Characterization of Neglected and Underutilized Fruits in the Philippines

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Abstract

Twelve previously unreported fruit species native to the Philippines were examined for their unique characteristics. 'Bayag-usa' (Voacanga globosa) is a 60.8±3.7 g dark gray, reniform fruit. Red mangosteen (Garcinia hombroniana) is a bright red, globose fruit weighing 45.2±7.77 g, with 18±2 °Brix total soluble solids (TSS). The false mangosteen (Garcinia xanthochymus) is light yellow, heart-shaped and weighs 151±36.46 g, with TSS at 16±0.89 °Brix. Yellow mabolo (Diospyros blancoi) is canary yellow, depressed ovate, weighing 273.33±87.9 g, with edible portion (EP) of 78.44±1.2%. 'Kolis' (Memecylon ovatum) is round, dark purple, weighing 0.73±0.02 g, with TSS at 13±1.41 °Brix and an EP of 84.2±7.59%. Raspberry Bush (Randia formosa) is a 2.03±0.18 g yellow, tubular fruit. 'Gabiroba' (Compomanesia xantocarpa) is round, yellow, weighs 11.95±1.68 g, has 18±1.08 °Brix TSS, and is sub-acid with a Titratable Acidity (TA) of 0.13±0.75 meq/10 mL juice. 'Tugos' (Alpinia galanga) is globose, yellow-brownish and weighs 1.55±0.50 g. 'Gapas-gapas' (Citrus hystrix) is sour, weighing 66.18±2.89 g, with a TA of 1.06±0.23 meq/10 mL juice. 'Bisbis' (Citrus aurantifolia) is green, weighing 36.59±2.81 g, with a TA of 0.85±0.26 meq/10 mL juice. Additionally, 'Kolisom' (Citrus hystrix var. micrantha) is green, sour, weighing 65.78±2.7 g, with a TA of 1.59±0.84 meq/10 mL juice, and 'Kolong-kolong' (Citrus hystrix var. boholensis) is also green, weighing 64±1.7 g, with a TA of 1.1±0.7 meq/10 mL juice. The study also explored the pharmacological and ethnobotanical uses of these diverse species.

Keywords*:* fruit weight, endemic, less known fruits, titratable acidity, total soluble solids

1. Introduction

The Philippines is blessed with a very rich biodiversity of food plants, and yet at present, there is no systematic and serious effort in exploiting this rich

biodiversity (Department of Agriculture – Bureau of Agricultural Research, 2011). Among these edible plants, the fruits have been generally known to be rich in nutrients and micronutrients including other components with medicinal value. According to Cordell (2006) and Palmer (2021), it has been estimated that around 25,000 different phytochemicals occur in fruits and vegetables and other plants eaten by man. Development of functional foods for nutraceuticals and cosmeceuticals are based on studies providing evidence on the health-promoting effects of plant-derived compounds including carotenoids, phenolics, phytostanols, organosulfur compounds and non-digestible carbohydrates (Sharma *et al.*, 2019). Presently, there is a rising demand for plant raw materials as ingredients for medicines for health and wellness. About 64% of the world's population uses plants as primary health care source (Cordell, 2006).

Wagan *et al.* (2009) and Ani and Castillo (2020) claimed that underutilized plants are plant and tree species that many communities traditionally use for food, fiber, animal fodder and medicine. They have other underdeveloped potential uses including diversifying cropping systems, developing value-added products, protecting the environment and restoring degraded lands. Furthermore, the Food and Agriculture Organization of the United Nations (FAO) (2017) noted that neglected and underutilized, 'minor' or 'promising' crops, or orphan crops have been overlooked by research, extension services and policy makers. The government rarely allocates resources for their promotion and development (FAO, 2017). That results in farmers planting them less often, reduced access to high quality planting materials and loss of traditional knowledge. Since they have a lot of potential, these neglected and underutilized fruit species shall be given more attention through re-introduction, propagation and research. Padulosi *et al.* (2013) and Bioversity International (2018) stated that neglected and underutilized species (NUS) are not traded as commodities. These species are wild or semi-domesticated varieties and non-timber forest species that are known to be adapted to local environments. They can help alleviate malnutrition and fight poverty. Padulosi *et al.* (2013) and Yang *et al.* (2022) further added that utilizing these NUS can make agricultural production systems more climate change resilient.

Fruits, aside from being consumed generally as fresh dessert or snack food, also have medicinal value. In the Philippines, while there are only five major economically important fruits, namely banana, mango, pineapple, papaya and citrus that are produced in major quantities, there are still many that are considered minor but economically important because of their nutritive and

culinary properties (Coronel, 2011; Palicte, 2018). Economically underutilized fruits may be explored as alternative or novel sources of natural colorants, inherent preservatives, oils and other exudates for industrial purposes (Donno and Turrini, 2020). In addition, they are also being processed into several products including jam, preserves, juice, tea, candies, chips, dehydrated and dried snack fruit, wine, vinegar, ingredients/flavorings for ice cream, pie and bakery products (Kamboj *et al.,* 2021).

