Comparative account of vitamin C contents, antioxidant properties and iron contents of minor fruits in Sri Lanka

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ABSTRACT

Sri Lanka is a habitat of diverse fruit varieties; nevertheless 95% of them are underutilized by people due to unawareness of their nutritional values and health aspects, and hence become ‘minor fruits’. This study was aimed on revealing vitamin C, iron and antioxidant contents of 29 varieties of minor fruits (MFs) with the comparison of the same with three best commonly consumable fruits (CFs), namely Carica papaya, Mangifera indica and Psidium guajava. Ascorbic acid (Asc), dehydroascorbic acid (DAsc), vitamin C (TC), phenolic (TP), flavonoid (TF), iron (Fe) contents and antioxidant capacities (AOCs) of fruits were determined using standard methods. The results of mean Asc, DAsc, TC, TP, TF and Fe contents in 100 gm of MFs ranged from 3.1 to 121.5 mg, 1.2 to 70.7 mg, 6.6 to 136.1 mg, 24.9 to 1613.3 mg Gallic acid equivalent, 6.2 to 228.0 mg Quercetin equivalents and 0.2 to 4.9 mg respectively. DPPH and Ferric Reducing Antioxidant Power (FRAP) assays were used for AOCs and variation of IC₅₀ values in a DPPH assay was 1.2 to 245.4 mg/ml whereas FRAP values ranged from 9.6 to 486.7 μmol FeSO₄/gm. Among the studied minor fruits, Melastoma malabathricum (Maha bovithya/Malabar melastome) is found as the best respect to all considered parameters. As a conclusion, it can be stated that, the Sri Lankan minor fruits are good alternatives to the common fruits as they are recognized as good source of vitamin C, iron and higher content of antioxidants. As an outcome, Sri Lankan minor fruits can be promoted as alternatives to common fruits and as source of revenue for national economy.

Introduction

Sri Lanka is a land which has been gifted with extremely high biodiversity and hence it is recognized as one of the biodiversity hotspots in the world (1–3). Even though Sri Lanka has been gifted with huge diversity of fruits by the nature, people in the country cultivate and consume only a limited number of fruit species (4). This may be due to the less awareness of nutritional and healthcare properties of them due to lacking data on scientific aspects.

The fruits grown can be divided in to two categories based on the consumer preference as ‘mainstream fruits’ or ‘common fruits’ and ‘underutilized fruits or minor fruits’. The ‘common fruits’ are well known and highly palatable and are having a higher demand in the market. In contrast, underutilized fruits are relatively less palatable and hence these are having a lower demand in the market. Some of the underutilized fruit are cultivated in homesteads and hence ‘Underutilized domesticated’ while the rest of the underutilized fruits which are naturally growing in forests and un-attended areas are considered as minor fruits (5).

In Sri Lanka, 100% of mainstream fruits are exotic, while more than 50% of minor fruits are indigenous to Sri Lanka. Most of edible fruits in Sri Lanka remained underutilized or unknown even without knowing taste or nutritional values (6–8). However, these are mainly minor fruits and wasted without utilizing and without knowing the values or potentials (9).

Some studies on underutilized fruits for their antioxidant capacity are highlighted by several authors (10–18). Recently, we have reported a comparative study on total vitamin C contents, antioxidants capacities and iron content of some underutilized fruits, with commonly consumed fruits (19). However, no adequate scientific reports are available on Sri Lankan minor fruits for their nutritional and biochemical properties especially on iron content, total vitamin C, dehydroascorbic acid...
contents and antioxidant capacities. The consumption of minor fruits in Sri Lanka has long history but it has been gradually neglected with the advancement of civilization. There is a substantial gap between demand and supply of fruits in the market as rejection of common fruits by general public is more common due to application of toxic chemicals at the various stages of cultivation and storing, aiming profits.

Therefore, the main objective of this research was to promote minor fruits available in Sri Lanka as the best alternative to the common fruits and to promote them as agricultural crops. For this purpose, some important health and nutritional parameters namely, ascorbic acid (Asc), total vitamin C (TC), dehydroascorbic acid (DAsc), total phenol (TP), total flavonoid (TF) and iron (Fe) contents and antioxidant activities (AOCs) of 29 species of minor fruits were harvested freshly from naturally grown trees at the wild. When fruits are consumed in both ripe and unripe stages at their maturity, both stages were tested (for example, fruits of L. camara, M. alba etc.). The plants were authenticated with the help of taxonomist, University of Ruhuna, Sri Lanka.

