw) flesh and seeds as affected by maturity and processing method. CMUJ. Nat. Sci. 2021;20(2):e2021042.

[8] Lizardo RC, Mabesa LB, Dizon EI, Aquino NA. Functional and antimicrobial properties of bignay [Antidesma bunius (L.) Spreng.] extract and its potential as natural preservative in a baked product. International Food Research Journal. 2015;22(1):88-95.

[9] El-Tantawy WH, Soliman ND, El-Naggar D, Shafei A. Investigation of antidiabetic action of Antidesma bunius extract in type 1 diabetes. Archives of physiology and biochemistry. 2015 May 27;121(3):116-22.

[10] Shariful Islam M, Sharif Ahammed M, Islam Sukorno F, Ferdowsy Koly S, Morad Biswas M, Hossain S. A review on phytochemical and pharmacological potentials of Antidesma bunius. Journal of Analytical & Pharmaceutical Research. 2018 Oct 24;7(5):602-4. Available from: https://doi.org/10.15406/japlr.2018.07.00289

[11] Islary A, Sarmah J, Basumatary S. Nutritional value, phytochemicals and antioxidant properties of two wild edible fruits (Eugenia operculata Roxb. and Antidesma bunius L.) from Assam, North-East India. Mediterranean Journal of Nutrition and Metabolism. 2017 Jan 1;10(1):29-40.

[12] Ayyanar M, Subash-Babu P. Syzygium cumini (L.) Skeels: a review of its phytochemical constituents and traditional uses. Asian Pacific Journal of Tropical Biomedicine. 2012 Mar;2(3):240-6. Available from: https://doi.org/10.1016/s2221-1691(12)60050-1

[13] Ramos IL, Bandiola TM. Phytochemical screening of Syzygium cumini (myrtaceae) leaf extracts using different solvents of extraction. Der Pharmacia Lettre. 2017;9(2):74-8.

[14] Bijauliya RK, Alok S, Singh M, Mishra SB. Morphology, phytochemistry and pharmacology of Syzygium cumini (Linn.)-an overview. International Journal of Pharmaceutical Sciences and Research. 2017 Jun 1;8(6):2360 -71.

[15] Ali S, Masud T, Abbasi KS, Ali A, Hussain A. Some compositional and biochemical attributes of jaman fruit (Syzygium cumini L.) from Potowar region of Pakistan. Research in Pharmacy. 2013;3(5):01-9.

[16] Bijauliya RK, Alok S, Sabharwal M, Chanchal DK. Syzygium cumini (linn.) - an overview on morphology, cultivation, traditional uses and pharmacology. International Journal of Pharmaceutical Sciences and Research. 2018;9 (9):3608-20.

[17] Mercado CJ, Atienza LM, Sunico DJ, Maniwang JR,

Gapasin RP, Gaban PJ, Castillo-Israel KA, Cena-Navarro R, Estacio MA. Antioxidant, Anti-obesity, and Lipid-lowering Properties of Philippine "Duhat"(Syzgium cumini L. Skeel) Freeze-dried Fruit Flesh. Philippine Journal of Science. 2021 Aug;150(4):793-808.

[18] Madulid D. Philippine eLib. Rare & vanishing fruit trees & shrubs in the Phils.; 1991. Available from: https://www.elib.gov.ph/details.php?uid=16481b51eee461c956173ebe7ba08e78&tab=2

[19] Bandiola TM, Ignacio GB, Yunson EG, Bandiola PD. Syzygium cumini (L.) Skeels: a review of its phytochemical constituents, toxicity studies, and traditional and pharmacological uses. Int. J. Appl. Pharm. Biol. Res. 2017;2 (6):15-23.

[20] Santiago DM, Garcia VV, Dizon EI, Merca FE. Antioxidant activities, flavonol and flavanol content of selected Southeast Asian indigenous fruits. Philippine Agricultural Scientist. 2007 Jun 1;90(2):123-30.

[21] Ilano MC, Sartagoda KJ, Flandez LE, Compendio MC, Morales DB, Castillo-Israel KA. Antioxidant properties of lipote (Syzygium polycephaloides (C.B. Rob.) Merr.) flesh and seeds as affected by maturity and processing method. Food Research. 2021 Apr 29;5(2):475-84. Available from: https://doi.org/10.26656/fr.2017.5(2).558

[22] Masuko T, Minami A, Iwasaki N, Majima T, Nishimura SI, Lee YC. Carbohydrate analysis by a phenol–sulfuric acid method in microplate format. Analytical Biochemistry. 2005 Apr;339(1):69-72. Available from: https://doi.org/10.1016/j.ab.2004.12.001

[23] Horwitz W, editor. Official methods of analysis of AOAC international. 17th ed. Gaithersburg, MD: AOAC International; 2000.