Beyond food and nutritive values, food-enhancing properties and health-beneficial properties, the neglected and underutilized fruit species also offer a wealth of environmental benefits for climate change adaptation (Li *et al.*, 2020). For instance, the planting of fruit trees as a component of agroforestry and reforestation could be one of the environmentally sound solutions to this alarming problem worldwide (Jose, 2019). The growing of fruit trees could also be a valuable component of conservation agriculture that can lead to prevention of soil erosion, loss of ground water and soil fertility (International Panel for Climate Change, 2007). Most importantly, trees may be utilized for the mitigation of the negative impact of anthropogenic activities (Turner-Skoff and Cavender, 2019). Furthermore, planting trees may help reduce man's carbon footprint and other environmental issues stemming from human's interactions with the environment (Coppolino, 2019).

Everybody may agree that growing trees has multiple benefits such as in environmental and psychological aspects benefits (Nisbet *et al.*, 2020). There is also a personal satisfaction for the grower when he or she sees the flowers and harvests the fruits after some years of waiting after planting (Turner-Skoff, 2022). This is especially true for underutilized fruit species that are usually not very common to many. Their fruits have enormous potentials for developing value-added products both for local and overseas markets (Magdalita and San Pascual, 2016; Ani and Castillo, 2020). Before this can be achieved, these neglected and underutilized fruit species shall be evaluated for fruit characteristics. Chacha *et al.* (2022) stated that these underutilized species, especially their fruits, have potential as sources of macro- and micro-food elements and as addition to address issues on mal- and under-nourishment in communities. They also elaborated that these fruits can also help to alleviate poverty through provision of income and profit from sales of fresh and processed products of these fruits.

Several parts of the fruit must be evaluated such as peel characteristics since these are of economic importance in determining the ripeness of fruit like peel

color generally changes from green to yellow, while peel texture and thickness changes from hard to firm then soft as the fruit approaches ripening. More importantly, flesh characteristics are likewise economically important for evaluation of the neglected and underutilized fruits since the TSS gives a picture of the sweetness of the flesh, while the edible portion and the weight dictates what portion of the fruit is edible for consumption. The peel (exocarp), flesh (mesocarp) and external fruit characteristics are routinely assessed in fruits to determine the economic value and the taxonomic characteristics of any fruit species (Coronel, 1998, 2011; Magdalita *et al.*, 2014). It is important to note that there are a few neglected and underutilized Philippine fruits that have been reported to contain high amounts of essential nutrients and bioactive compounds (Magdalita *et al.*, 2014; Dizon *et al.*, 2016). However, other underutilized and rare species have not yet been reported or have not fully been described, hence the subject of this study. Generally, the study aimed to characterize the morphology of neglected and underutilized fruit species in the Philippines.

2. Methodology

2.1 Materials

This study was conducted from May 2018 to April 2019 at the Institute of Plant Breeding, College of Agriculture and Food Science (CAFS), University of the Philippines Los Baños (UPLB), College, Laguna, Philippines. Twelve neglected and underutilized fruit species were evaluated for various morphological characteristics. These plants have been identified by some informants during collection trips to have potential uses but were not widely utilized. Twenty-five ripe fruit samples were taken from each mature tree aged 15 to 25 years and five trees of each species were sampled. Fresh ripe fruit samples were obtained from trees grown in the Roberto Coronel Farm (RCF) in Mabacan, Calauan, Laguna; Fruit Crops Nursery, College of Agriculture and Food Science, UPLB, College, Laguna; the PMM Farm in Balagasan, Boac, Marinduque; Botolan, Zambales; and Davao City in the Philippines (Table 1). The healthy trees were maintained in the backyards of the said properties. Fruits were taken to the laboratory at the Institute of Plant Breeding (IPB), CAFS, UPLB for evaluation and characterization of selected fruit traits. Harvesting throughout the year was done when ripe fruits become available for each species. The authentication and identification of these

different underutilized species were done using visual inspection by Dr. Roberto E. Coronel, and fruit characterization (fruit weight, length, width TSS, etc.) and the aid of various references like Madulid (2001) and Brown (1954).

Table 1. The common and scientific name, place of collection, and the fruiting season of the different underutilized fruit species evaluated

Common name	Scientific name and family	Fruiting season	Place of collection (Philippines)
'Bayag-usa'	*Voacanga globosa*, *Apocynaceae*	December to February	Sitio Man-iling, Balagasan, Boac. Marinduque
Red mangosteen	*Garcinia hombroniana*, Guttiferae	March to May	Davao City, Philippines
False mangosteen	*Garcinia xanthochymus*, Guttiferae	March to May	RCF Farm, Mabacan, Calauan, Laguna
Yellow mabolo	*Diospyros blancoi*, Ebenaceae	June to September	UPLB Orchard, College, Laguna
'Kolis'	*Memecylon ovatum*, Melastomataceae	April to May	Botolan, Zambales
Raspberry bush	*Randia formosa*, Rubiaceae	May to June	Botolan, Zambales
'Gabiroba'	*Compomanesia xantocarpa*, Myrtaceae	February to April	Dr. Roberto E. Coronel Umali Subdivision, Los Baños, Laguna
'Bisbis'	*Citrus aurantifolia*, Rutaceae	September to December	PMM Farm, Balagasan, Boac, Marinduque
'Gapas-gapas'	*Citrus hystrix*, Rutaceae	September to December	PMM Farm, Balagasan, Boac, Marinduque
'Kolisom'	*Citrus hystrix* var. *micrantha*, Rutaceae	September to December	PMM Farm, Balagasan, Boac, Marinduque
'Kolong-kolong'	*Citrus hystrix* var. *boholensis*, Rutaceae	September to December	PMM Farm, Balagasan, Boac, Marinduque
'Tugos'	*Alpinia galangal*, Zingeberaceae	March to May	Sitio Binubuno, Puyog, Boac, Marinduque