### Materials and Methods

#### Fruit samples

About 29 locally grown Minor fruits (MFs) were used in this study (Table 1). For comparison of the selected parameters, three Common fruits (CFs) were used which were chosen based on our previous study (19). Carica papaya, Mangifera indica and Psidium guajava were selected as the top three CFs. The studied minor fruits were harvested freshly from naturally grown trees at the wild. The plants were authenticated with the help of taxonomist, University of Ruhuna, Sri Lanka.

#### Preparation of fruit samples

Representative samples were obtained from different plants of the same species. The harvested fruits were combined to obtain the studied sample. A known weight of edible portion, obtained from the sorted and cleaned fruits, was used to prepare extracts. Extractions were done in triplicate.

### Table 1. Harvesting season/time of the studied fruit species

| Sl. No. | Commonly consumed fruits (CFs) | Edible part(s)* | Harvested location | Harvested season Month/year |
|---------|-------------------------------|-----------------|--------------------|-----------------------------|
| 1       | Carica papaya L.              | FWS             | M* S*              | 03/ 2018                    |
| 2       | Mangifera indica L.           | FWS             | M, S               | 05/ 2017                    |
| 3       | Psidium guajava L.            | FWS             | M                  | 06/ 2017                    |
| Minor fruits (MFs) |                                |                 |                    |                             |
| 1       | Acronychia pedunculata (L.) Miq. | FWS             | M                  | 06/ 2018                    |
| 2       | Antidesma alexiteria L.       | FWS             | M                  | 09/ 2017                    |
| 3       | Ardisia wilisii Mez.          | FWS             | M                  | 07/ 2018                    |
| 4       | Artocarpus nobilis Thwaites   | FWS             | M                  | 07/ 2018                    |
| 5       | Borassus flabellifer L.       | FWS             | AN                 | 01/ 2018                    |
| 6       | Clidemia hirta (L.) D. Don    | FWS             | M                  | 08/ 2017                    |
| 7       | Dillenia retusa              | FWS             | M                  | 06/ 2018                    |
| 8       | Dovyalis hebecarpa (Gardner) Warb. | FWS         | M                  | 10/ 2017                    |
| 9       | Erythroxylum mooni Hochr.     | FWS             | M                  | 09/ 2017                    |
| 10      | Flacourtia indica (Burm.f.) Merr. | FWS           | M                  | 06/ 2018                    |
| 11      | Garcinia quaestia Pierre      | FWS             | M                  | 06/ 2018                    |
| 12      | Garcinia zeylanica Roxb.      | FWS             | M                  | 07/ 2018                    |
| 13      | Ixora coccinea L.             | FWS             | M                  | 10/ 2017                    |
| 14      | Lantana camara L.             | FWS             | M                  | 09/ 2017                    |
| 15      | Lantana camara L.             | FWS             | M                  | 09/ 2017                    |
| 16      | Melastoma labalathricum L.    | FWS             | M                  | 10/ 2017                    |
| 17      | Microcos paniculata L.        | FWS             | M                  | 07/ 2017                    |
| 18      | Morus alba L.                 | FWS             | M                  | 09/ 2017                    |
| 19      | Mulas maderaspatana L.        | FWS             | M                  | 10/ 2017                    |
| 20      | Muntingia calabura L.         | FWS             | M                  | 09/ 2017                    |
| 21      | Ophiorrhiza dillenii (Ker. Gawl.) Haw. | FWS | M                  | 07/ 2018                    |
| 22      | Oxalis berteri L.             | FWS             | M                  | 09/ 2017                    |
| 23      | Passiflora foetida L.         | FWS             | M                  | 09/ 2017                    |
| 24      | Polyscias kiri (Dunal) Thwaites | FWS             | M                  | 09/ 2017                    |
| 25      | Psidium guajava L.            | FWS             | M                  | 06/ 2017                    |
| 26      | Syzygium cumini (L.) Skeels.   | FWS             | M                  | 06/ 2017                    |
| 27      | Trichopus zeylanicus Gaertn.  | FWS             | M                  | 06/ 2017                    |

*Edible part(s) of the fruit studied: FWS – Only flesh without peel and seed(s); FWP – Flesh without peel; FWS – Whole fruit without seed(s); WF – Whole fruit

*Fruits harvested district in Sri Lanka: AN – Anuradhapura; M – Mataara; HB – Hambantota; RP – Ratnapura
**Extraction of Vitamin C**

From the ground fruit sample, vitamin C was extracted to the solution containing meta-phosphoric acid and glacial acetic acid (20).