[24] Shimada K, Fujikawa K, Yahara K, Nakamura T. Antioxidative properties of xanthan on the autoxidation of soybean oil in cyclodextrin emulsion. Journal of Agricultural and Food Chemistry. 1992 Jun;40(6):945-8. Available from: https://doi.org/10.1021/jf00018a005

[25] Tomasina F, Carabio C, Celano L, Thomson L. Analysis of two methods to evaluate antioxidants. Biochemistry and Molecular Biology Education. 2012 Jul;40(4):266-70.

[26] Khorasani Esmaeili A, Mat Taha R, Mohajer S, Banisalam B. Antioxidant activity and total phenolic and flavonoid content of various solvent extracts fromin vivo and in vitro grown Trifolium pratense. (red clover). BioMed Research International [Internet]. 2015 May;2015:643285. Available from: https://doi.org/10.1155/2015/643285

[27] Patel S, Patel J, Patel R. To study proximate analysis & biological evaluation of Triphala guggulu formulation. International Journal of PharmTech Research. 2012;(4):1520-6.

[28] Kamtekar S, Keer V, Patil V. Estimation of phenolic content, flavonoid content, antioxidant and alpha amylase inhibitory activity of marketed polyherbal formulation. Journal of Applied Pharmaceutical Science. 2014 Sep 27;4 (9):061-5.

[29] Wetzel DL, Charalambous G, editors. Instrumental methods in food and beverage analysis. Amsterdam: Elsevier; 1998.

[30] Rodrigues LM, Souza DF, Silva EA, Oliveira TO, Lima JP. Physical and chemical characterization and quantification of bioactive compounds in berries and berry jams. Semina: Ciências Agrárias. 2017;38(4):1853-64.

[31] Bugaud C, Deverge E, Daribo MO, Ribeyre F, Fils-Lycaon B, Mbéguié-A-Mbéguié D. Sensory characterisation enabled the first classification of dessert bananas. Journal of the Science of Food and Agriculture. 2011 Jan 11;91(6):992-1000. Available from: https://doi.org/10.1002/jsfa.4270

[32] Hoffman AC, Salgado RV, Dresler C, Faller RW, Bartlett C. Flavour preferences in youth versus adults: a review. Tobacco Control [Internet]. 2016 Sep 15;25(Suppl 2):32-9. Available from: https://doi.org/10.1136/tobaccocontrol-2016-053192

[33] Barbosa-Cánovas GV, Fontana Jr AJ, Schmidt SJ, Labuza TP, editors. Water activity in foods: water activity in foods: fundamentals and applications [Internet]. Oxford, UK: Blackwell Publishing Ltd; 2007. Available from: https://doi.org/DOI:10.1002/9780470376454

[34] Juarez-Enriquez E, Olivas GI, Ortega-Rivas E, Zamudio-Flores PB, Perez-Vega S, Sepulveda DR. Water activity, not moisture content, explains the influence of water on powder flowability. LWT. 2019 Feb;100:35-9. Available from: https://doi.org/10.1016/j.lwt.2018.10.043

[35] Mahmood T, Anwar F, Abbas M, Boyce MC, Saari N. Compositional variation in sugars and organic acids at different maturity stages in selected small fruits from pakistan. International Journal of Molecular Sciences. 2012 Jan 27;13(2):1380-92. Available from: https://doi.org/10.3390/ijms13021380

[36] Akšić MF, Tosti T, Sredojević M, Milivojević J, Meland M, Natić M. Comparison of sugar profile between leaves and fruits of blueberry and strawberry cultivars grown in organic and integrated production system. Plants. 2019 Jul 4;8(7):205. Available from: https://doi.org/10.3390/plants8070205

[37] Fulgoni V, Painter J, Carughi A. Raisin consumption is associated with increased nutrient intake and better diet quality in children (2-18 years): an analyses of NHANES (2001-2012). Journal of the Academy of Nutrition and Dietetics. 2017 Sep ;117(9):A93. Available from: https://doi.org/10.1016/j.jand.2017.06.087