2.2 Phenotypic Characterization

The fruits were characterized based on measurements of the whole fruit size or weight, shape, fruit length and width, thickness, peel and pulp thickness, titratable acidity (TA), total soluble solids (TSS) and edible portion (%); visual inspection of color was done using the Royal Horticultural Society (1986) color charts and color coordinate for peel and flesh color, and descriptive

evaluation for texture and taste and flavor was also done and guided by references such as 'Guidelines for Evaluation, Selection and Registration of New Fruit Crops Varieties' (Fruit Crops Technical Working Group- National Industry Council, 2009) and 'Important and Underutilized Edible Fruits of the Philippines' by Coronel (2011).

The weight of the fruit (g), exocarp and seed were determined using an electronic weighing balance (SF-400, Zhejiang, China) to determine the percent edible portion while fruit and seed weight (g), length and width (mm) were measured using a Vernier caliper (Mitutuyo, Japan). A hand-held refractometer (Atago Handheld Refractometer, Japan) was used to measure the TSS (^{o}Brix), while the edible portion (%) was determined by dividing the edible portion by the total fruit weight and the quotient was multiplied by 100. The TA was determined by obtaining 10 mL of the juice and then volume to 50 mL distilled water and added with 1% phenolphthalein. The TA value was obtained by dividing the product of the normality used and the volume of standardized 1N NaOH dropped to the solution to obtain slight color change and then divided by the amount of juice used (Magdalita *et al.*, 2013). Extractable juice was done by squeezing the fruits through manual extraction using a handheld fruit juice extractor. In addition, the seed was evaluated based on seed number per fruit, total seed weight per fruit, weight of individual seed, length, width, thickness, seed color and shape.

In general, the fruit weight, polar and equatorial diameter including the thickness were evaluated because these characteristics reflect the taxonomic size of the fruits which has economic value for consumers' use (e.g., big fruits are attractive to consumers), marketing and processing. Qualitative characterization of fruits was based from the standard descriptions and illustrations by Radford *et al.* (1976). The shape of fruit and seed were determined based on the varietal selection standards found in the guidelines by FCTWG-NSIC (2009).

2.3 Statistical Analysis

In each fruit species evaluated, five trees were used as sources of ripe fruits. Twenty-five ripe fruit samples of the different neglected and underutilized fruit species collected randomly in the middle portion of the tree well-exposed to sunlight were used for the evaluation of the different fruit characteristics. Characterization of all fruit traits was conducted thrice during the peak of the fruiting seasons with a total of 75 fruits evaluated per tree (Table 1).

Measurement of TSS and TA were replicated thrice with three samples per replicate. In assessing seed characters, 30 seed samples were used for multi-seeded and 25 seed samples for single seeded fruit species. This was also replicated thrice with a total of 90 seed samples for multi-seeded species and 75 seed samples for single seeded species. Since these tree species are not very common in the country, purposive sampling was used in the evaluation. Descriptive statistics such as the mean or average and standard deviation were used for all quantitative fruit characteristics determined. Descriptive statistics were computed using the Statistical Tool for Agricultural Research (STAR) (International Rice Research Institute, 2014).

3. Results and Discussion

3.1 Internal and External Fruit characteristics of 'Bayag-usa'

The 'Bayag-usa' or testicle tree (*Voacanga globosa* (Blanco) Merr; family Apocynaceae) is endemic to the Philippines (Brown, 1954). The fruits of 'Bayag-usa' mature almost uniformly on the tree. Fruits come in pairs and are colored gray when ripe while the immature fruits are greenish grey (Figure 1). The reddish-orange flesh coated the seeds for ripe fruits. The ripe fruit split open at the time of ripening and releases the seeds out of the fruit freely at the time of ripening. The fruits are borne in pairs hanging in the peduncle that looks like the scrotum of the deer; hence, its name 'Bayag-usa.' The peduncle that holds the fruit are borne on the leaf axils.

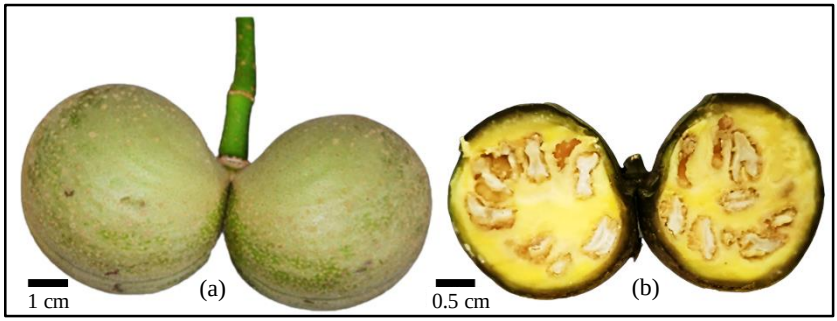

Figure 1. Ripe (a) and sliced unripe (b) fruit of 'Bayag-usa' (*V. globosa*)

The whole ripe fruits of 'Bayag-usa' are dark gray. The reniform fruit has an average weight of 60.8±3.7 g. It has a polar diameter of 43.18±4.65 mm and

equatorial diameter of 33.4±1.68 mm. The peel weighs 9.4±7.06 g while the thickness is 2.3±1.43 mm. The reddish-orange aril with the seeds weighs 5.64±1.2 g. The seeds are bitter and dry that is why it cannot be eaten by man. The peel is dark gray when fully ripe, smooth, and weighs 0.1±0.84 g with a thickness of 1.2±0.14 mm. There are many seeds inside the fruit cavity. The brown seed that is roundish weighs 0.07±0.02 g.