**Methanolic extract of fruits**

Maceration was done with methanol to obtain methanolic extract of fruits (21).

**Sample analysis**

**Quantification of total vitamin C (TC)**

Quantification of Vitamin C was done using a method with slight modification (22). Briefly, bromine water was added into extract to oxidize all Asc to DAsc and then excess of bromine was removed by adding of thiourea solution. After adding 2,4-dinitrophenylhydrazine solution, all samples, standards and blanks were kept in a water bath (37 °C) for 3 hrs and the absorbance was measured at 520 nm, after addition of sulfuric acid (85%, v/v) to each sample.

**Quantification of ascorbic acid (Asc)**

Asc of fruits samples were determined using two methods. At the first method, quantification of Asc was done by titrating with iodine (23).

The AOAC’s official titrimetric method for the determination of Asc as explained was used as the second method (20). Each titration was triplicated.

Iodine titrimetric method was applied with to all fruits while 2,6-dichlorophenolindophenol titrimetric method was not possible to intense colored fruits extracts (M. malabathricum, C. hirta, S. americanum, S. cumini, O. dillenii, I. coccinea, D. retusa, M. alba (ripe), G. quaestia, G. zeylanica and T. zeylanicus).

**Quantification of dehydroascorbic acid (DAsc)**

DAsc content of the fruits was obtained using following equation:

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\text{Dehydroascorbic acid content} = \frac{\text{[Total vitamin C content]} - \text{[Mean Ascorbic acid content]}}{\text{[Total vitamin C content]}}
\]

**Quantification of total phenolic (TP)**

Folin-Ciocalteu’s reagent (2.5 ml) was mixed with fruit extract (0.5 ml). After 5 min, Na2CO3 (2 ml of 7.5% w/v) was added and the absorbance was measured at 765 nm after incubating in the dark for 30 min. Total phenol content was quantified using a standard curve of gallic acid (0.02 – 0.1 mg/ml) and TP contents of fruits were expressed in mg of gallic acid equivalents (GE) per 100 gm of fresh fruit (24).

**Quantification of total flavonoid (TF)**

A mixture containing fruits extract (1 ml), methanol (3 ml), 10% (w/v) Aluminium chloride solution (0.2 ml), 1 M potassium acetate (0.2 ml) and distilled water (5.6 ml) was used, the absorbance was measured at 420 nm after incubating in the dark for 30 min. TF of each fruit extract was determined using a standard curve prepared with Quercetin (0.01 – 0.1 mg/ml). TF contents of fruits were expressed as mg of Quercetin equivalents (QE) per 100 gm of fresh fruit (25).

**DPPH assay**

Fruit extracts (100 µl) with 6 different concentrations were mixed with 3.9 ml of methonolic DPPH radical solution (0.06 mM) and samples were stand in the dark for 30 min and absorbance (at 517 nm) was measured. The antioxidant activity was expressed by IC₅₀ value that was calculated using the plot of % disappearance vs. concentration (here concentration is mg of fruit extract into 1 ml of solution) (26).

**FRAP assay**

Properly diluted sample (100 µl) was mixed with FRAP reagent (3 ml) and absorbance was measured at 593 nm, after incubating at 37 °C for 30 min. Aqueous solutions of FeSO₄·7H₂O with the concentration ranged from 100 to 1200 mM were used for calibration (27).

**Quantification of total iron (Fe)**

The fruit (10 – 20 gm) was burnt in a muffle furnace (Yamato FM-36) (at 450 °C) to get white/ gray colour ash and the residue in the crucible was dried on a hot plate after adding 6 M HCl (5 ml) and remaining content was dissolved in 0.1 M HNO₃ (15 ml) (28). The dissolved content was transferred and the volume was made to 25 ml with 0.1 M HNO₃. The above ampule was mixed with Conc. H₂SO₄ (0.5 ml), saturated K₂S₂O₅ (1 ml) and 3 N KSCN (2 ml) and volume was made up to 15 ml. Absorbance was measured immediately at 480 nm. Calibration curve was built using iron standards ranged from 5 to 25 mg/l (22).