[38] Hapsari L, Lestari DA. Fruit characteristic and nutrient values of four Indonesian banana cultivars (Musa spp.) at different genomic groups. AGRIVITA, Journal of Agricultural Science. 2016 Aug 2;38(3):303-11. Available from: https://doi.org/10.17503/agrivita.v38i3.696

[39] Dreher ML, Davenport AJ. Hass avocado composition and potential health effects. Critical Reviews in Food Science and Nutrition . 2013 Jan;53(7):738-50. Available from: https://doi.org/10.1080/10408398.2011.556759

[40] Aiwonegbe AE, Iyasele JU, Izevbuwa NO. Proximate composition, phytochemical and antimicrobial screening of the methanol and acetone extracts of *Vitex doniana* fruit pulp. Ife Journal of Science [Internet]. 2018 Aug 13;20(2):317-23. Available from: https://doi.org/10.4314/ijs.v20i2.12

[41] Gümüşay ÖA, Yalçın MY. Effects of freeze-drying process on antioxidant and some physical properties of cherry laurel and kiwi fruits. Akademik Gıda [Internet]. 2019 Mar

26;17(1):9-15. Available from: https://doi.org/10.24323/akademik-gida.543985

[42] Zhang Z, Lv G, Pan H, Wu Y, Fan L. Effects of different drying methods and extraction condition on antioxidant properties of shiitake (Lentinus edodes). Food Science and Technology Research. 2009;15(5):547-52. Available from: https://doi.org/10.3136/fstr.15.547

[43] Mitra P, Meda V, Green R. Effect of drying techniques on the retention of antioxidant activities of saskatoon berries. International Journal of Food Studies. 2013 Oct 18;2(2). Available from: https://doi.org/10.7455/ijfs.v2i2.183

[44] Rahman MM, Das R, Hoque MM, Zzaman W. Effect of freeze drying on antioxidant activity and phenolic contents of mango (Mangifera indica). International Food Research Journal. 2015 Mar 1;22(2):613-17

[45] Nanjo F, Goto K, Seto R, Suzuki M, Sakai M, Hara Y. Scavenging effects of tea catechins and their derivatives on 1,1-diphenyl-2-picrylhydrazyl radical. Free Radical Biology and Medicine. 1996 Jan;21(6):895-902. Available from: https://doi.org/10.1016/0891-5849(96)00237-7

[46] Najafabad AM, Jamei R. Free radical scavenging capacity and antioxidant activity of methanolic and ethanolic extracts of plum (Prunus domestica L.) in both fresh and dried samples. Avicenna Journal of Phytomedicine. 2014 Sep;4 (5):343-353

[47] Lalhminghlui K, Jagetia GC. Evaluation of the free-radical scavenging and antioxidant activities of Chilauni, Schima wallichii Korth in vitro. Future Science OA. 2018 Feb;4(2):FSO272. Available from: https://doi.org/10.4155/fsoa-2017-0086

[48] Islary A, Sarmah J, Basumatary S. Proximate composition, mineral content, phytochemical analysis and in vitro antioxidant activities of a wild edible fruit (Grewia sapida Roxb. ex DC.) found in Assam of North-East India. American Journal of Physiology, Biochemistry and Pharmacology. 2016 Apr 24;5(1):1-1.

[49] Shivembe A, Ojinnaka D. Determination of vitamin C and total phenolic in fresh and freeze dried blueberries and the antioxidant capacity of their extracts. Integrative Food, Nutrition and Metabolism. 2017;4(6). Available from: https://doi.org/10.15761/ifnm.1000197

[50] Shofian NM, Hamid AA, Osman A, Saari N, Anwar F, Pak Dek MS, Hairuddin MR. Effect of freeze-drying on the antioxidant compounds and antioxidant activity of selected tropical fruits. International Journal of Molecular Sciences. 2011 Jul 20;12(7):4678-92. Available from: https://doi.org/10.3390/ijms12074678

[51] Yang J, Ou X, Zhang X, Zhou Z, Ma L. Effect of different solvents on the measurement of phenolics and the antioxidant activity of mulberry (Morus atropurpurea Roxb.) with accelerated solvent extraction. Journal of Food Science. 2017 Feb 22;82(3):605-12. Available from: https://doi.org/10.1111/1750-3841.13638

Acknowledgments

The authors would like to acknowledge the research funding from the Department of Science and Technology - Philippine Council for Health Research and Development (DOST-PCHRD) and the University of the Philippines Office of the Vice President in Academic Affairs (UP-OVPAA) through the Enhanced Creative Work and Research Grant (ECWRG).