The Philippine Traditional Knowledge Digital Library on Health (TKDL) (2016) reported that 'Bayag-usa' had been used to treat 'Kulebrang ahas' or shingles in Marinduque, Philippines and the fruits are used as antidote to food poisoning. 'Bayag-usa' has medicinal properties because it contains phytochemicals like saponins and terpenoids (Acebedo, 2014). Further, in Lanao del Norte, Philippines, the fruits are used to treat diarrhea while in Alabat islands also in the Philippines, traditional healers use the fruit to enable easier delivery of infants (TKDL, 2016)

3.2 Internal and External Fruit characteristics of Red Mangosteen

The mangosteen (*Garcinia mangostana* L.) was introduced into the country during the prehistoric times (Coronel, 2011). On the other hand, the red mangosteen or seashore mangosteen (*Garcinia hombroniana*, family Guttiferae) reported in this research originated from Davao City, Philippines. This species is native to Malaysia, Cambodia, Thailand and Vietnam. The whole ripe fruit of red mangosteen is bright red (Figure 2).

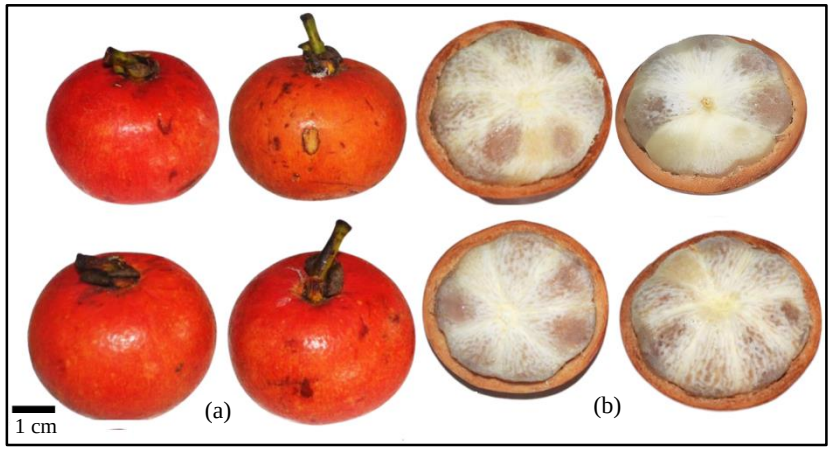

Figure 2. The external (a) and internal (b) look of ripe fruits of red mangosteen (*G. hombroniana*)

The globose fruit has an average weight of 45.2±7.77 g with a polar diameter of 4.34±0.386 mm and equatorial diameter of 4.53±0.3743 mm. The sweet, white flesh has a TSS of 18±2 °Brix and TA of 0.27±0.75 meq/10 mL juice. The fruit has an edible portion of 26.78±9.36%. The peel is bright reddish orange when fully ripe, smooth and weighs 17.8±2.97 g with a thickness of 2.6±0.699 mm. There are 5.6±0.84 seeds in a fruit. The oblong seed weighs 2.14±0.43 g.

Red mangosteen has antioxidants and xanthone (Jamila *et al.*, 2016). The closest relative of red mangosteen in the family Clusiaceae is the common mangosteen (*G. mangostana*). More than their difference in color, their phytochemistry is also different. Jamila *et al.* (2014) reported that the rind of the ripe fruits of red mangosteen is used as seasoning for curries and culinary dishes in Malaysia. Yaacob and Tindall (1995) also reported that *G. hombroniana* are effective rootstocks for *G. mangostana* and other *Garcinia* species to improve their fruit quality.

3.3 Internal and External Fruit Characteristics of False Mangosteen

The false mangosteen (*Garcinia xanthochymus;* family Guttiferae) described in this study was reported to have originated from India (Figure 3).

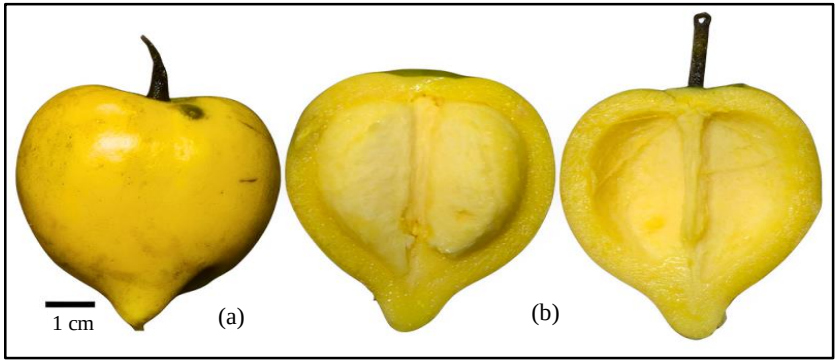

Figure 3. External (a) and internal (b) views of ripe fruits of false mangosteen (*G. xanthochymus*)