**Statistical analysis**

One-way analysis of variance (ANOVA) and Tukey post-hoc test was used to find out the significant differences (p < 0.05) of the means (n=3) of studied parameters of fruits. Dependent variables are TC, mean Asc, DAsc, TP, TF, antiradical power (ARP), FRAP value and Fe content. Statistical analysis was carried out using the IBM SPSS 25.0 package (SPSS Inc., Chicago, USA). Classification and discrimination between fruits were done by PCA. In PCA, DPPH assay data were fed as ARP (ARP = 1/IC₅₀).

**Results and Discussion**

**Comparison of total vitamin C (TC), ascorbic acid (Asc) and dehydroascorbic acid (DAsc) contents of underutilized minor fruits (MFs)**

TC, Asc and DAsc contents of MFs in Sri Lanka is given in Table 2 and it varies from 6.6 to 136.1 mg/100 gm FW. Only these three fruits are the fruits with highest Asc content. These three MF species contain Asc greater than 100 mg/100 gm FW but any of the common fruits do not contain Asc larger than 100 mg/100 gm FW.
This study emphasizes higher Asc and TC contents in MFs compared to CFs with minor exceptions such as wild guava which has significantly lower Asc content compared to cultivated guava ‘cv. Horana white’ (18). DAsc content of MFs varied between 1.2 to 70.7 mg/100 gm FW (Table 2). The highest DAsc content was observed in A. willisis while decrease as they ripen and then remains at a fairly stable level until complete ripening. On considering the acidity and sugar levels of fruits, it has been reported that, acidity decreases while sugar content increases (30). Consequently, this changes the redox state of the fruit and the activity of enzymes related to ascorbate metabolism. In addition, the breakdown lowest was observed in ripe fruits of M. alba.

When the two maturity stages of L. camara were considered, it was observed that TC has increased upon ripening of the fruit. Ripe fruits had significantly higher TC compared to unripe stage, but Asc content remained unchanged for two stages. The possible reason could be the rapid conversion of Asc to DAsc during ripening while actively continuing biosynthesis pathway of Asc. In contrast, there was no significant change in Asc and TC contents in M. alba during ripening. Asc content in some fruits such as, Solanum lycopersicum, Vitis vinifera, Fragaria spp. etc. increase with the ripening. However, the fruits like Prunus persica and Actinidia spp., a maximum Asc level is achieved at the immature stage and gradually decreased during ripening (29). These fruits must have higher biosynthesis rate initially but of pectin due to degradation of cell wall during ripening may provide more supply of D-galacturionate, which helps the synthesis of Asc. However, the variation of Asc during ripening of fruit is an attribute dependent on the species (29). Similar Asc content for the MF, M. alba, has been reported by Erçisli and Orhan (22.4 mg/100 gm) (31) and Gungor and Sengul (10.5 – 21.50 mg/100 gm) (32).

**Comparison of total phenolic (TP), total flavonoid (TF) contents and antioxidant capacities (AOCs) of underutilized minor fruits (MFs)**

As given in Table 3, TP contents of studied MFs greatly varied in between 24.9 to 1613.3 mg GE (Gallic acid equivalent)/100 gm of FW with the highest and the lowest TP content in M. malabathricum and O. berrelieri respectively. When all the fruits are considered, M. malabathricum contains the highest

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**Table 2. TC, Asc, DAsc and iron content of minor fruits, compared to selected CFs in Sri Lanka**

