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RESEARCH ARTICLE

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 IC_{50} values in a DPPH assay was 1.2 to 245.4 mg/ml whereas FRAP values ranged from 9.6 to 486.7 µmol $FeSO_4$/gm. Among the studied minor fruits, *Melastoma malabathricum* (Maha bovitiya/ 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 available in Sri Lanka were determined and compared them with the best three commonly consumed fruits (*Carica papaya*, *Mangifera indica* and *Psidium guajava*).

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. 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.

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.	Botanical name	Common/ Local name(s)	Edible part(s)[a]	Harvested location	Harvested season Month/ year
	Commonly consumed fruits (CFs)				
1	*Carica papaya* L.	Papaya ('Red lady')	FWPS	M[b], SP[c]	03/ 2018
2	*Mangifera indica* L.	Mango	FWPS	M, SP	05/ 2017
3	*Psidium guajava* L.	Guava (white flesh)	WF	HB, SP	06/ 2017
	Minor fruits (MFs)				
1	*Acronychia pedunculata* (L.) Miq.	Unkenda, Indian aspen	FWS	RP	10/ 2017
2	*Antidesma alexiteria* L.	Heen ambilla, Wild cherry / Ceylon bignay	WF	RP	10/ 2017
3	*Ardisia willisii* Mez.	Lunu dan	FWS	M	07/2018
4	*Artocarpus nobilis* Thwaites	Bedi del/ Wal del, Ceylon wild bread fruit	FWPS	M	07/ 2018
5	*Borassus flabellifer* L.	Thal, Palmyrah	FWPS	AN	01/2018
6	*Clidemia hirta* (L.) D. Don	Kinithulu bovitiya, Soap bush	WF	M	08/ 2017
7	*Dillenia retusa*	Godapara	FWPS	M	06/ 2018
8	*Dovyalis hebecarpa* (Gardner) Warb.	Ketambilla, Ceylon gooseberry	FWPS	M	10/ 2017
9	*Erythroxylum moonii* Hochr.	Batakirilla	WF	M	09/ 2017
10	*Flacourtia indica* (Burm.f.) Merr.	Uguressa, Governor's plum	FWS	M	06/ 2018
11	*Garcinia quaestia* Pierre	Rath goraka, Malabar tamarind/ Brindle berry	FWPS	M	06/ 2018
12	*Garcinia zeylanica* Roxb.	Ela goraka, Malabar tamarind/ Brindle berry	FWPS	M	07/ 2018
13	*Ixora coccinea* L.	Rathambala/ Rathmal, Jungle geranium/ Jungle flame	WF	M	10/ 2017
14	*Lantana camara* L.	Gandapana/ Rata hinguru (unripe)	WF	M	09/ 2017
15	*Lantana camara* L.	Gandapana/ Rata hinguru (ripe)	WF	M	09/ 2017
16	*Melastoma malabathricum* L.	Maha bovitiya/ Katakaluwa, Malabar melastome/ Indiana rhododendron	FWP	M	10/ 2017
17	*Microcos paniculata* L.	Kohukirilla, Shiral/ Mahang	FWS	AN	07/ 2017
18	*Morus alba* L.	Rata embilla, Mulberry (unripe)	WF	M	09/ 2017
19	*Morus alba* L.	Rata embilla, Mulberry (ripe)	WF	M	09/ 2017
20	*Mukia maderaspatana* L.	Gonkakiri, Madras pea pumpkin	WF	M	10/ 2017
21	*Muntingia calabura* L.	Jam, Jamaica cherry	WF	M	09/ 2017
22	*Opuntia dillenii* (Ker. Gawl.) Haw.	Pathok, Common prickly pear	FWPS	HB	09/ 2017
23	*Oxalis berrelieri* L.	Heen bilin, Lavender sorrel	WF	M	09/ 2017
24	*Passiflora foetida* L.	Del batu, Wild water melon/ Love-in-a-mist	FWP	M	09/ 2018
25	*Polyalthia korintii* (Dunal) Thwaites	Ulkenda	WF	RP	10/ 2017
26	*Psidium guajava* L.	Ambul pera, Wild guava	WF	M	09/ 2017
27	*Schleichera oleosa* (Lour.) Oken	Katu koan, Ceylon oak	FWPS	AN	08/ 2017
28	*Solanum americanum* Mill.	Kalu kemberiya, American night shed	WF	M	10/ 2017
29	*Solanum capsicoides* All.	Nai batu/ Dehel batu, Soda apple/ Cockroach berry	FWS	RP	08/ 2017
30	*Syzygium cumini* (L.) Skeels.	Madan, Java-plum/ jamun/ jambolan	FWS	M	06/ 2018
31	*Trichopus zeylanicus* Gaertn.	Bin pol	WF	M	06/ 2018

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

[b]Fruits harvested district in Sri Lanka: AN – Anuradhapura; M – Matara; 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:

Dehydroascorbic acid content =
[Total vitamin C content] – [Mean Ascorbic acid 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 IC_{50} 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 $FeSO_4.7H_2O$ 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 HNO_3 (15 ml) (28). The dissolved content was transferred and the volume was made to 25 ml with 0.1 M HNO_3. The above ample was mixed with Conc. H_2SO_4 (0.5 ml), saturated $K_2S_2O_8$ (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 ($ARP = 1/IC_{50}$).