The whole ripe fruit of the false mangosteen is light yellow, heart-shaped, with pointed tip, has an average weight of 151±36.46 g, with a polar diameter of 7.38±0.79 mm and equatorial diameter of 6.64±0.85 mm. The flesh has a TSS of 16±0.89 °Brix. The flesh is bright orange yellow and sub-acid with TA of 0.04±0.75 meq/10 mL juice. The fruit has an EP of 86.58±0.86%. The peel is

smooth when fully ripe and weighs 9.98±3.02 g with a thickness of 0.6±0.05 mm. There are 2.13±0.99 seeds in a fruit with a total weight of 10.3±6.62 g. The oblong seed weighs 5.31±1.26 g.

Hassan *et al.* (2018) reported that *G. xanthochymus* are eaten as fresh fruit or processed as preserved food like jams and are also made into vinegar and beverages in other countries. The yellow fruits are also used as yellow dye for watercolor and fabric dyeing (Acuña *et al.*, 2012). Krishnamoorthy (2006) reported that the fruits are used in India for culinary purposes specifically for preparation of chutney, curries and pickles. Further, Patra *et al.* (2016) explored their ethnobotanical use in Malaysia. They reported that eating its fruits can help treat diarrhea and stomachache, while the latex of the fruits is used to treat curing wound and even treat sexual diseases. Patra *et al.* (2016) and Hassan *et al.* (2018) found the presence of saponins, tannins, steroids, terpenoids and flavonoids from its fruit extract. They also observed anti-carcinogenic and antimicrobial properties. Because of these potentials, the authors also suggested the utilization of this crop for pharmacological purposes.

3.4 Internal and External Fruit characteristics of Yellow Mabolo

The yellow mabolo (*Diospyros blancoi*; family: Ebenaceae) is endemic to the Philippines (Brown 1954; Coronel, 2011). The whole ripe fruit of yellow mabolo is canary yellow, hairy and leathery (Figure 4).

Figure 4. Ripe (a) and sliced (b) fruits of yellow mabolo (*D. blancoi*)

The depressed ovate fruit has an average weight of 273.33±87.9 g, with a polar diameter of 77.33±5.69 mm and equatorial diameter of 82±11.79mm. The leathery peel is 0.1±0.02 mm thick and weighs 50.33±3.51 g. The flesh is white, starchy, smooth, and sweet. A fruit contains 1.67±0.58 seeds that

weigh 8.67±3.51 g. The fruit has an EP of 78.44±1.2 %. The seed that is oblong weighs 4.67±0.58 g, measures 3.1±0.17 mm long, 1.9±0.17 mm wide, and 1.4±0.1 mm thick.

Mabolo has been reported to be used to treat diarrhea, dysentery, aphthous stomatitis, snakebites, heart problems, hypertension, spider bites, stomach aches, diabetes and eczema (Akter, 2015). Further it also has pesticidal properties (Dacanay *et al.*, 2017). Baclayon *et al.* (2020) reported the use of mabolo fruits for development of pastries such as tarts. Mabolo fruits have bioactive compounds and micronutrients like vitamins C and E, potassium, iron, calcium, folic, pantothenic and malic acids, and magnesium among others (Baclayon *et al.*, 2020).

3.5 Internal and External Fruit Characteristics of 'Kolis'

The 'Kolis' or Ironweed tree **(***Memycylon ovatum* Smith; family Melastomataceae) is found in the Batan Islands and northern Luzon to Palawan and Mindanao and also in India and Malaya (Stuart, 2021). The whole dark purple velvety ripe fruit of 'Kolis' is round, has an average weight of 0.73±0.02 g and measures 6.1±1.1 mm long and 7.4±1.08 mm wide. The ripe fruit has one blackish rounded seed (Figure 5).

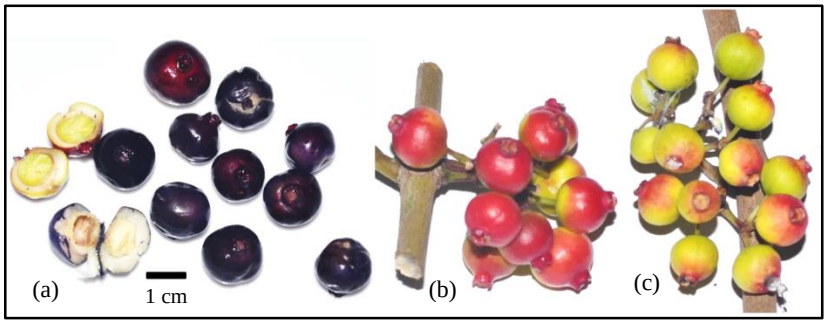

Figure 5. Ripe (a), semi-ripe (b) and unripe (c) fruits of 'Kolis' (*M. ovatum*)

The fruit has white and sweet flesh with TSS of 13±1.41 °Brix and EP of 84.2±7.59%. The thin peel is dark purple when ripe and green when unripe. The rounded seed is small and measures 0.57±0.07 mm long and 0.6±0.09 mm wide.