| Fruits | TC (mg/100 gm FW) | Asc-E (mg AscE/100 gm FW) | Asc-DCPIP (mg AscE/100 gm FW) | DAsc (mg/100 gm FW) | Fe content (mg of Fe(III)/100 gm FW) |
|--------|------------------|---------------------------|------------------------------|---------------------|-------------------------------------|
| C. papaya | 73.2 ± 1.6^a | 69.5 ± 1.7a | 64.9 ± 1.8^a | 6.0 | 0.3 ± 0.0 |
| M. indica | 36.8 ± 0.4^a | 30.8 ± 0.4^a | 28.6 ± 0.2^a | 7.1 | 0.2 ± 0.1 |
| A. pedunculata | 76.2 ± 3.7 | 68.8 ± 1.0^a | 70.3 ± 3.5^a | 6.7 | 1.1 ± 0.1 |
| A. willisis | 186.1 ± 5.4 | 167.4 ± 1.8^a | 63.4 ± 3.5^a | 70.7 | 0.4 ± 0.1 |
| O. berrelieri | 75.8 ± 0.9 | 68.9 ± 1.0^a | 69.8 ± 6.2^a | 6.9 | 0.3 ± 0.1 |
| E. moonii | 19.0 ± 1.8^a | 10.9 ± 0.4^a | NA | 7.1 | 0.3 ± 0.1 |
| G. quaestia | 18.0 ± 0.3^a | 18.1 ± 0.7^a | 14.4 ± 0.9^a | 4.1 | 0.3 ± 0.1 |
| M. malabathricum | 6.6 ± 0.4^a | 3.3 ± 0.5^a | 2.9 ± 0.3^a | 3.5 | 0.4 ± 0.1 |
| F. indica | 12.8 ± 0.5^a | 11.0 ± 0.7^a | NA | 1.8 | 0.3 ± 0.2 |
| G. zeylanica | 11.4 ± 0.8^a | 7.7 ± 0.9^a | NA | 3.7 | 0.3 ± 0.0 |
| T. coecinea | 29.5 ± 0.2^a | 23.9 ± 0.4^a | NA | 5.9 | 0.3 ± 0.1 |
| L. camara (unripe) | 28.6 ± 0.2^a | 22.9 ± 2.0^a | 19.5 ± 0.6^a | 7.4 | 0.3 ± 0.1 |
| L. camara (ripe) | 37.3 ± 0.5^a | 21.0 ± 0.6^a | 19.3 ± 0.8^a | 17.2 | 0.8 ± 0.1 |
| M. alba (unripe) | 18.6 ± 0.6^a | 15.3 ± 0.2^a | 13.6 ± 0.7^a | 4.2 | 1.4 ± 0.1 |
| M. alba (ripe) | 17.9 ± 0.2^a | 16.7 ± 0.4^a | NA | 1.2 | 1.4 ± 0.1 |
| M. calabura | 123.7 ± 0.4^a | 121.7 ± 2.7^a | 121.2 ± 1.6^a | 2.2 | 0.4 ± 0.1 |
| M. maderspatana | 21.9 ± 1.8^a | 19.7 ± 0.9^a | 18.3 ± 1.3^a | 2.9 | 0.4 ± 0.1 |
| M. malabathricum | 101.6 ± 1.0^a | 95.3 ± 0.8^a | NA | 6.3 | 0.3 ± 0.1 |
| M. paniculata | 21.6 ± 0.3^a | 20.2 ± 0.2^a | 18.8 ± 0.8 | 2.1 | 0.6 ± 0.1 |
| O. berrelieri | 30.8 ± 0.1^a | 25.1 ± 0.5^a | 24.1 ± 1.6^a | 6.2 | 0.3 ± 0.1 |
| O. dilleni | 30.4 ± 0.4^a | 24.3 ± 0.5^a | NA | 18.2 | 0.4 ± 0.1 |
| P. foetida | 22.4 ± 0.9^a | 12.9 ± 0.9^a | 10.6 ± 0.7^a | 10.7 | 1.0 ± 0.3 |
| P. guajava (wild) | 39.7 ± 3.7 | 17.1 ± 1.0^a | 15.5 ± 0.8^a | 23.4 | 0.6 ± 0.1 |
| P. koraini | 15.9 ± 0.2^a | 12.9 ± 0.6^a | 10.8 ± 0.7^a | 4.1 | 0.4 ± 0.1 |
| S. americanum | 52.4 ± 0.4^a | 42.5 ± 0.5^a | NA | 9.9 | 1.1 ± 0.2 |
| S. capsicosides | 32.0 ± 0.4^a | 26.0 ± 0.7^a | 22.4 ± 0.8 | 7.8 | 0.4 ± 0.1 |
| S. cumini | 35.3 ± 1.9^a | 13.4 ± 0.5^a | NA | 26.6 | 0.4 ± 0.0 |
| S. oleosa | 23.7 ± 1.8^a | 19.0 ± 2.4^a | 11.4 ± 0.7^a | 4.3 | 0.4 ± 0.1 |
| A. willisis | 18.8 ± 3.0 | 7.3 ± 1.5^a | NA | 2.6 | 4.9 ± 1.1 |

Means with different superscript letters in individual column for each fruit category are significantly (p < 0.05) different from each other.