Ramya Sree and Toppil (2021) reported that Memecylon fruits have alkaloids, terpenoids, flavonoids and phenols. They also mentioned that the fruit has

antioxidants that can be utilized for pharmacological purposes. Further, the pulp was reported to be astringent. In Thailand, the fruit are used as a mordant for silk dyeing (Palaniselvam *et al.*, 2012).

3.6 Internal and External Fruit Characteristics of Raspberry Bush

The raspberry bush (*Randia formosa*; family Rubiaceae) used in this research came from Botolan, Zambales. The whole ripe fruit of raspberry bush is yellow and tubular and smooth (Figure 6). It has an average weight of 2.03±0.18 g. The fruit measures 25.2±2.48 mm long and 13.33±1.36 mm wide. The fruit cavity is full of black seeds coated with a thin brown aril. The total seed number in a fruit is 8.67±0.82. Each seed weighs 0.53±0.08 g and measures 0.27±0.05 mm long and 0.18 ± 0.04 mm wide.

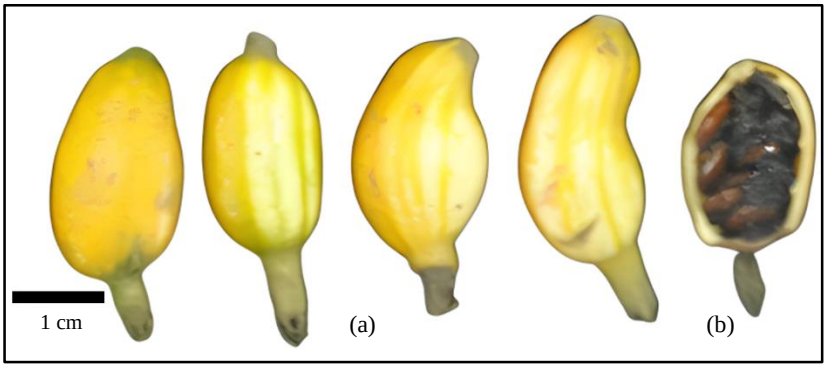

Figure 6. External (a) and internal (b) view of the ripe fruits of raspberry bush (*R. formosa*)

The small fruits are edible and was reported as blackberry jam (Gardino Nursery, Corp., 2021). de Mello e Silva *et al.* (2021) underscored that the fruits are nutraceutical prospects for management of neurodegenerative and neuropsychological disorders like Alzheimer's and Parkinson's diseases, autism spectrum disorder and attention deficit hyperactive syndrome.

3.7 Internal and External Fruit Characteristics of 'Gabiroba'

'Gabiroba' (*Compomanesia xantocarpa* Berg. family: Myrtaceae) is a native fruit of Brazil (Ferreira *et al.*, 2015). The whole ripe fruit of 'Gabiroba' is round and crowned by the calyx limb and the small round disk at the fruit apex (Figure 7).

Figure 7. External (a) and internal (b) views of unripe fruits of 'Gabiroba' (*C. xanthocarpa*)

It has an average weight of 11.95±1.68 g. The fruit has a polar diameter of 8.24±2.49 mm while the equatorial diameter is 26.16±3.41 mm wide. The peel is yellow and smooth when ripe. Individual fruits weigh 4.30±0.56 g with a peel thickness of 1.42±0.43 mm. The total seed number in a fruit is 2±0.12. The total weight of seeds in a fruit is 0.45 ± 0.15 g. The flesh has a TSS of 18±1.08 °Brix, while the TA is 0.13±0.75 meq/10 mL juice.

de Oliveira Raphaelli *et al.* (2021) elaborated that the fruits of 'Gabiroba' have acid sweet flavor that can be eaten raw or processed into ice cream, jellies, liquor and tea. Further, the fruit is rich in carbohydrates, fibers, vitamins C, A and potassium. Secondary metabolites like carotenoids and flavonoids were also present in the fruit (de Oliveira Raphaelli *et al.*, 2021). In addition, Souza-Moreira (2011) stated that extracts from its fruits have anti-diarrheal and antimicrobial effects.

3.8 Internal and External Fruit Characteristics of 'Tugos'

'Tugos' (*Alpinia galanga:* family: Zingeberaceae) is endemic to the Philippines (Brown, 1954; Magdalita *et al.*, 2016a). The yellow brownish and hairy ripe fruits are clustered and borne in a stalk (Figure 8). The individual globose fruit weighs 1.55±0.50 g with a polar diameter of 1.61±0.16 mm and equatorial diameter of 1.20±0.13 mm. The peel is smooth with a thickness of 0.41±0.10 mm and weighs 0.82±0.32 g. The fruit is filled up with black seeds coated with thin, colorless and sour aril. The fruit has a mild and a soothing

aroma. A fruit contains 9.07±2.02 seeds that weigh 0.41±0.19 g. The seeds are black and small.