NA – Not applicable; TC – Total vitamin C content, Asc – Ascorbic acid content, DAsc – Dehydroascorbic acid content; Asc-E – Ascorbic acid equivalent. Asc-I – Ascorbic acid content determined by iodine titrimetric method, Asc-DCPIP – Ascorbic acid content determined by 2,6-dichlorophenolindophenol titrimetric method, Asc-E – Ascorbic acid equivalent.

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TP content followed by C. hirta and M. paniculata. From CFs, highest TP and TF contents were observed in P. guajava (white), but its TP content is about 9 times lower than that of M. malabathricum. TP content of ripe fruits of L. camara and M. alba are higher than in unripe stage, emphasizing that significant increase in TP during ripening. Increase in TP and antioxidant capacities with ripening has been reported by previous researchers for Vaccinium ashei (33) and Solanum lycopersicum (34). In contrast some authors have reported decrease in TP in P. guajava (35), Musa spp. (36) and M. indica (37) during ripening. TF of minor fruits are ranged from 6.2 to 228.0 mg QE (Quercetin equivalent)/100 gm FW while M. malabathricum and C. hirta reported to have the highest and they are the only TF with higher than 100 mg QE/100 gm FW. The MF, F. indica is with mg/ml giving the highest AOC (lowest IC₅₀) in M. malabathricum followed by A. willisii, C. hirta, M. calabura, A. pedunculata and A. alexiteria. The lowest AOC (highest IC₅₀) was observed in T. zeylanicus followed by B. flabellifera and G. zeylanica. MFs have high free radical scavenging capacity compared to CFs. From the CFs, P. guajava (white flesh) shows the highest radical scavenging capacity, but about 8 times less than M. malabathricum.

**FRAP values of minor fruits**

FRAP values of MFs studied is given in Table 3 and they are varied within a wide range of 9.6 to 486.7 μmol FeSO₄/gm FW while M. malabathricum showed the highest FRAP (highest AOC) followed by A. willisii, C. hirta and M. calabura. The lowest AOC in FRAP was observed in G. zeylanica. Among CFs the highest

| Fruits          | TP (mg QE/100 gm FW) | TF (mg QE/100 gm FW) | DPPH - IC₅₀ (mg/ml) | FRAP (μmol FeSO₄/gm FW) |
|-----------------|---------------------|---------------------|---------------------|-----------------------|
| C. papaya       | 57.4 ± 1.1 a        | 17.3 ± 0.4 a        | 120.0 ± 10.0 b      | 108.3 ± 7.6 b         |
| M. indica       | 103.8 ± 15.4 a      | 62.2 ± 2.8 a        | 12.9 ± 2.1 b        | 950.0 ± 78.1 b        |
| P. guajava (white flesh) | 180.6 ± 4.3 a | 92.0 ± 0.3 a        | 9.8 ± 0.1 a         | 131.5 ± 0.5 a         |

**Minor fruits (MFs)**

- A. alexiteria
- A. nobilis
- A. pedunculata
- A. willisii
- B. flabellifera
- C. hirta
- D. hebecarpa
- D. retusa
- E. moonii
- F. indica
- G. quaestia
- G. zeylanica
- L. coccinea
- L. camara (unripe)
- L. camara (ripe)
- M. alba (unripe)
- M. alba (ripe)
- M. calabura
- M. madaraspatana
- M. malabathricum
- M. paniculata
- O. berrelieri
- O. dillenii
- P. foetida
- P. guajava (wild)
- P. korinnaeus
- S. americanus
- S. capsicoides
- S. cuminum
- S. oleosa
- T. zeylanicus

| Commonly consumed fruits (CFs) | TP (mg GE/100 gm FW) | TF (mg QE/100 gm FW) | DPPH - IC₅₀(μmol FeSO₄/gm FW) |
|-------------------------------|---------------------|---------------------|-----------------------------|
| C. papaya                     | 57.4 ± 1.1          | 17.3 ± 0.4          | 120.0 ± 10.0                |
| M. indica                     | 103.8 ± 15.4        | 62.2 ± 2.8          | 12.9 ± 2.1                  |
| P. guajava (white flesh)      | 180.6 ± 4.3         | 92.0 ± 0.3          | 9.8 ± 0.1                   |

Means with different superscript letters in individual column for each fruit category are significantly (p < 0.05) different from each other.

ND - Not detected; NA - Not applicable; TP - Total phenolic content; TF - Total flavonoid content; GE - Gallic acid equivalents; QE – Quercetin equivalent.

Table 3. TP and TF contents of minor underutilized fruits, compared to selected CFs in Sri Lanka

Mean ± SE

The lowest TF. It was reported similar values for TP (181 mg GE/100 gm) and TF (29 mg QE/100 gm) for M. alba as obtained in this study (31).

**DPPH assays for underutilized minor fruits**

DPPH assay measures the quenching DPPH radical by concerned extracts, and given as IC₅₀ values (Table 3). Accordingly, the IC₅₀ varied in between 1.2 to 245.4 FRAP was observed in M. indica and it has a higher FRAP value compared to the MF; M. malabathricum. When both AOC assays are considered, M. malabathricum, A. willisii, C. hirta and M. calabura are the MFs with highest AOCs. M. malabathricum and C. hirta are the fruits with highest TF and TP contents. The higher TF and CF can be responsible for the high AOCs. Some contradict results has been...
observed for example, high AOC in *A. willisii* is not due to the high TP and TF, but due to high amount of TC. In *D. hebecarpa* and *O. berrelieri*, the TP and TF are low whereas TC, Asc and AOCs are high. These results revealed that higher level of AOC in *D. hebecarpa* is due to higher contents of TC and Asc not because of TP and TF. It has been observed that the major contribution of Asc for antioxidant capacity other than phenolic compounds (38).

**Iron (Fe) content of minor fruits**

Fe contents of MFs studied are given in Table 2 and it varied in between 4.9 and 0.2 mg/100 gm FW. Fe contents were high in the fruit of *T. zeylanicus* and then showed reducing in *M. alba, A. pedunculata, S. americanum* and *P. foetida*. However, these fruits contain significantly higher iron contents than the iron content of commonly consumed fruit, *P. guajava* (white flesh).

This study gets credited as the first study done for many important health and nutritional parameters such as Asc, TC, DAsc, TP, TF, Fe contents and AOCs for higher number of MFs. According to our knowledge, only two studies on minor fruits have been reported by Sri Lankan scientists. One is AOC of *S. oleosa* (9) and the other was AOC of MF, *A. alexiteria* (39) observation is on similar TP (223.67 mg GE/100 gm) for *S. oleosa* (9). They also have determined DPPH (1580 ppm) and FRAP value (1.12 Fe2+ mM/gm) of *S. oleosa*. Agreeing with our results (39). It was reported that TP in *A. alexiteria* that is ranged from 3.33 to 6.77 mg GE/gm.

Some literature data on minor fruits considered in this study are available for from other countries as many of those fruits are underutilized in other countries as well. The antioxidant properties of minor fruits, *M. alba, S. cumini* and *D. hebecarpa* etc. have been reported by many researchers (31, 32, 40–43). A similar Asc content for *S. cumini* (14 mg/100 gm) was also reported (41). However, discordant value for Asc of *S. cumini* (112 mg/100 gm) has been observed (42). TP of *S. cumini* that ranged from 497 to 185 mg GE/100 gm as reported (41) and (42) respectively.