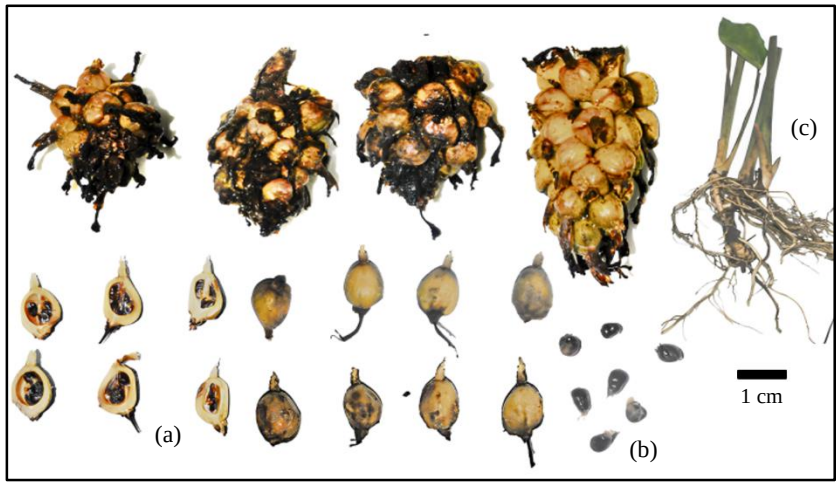

Figure 8. Ripe fruits (a), seeds (b) and plant (c) of 'Tugos' (*A. galanga*)

Chouni and Paul (2018) reported that the plant has essential oils that can be extracted and used for topical application. Furthermore, its seeds can be used to clean the mouth and emaciation. In Marinduque, Tugos is used to treat stomachache. The seeds are also purgative and can improve digestive power and improve appetite. While in China and Thailand, the rhizomes of this plant are used as spice.

3.9 Internal and External Fruit Characteristics of 'Gapas-gapas'

'Gapas-gapas' (*Citrus hystrix*, family: Rutaceae) is endemic to the Philippines (Coronel, 2011). The fruits are round and have green peel when unripe and yellow peel when ripe (Figure 9). Unripe mature fruits have sour juice while ripe fruits have sub-acid juice. The obovoid fruit weighs 66.18±2.89 g, with TSS of 10.9±1.42 °Brix and TA of 1.06±0.23 meq/10 mL juice. The fruit has EP of 24.06 ± 1.65 %. The equatorial diameter is 47.08±2.19 mm, while the polar diameter is 49.47±2.69 mm. Rind (exocarp and mesocarp) weighs 49.24±2.11 g, and it has a thickness of 4.12±0.66 mm. Moreover, the rind has a smooth and leathery texture. The endocarp weighs 9.92±1.77 g with 8.64±2.55 mL extractable juice. The fruit contains 16.44±2.17 seeds. The seed weighs 2.94±1.74 mg and measures 12.84±1.40 mm long, 5.75±1.03 mm wide and 3.09±0.79 mm thick. The seed is light brown, round and smooth.

Figure 9. External (a) and internal (b) views of ripe fruits of 'Gapas-gapas' (*C. hystrix* var. *micrantha*)

Zibaee *et al.* (2020) reported that the plant has antimicrobial effects. Further, hespiridine, flavonoids and phenolics were also present on its extracts. The fruit extracts are also squeezed and are prepared into juice. Extracts and oils from the plant have pesticidal effects also. The oils from its peels are also used as repellant from mosquito.

3.10 Internal and External Fruit Characteristics of 'Bisbis'

'Bisbis' (*Citrus aurantifolia* (Chrism.) Swg., family: Rutaceae) is endemic to the Philippines (Coronel, 2011). The fruit is round, has green peel when unripe and yellow peel when ripe (Figure 10).

Figure 10. External (a) and internal (b) views of ripe fruits of 'Bisbis' (*C. aurantifolia*)

Unripe fruits have sour juice, while ripe fruits have sub-acid juice. Fruit weighs 36.59±2.81 g with TSS of 11±1.2 °Brix and TA of 0.85±0.26 meq/10 mL juice. The round fruit has an equatorial diameter of 40.48 ± 1.86 mm and polar diameter of 39.72±2.35 mm. The rind weighs 17.38±2.21 g, and it is 2.02±0.51 mm thick with smooth and leathery texture. The unripe fruit is green while the ripe fruit is yellow. The mesocarp weighs 17.38±2.21 g, and the EP is 50.17±2.87%. The fruit contains 15.8±2.77 mL extractable juice. A

fruit contains 15±1.2 seeds. The seed weighs 1.42±0.19 mg and measures 8.38±1.02 mm long, 5.41±0.67 mm wide and 3.12±0.51 mm thick. The seed is light brown, round and smooth.

Like 'Gapas-gapas', 'Bisbis' also has essential oils with pharmacological potentials. Further, like calamansi, which is a common citrus in the country, the extracts can be made into juice. Although 'Bisbis' has been noted to have more extractable juice (Magdalita *et al*., 2016b). Narang and Jiraungkoorskul (2016) stated that the fruit had "alkaloids, carotenoids, coumarins, flavonoids, phenolic acids, triterpenoids. apigenin, hesperetin, kaempferol, limonoids, quercetin, naringenin, nobiletin and rutin" which had anti-inflammatory, anti-bacterial, anticancer and anti-diabetic properties; all of these contribute to its remedial properties.

3.11 Internal and External Fruit Characteristics of 'Kolisom'

'Kolisom,' 'Kulubot' or 'Kabuyaw' (*Citrus hystrix* DC var. *micrantha* (West.) Merr., family: Rutaceae) is indigenous to the Philippines (Coronel, 2011). The bumpy and leathery fruit has green peel when unripe and has yellow peel when ripe (Figure 11).