**Iron (Fe) content of minor fruits**

*D. hebecarpa* is a fruit native to Sri Lanka and it is a good source of anthocyanin (44, 45). According to past studies, vitamin C content of *D. hebecarpa* is ranged from 98 mg/100 gm (44) to 143.4 mg/100 gm (46). TP of *D. hebecarpa* as observed (45) is ranged from 195 to 239 mg GE/100 gm FW. Same reports are on AOC of *D. hebecarpa*, determined by FRAP assay 10.7 – 13.8 μmol GE/gm and 7.9 – 10.3 μmol trolox equivalents (TE)/gm (45). TP and TF values lower than ours which is 4.35 mg GE/100 gm and 9.64 mg QE/100 gm respectively (46). Furthermore, the authors have reported AOC as DPPH and FRAP for *D. hebecarpa* as, 17.08 mg TE/100 gm and 487.13 mg FeSO4/100 gm respectively (46). It was reported that TP and vitamin C contents of *A. pedunculata* as 0.8 gm gallic acid/100 gm dry weight and 6.0 μmol ascorbate/g dry weight. Moreover, the author has elaborated that main flavonoids present in *A. pedunculata* are flavanones (naringin), phenolic acids and phenolic terpenoids (47).

As Asc can support the non-heme iron absorption, fruit sources which contain high Asc and iron can help to prevent iron deficiency among people (48). For developing countries like Sri Lanka, MF species will be important as low cost sources to alleviate iron deficiency anemia from the society. *S. Americanum* and *P. guajava* (white flesh) can be considered as a potential source of iron as well as Asc that may have iron with high bioavailability. Although *T. zeylanicus, M. alba* and *A. pedunculata* have higher amounts of total iron content, the Asc content is low in these fruits. According to previous studies iron content of *M. alba* is ranged from 0.2 to 4.67 mg/100 gm (31, 32, 40).

**Principal component analysis (PCA)**

In PCA, 2 principal components (PCs) have been extracted from the original data, according to the Kaiser’s rule (eigenvalues > 1.0). The Kaiser-Meyer-Olkin measure of sampling adequacy is 0.792. Loading values, eigenvalues and % cumulative variance obtained for PCs are as in the Table 4. The percent cumulative variance of first two principal components was almost 64% of the total variance. Loading values higher than 0.7 are marked in boldface type in Table 4. The PC1 correlates highly with the original variables in descending order as ARP, TC, mean Asc and TF. These variables positively loaded heavily on the PC1, as worked out on the guideline provided by Pituch and Stevens (factor loading > 0.72) (49). These variables are highly correlated. However, DAsc, FRAP, TF and Fe did not match the Steven’s guideline.

The score plot resulted from PCA is illustrated in the Fig. 1. In the plot 4 separated clusters can be seen those are separated by PC2. Majority of fruits are along the zero of the PC2 and in the negative side of PC1. Only 6 fruits are in the positive side of PC1 and these fruits have been extracted from other fruits due to high contents of studied health prompting factors. *M. malabathricum* is the best fruit among studied fruits which has the highest PC1 value. Secondly best fruit is *A. willisii* followed by *C. hirta* and *M. calabura*. The results of this study emphasize that the locally available MFs are rich in nutritional and health factors compared to most of the CFs.

**Table 4. Loading values, eigenvalues and percent cumulative variance obtained for the 2 PCs.**

| Variable | PC1 | PC2 |
|----------|-----|-----|
| TC       | 0.896 | −0.264 |
| Mean Asc | 0.851 | 0.054 |
| DAsc     | 0.395 | −0.822 |
| TP       | 0.638 | 0.421 |
| TF       | 0.773 | 0.399 |
| ARP      | 0.913 | −0.056 |
| FRAP     | 0.653 | 0.066 |
| Fe       | −0.265 | 0.206 |
| Eigenvalue | 4.019 | 1.134 |
| % Cumulative | 50.235 | 64.408 |

PC – Principal components; TC – total vitamin C; Asc – ascorbic acid; TP – total phenolic content; TF – total flavonoid content; ARP – antioxidative power; FRAP – ferric reducing antioxidant power.
Conclusion

The results of the study revealed that minor fruits are rich in nutritional and health factors compared to common fruits in Sri Lanka. *M. malabathricum* is the fruit with the highest TP, TF and AOCs. The highest TC and DAsc are in *A. willisii* and the highest Asc content is found in *M. calabura*. *T. zeylanicus* has remarkably higher iron content. The results of this study reveal the importance of paying attention for utilization, cultivation, value addition and creating proper marketing channels to promote consumption of minor fruits among Sri Lankans as an alternative to common fruits.

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Authors’ contributions

All authors collaborated in the development of research, experimental designing, writing and editing the manuscript.

Conflict of interests

The authors declare that they have no competing interests regarding the publication of this paper.

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