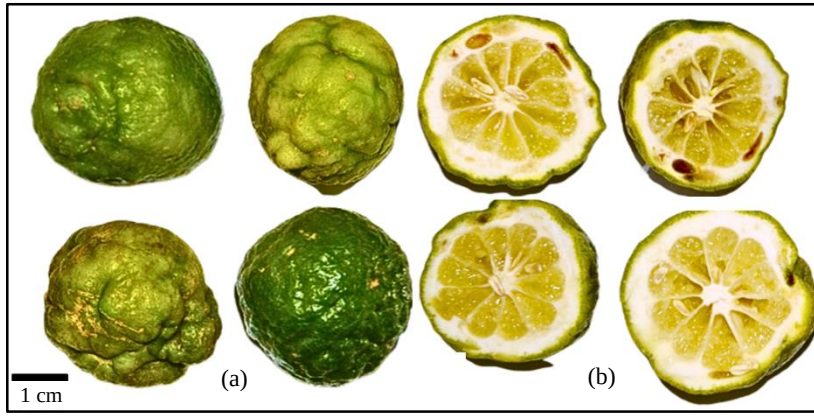

Figure 11. External (a) and internal (b) views of ripe fruits of 'Kolisom' (*C. hystrix*)

The fruit weighs 65.78±2.7 g, with TSS of 15±0.5 °Brix and TA of 1.59±0.84 meq/10 mL juice. The round fruit has an equatorial diameter of 52.98±2.4 mm and a polar diameter of 54.37±1.4 mm. The rind weighs 39.2±2.68 g with a thickness of 6.42±0.62 mm. It has an EP of 49.8±2.42% and extractable juice of 13.46±2.5 mL. The mesocarp weighs 21.78±2.45 g, and the juice from the

ripe fruit is sub-acid, while it is sour from the unripe fruit. A fruit contains 18.55±2.2 seeds. A seed weighs 2.04±0.65 mg and measures 11.41±1.05 mm long, 5.48±0.61 mm wide and 3.06±0.52 mm thick. The seed is light brown, round and smooth.

The fruits of 'Kolisom' or 'Kulubot' have bumpy and rough peels, and the juice of this species is aromatic. The juice is used for flavoring raw fish or for making beverage, while the leaves is used or cooking curry and seasoning dishes (Coronel, 2011). Extracts of 'Kolisom' fruits are also utilized to treat dandruff. They also have antibacterial and anti-fungal properties. Furthermore, the plant is rich in alkaloids, arachidic acid and alpha terpineol (Herbpathy, 2023).

3.12 Internal and External Fruit Characteristics of 'Kolong-kolong'

'Kolong-kolong' (*Citrus hystrix* var. *boholensis* West. (Syn: *C. hysterix* DC.), family: Rutaceae), is endemic in the Philippines (Coronel, 2011). The fruit is hesperidium, characterized to have round fruits that are light green when unripe and yellow when ripe (Figure 12).

Figure 12. External (a) and internal (b) views of semi-ripe fruits of 'Kolong-kolong' (*C. hystrix* var. *boholensis*)

The fruit weighs 64±1.7 g, with an equatorial diameter of 50.8±0.8 mm and polar diameter of 61±1.8 mm. The fruit juice has a TSS of 11±0.9 °Brix and TA of 1.1±0.7 meq/10 mL juice. The fruit has an EP of 24.4±1.5% and extractable juice of 13.5±1.5 mL. Rind weighs 47.3±1.5 g with a thickness of 6.5±1.8 mm. The peel is smooth and leathery. The mesocarp weighs 11±1.5 g and contains sour juice when unripe and sub-acid juice when ripe. A fruit contains 16.5±1.2 seeds. The seed weighs 3.5±2.3 mg and measures 10.2± 1.4 mm long, 6.4±1.5 mm wide and 2.7±0.9 mm thick. It is light brown, round and smooth.

Gopilan (2020) stated that 'Kolong-kolong is rich in antioxidants. The juice of the fruits is also extracted and consumed as juice due to its high vitamin C

content. Recuenco *et al.* (2020) also found that the extracts of the fruit have anti-microbial effects specifically to *Escherichia coli*. In Thailand, the fruits, its extracts and its leaves are used as flavorant (Panthong *et al.*, 2013).

4. Conclusion and Recommendation

Fruit samples of 12 neglected and underutilized fruit species that are either endemic or introduced in the Philippines were evaluated for various fruit morphological characteristics. Among the species evaluated included 'Bayag-usa' (*V. globosa* (Blanco) Merr.), red mangosteen (*G. hombroniana*), false mangosteen (*G. xanthochymus*), yellow mabolo (*D. blancoi*), 'Kolis' **(***M. ovatum*), raspberry bush (*R. formosa*), 'Gabiroba' (*C. xantocarpa*), 'Tugos' (*A. galanga*), 'Gapas-gapas' (*C. hystrix*), 'Bisbis' (*C. aurantifolia*), 'Kolisom' or 'Kulubot' or 'Kabuyaw' (*C. hystrix* var. *micrantha*) and 'Kolong-kolong' (*C. hystrix* var. *boholensis*). All the evaluated species have been known to have pharmacological potential. It is recommended that high-yielding genotypes and those with good horticultural characteristics, resistance to pests and potential for climate change adaptation, and those with pharmaceutical uses shall be studied further. In addition, it is recommended that these underutilized species should be propagated and further conserved for future utilization.

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