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 (Fresh weight), while *A. willisii* being the fruit with highest TC followed by *M. calabura* and *M. malabathricum*. Only these three fruits are the fruits with high TC content and *C. hirta*, *D. hebecarpa* and *S. americanum* are the fruits with moderately high TC among studied MFs. The lowest TC was observed in *F. indica*. Mean Asc content was in the range of 3.1 -121.5 mg/100 gm FW in MFs. *M. calabura* followed by *M. malabathricum* and *C. hirta* 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. willisii* while lowest was observed in ripe fruits of *M. alba*.

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-I_2 (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)
Commonly consumed fruits (CFs)					
C. papaya	73.2 ± 1.6^{b}	69.5 ± 1.7^{b}	64.9 ± 1.8^{b}	6.0	0.3 ± 0.0
M. indica	36.8 ± 0.4^{a}	30.8 ± 0.4^{a}	28.8 ± 0.2^{a}	7.1	0.2 ± 0.1
P. guajava (white flesh)	76.2 ± 0.7^{c}	68.8 ± 1.0^{b}	70.3 ± 0.3^{c}	6.7	1.1 ± 0.1
Minor fruits (MFs)					
A. alexiteria	46.1 ± 0.3^{no}	30.3 ± 0.5^{n}	28.7 ± 1.2^{k}	16.6	0.4 ± 0.1
A. nobilis	14.3 ± 2.6^{de}	4.6 ± 0.4^{b}	4.0 ± 0.6^{b}	10.0	0.4 ± 0.1
A. pedunculata	24.8 ± 1.0^{ij}	18.9 ± 1.0^{fghi}	17.0 ± 0.7^{fgh}	5.9	1.3 ± 0.1
A. willisii	**136.1 ± 5.4^{r}**	67.4 ± 1.8^{p}	63.4 ± 3.5^{l}	**70.7**	0.4 ± 0.1
B. flabellifer	20.4 ± 1.2^{ghi}	8.1 ± 0.4^{c}	7.2 ± 0.3^{c}	12.8	0.2 ± 0.0
C. hirta	75.8 ± 0.3^{p}	68.9 ± 1.0^{p}	NA	6.9	0.3 ± 0.1
D. hebecarpa	70.9 ± 0.3^{p}	66.8 ± 3.8^{p}	68.9 ± 0.5^{l}	3.0	0.2 ± 0.0
D. retusa	18.0 ± 1.8^{fg}	10.9 ± 0.4^{d}	NA	7.1	0.3 ± 0.1
E. moonii	20.3 ± 0.3^{ghi}	18.1 ± 0.7^{fgh}	14.4 ± 0.9^{ef}	4.1	0.3 ± 0.1
F. indica	6.6 ± 0.4^{a}	3.3 ± 0.5^{a}	2.9 ± 0.3^{a}	3.5	0.4 ± 0.1
G. quaestia	12.8 ± 0.5^{cd}	11.0 ± 0.7^{d}	NA	1.8	0.5 ± 0.2
G. zeylanica	11.4 ± 0.8^{bc}	7.7 ± 0.9^{c}	NA	3.7	0.3 ± 0.0
I. coccinea	29.8 ± 0.2^{jk}	23.9 ± 0.4^{jklm}	NA	5.9	0.3 ± 0.1
L. camara (unripe)	28.6 ± 0.2^{jk}	22.9 ± 0.3^{ijklm}	19.5 ± 0.6h^{i}	7.4	0.6 ± 0.1
L. camara (ripe)	37.3 ± 0.3^{lmn}	21.0 ± 0.6^{hijkl}	19.1 ± 0.8^{hi}	17.2	0.6 ± 0.1
M. alba (unripe)	18.6 ± 0.6^{fgh}	15.3 ± 0.2^{ef}	13.6 ± 0.7^{e}	4.2	1.4 ± 0.1
M. alba (ripe)	17.9 ± 0.2^{fg}	16.7 ± 0.4^{fg}	NA	1.2	1.4 ± 0.1
M. calabura	123.7 ± 0.4^{q}	**121.7 ± 2.7^{r}**	**121.2 ± 1.6^{m}**	2.2	0.4 ± 0.1
M. maderaspatana	21.9 ± 1.8^{ghi}	19.7 ± 0.9^{ghij}	18.3 ± 1.3^{gh}	2.9	0.4 ± 0.1
M. malabathricum	101.6 ± 1.0^{q}	95.3 ± 0.8^{q}	NA	6.3	0.3 ± 0.1
M. paniculata	21.6 ± 0.3^{ghi}	20.2 ± 0.2^{ghijk}	18.8 ± 0.8^{h}	2.1	0.6 ± 0.1
O. berrelieri	30.8 ± 0.1^{kl}	25.1 ± 0.3^{lmn}	24.1 ± 1.6^{j}	6.2	0.3 ± 0.1
O. dillenii	30.4 ± 0.4^{jkl}	24.3 ± 0.5^{klm}	NA	18.2	0.4 ± 0.1
P. foetida	22.4 ± 0.9^{hi}	12.9 ± 0.9^{de}	10.6 ± 0.7^{d}	10.7	1.0 ± 0.3
P. guajava (wild)	39.7 ± 0.3^{mn}	17.1 ± 1.0^{fgh}	15.5 ± 0.8^{efg}	23.4	0.6 ± 0.1
P. korintii	15.9 ± 0.2^{ef}	12.9 ± 0.6^{de}	10.8 ± 0.7^{d}	4.1	0.4 ± 0.1
S. americanum	52.4 ± 0.4^{o}	42.5 ± 0.5^{o}	NA	9.9	1.1 ± 0.2
S. capsicoides	32.0 ± 0.4^{klm}	26.0 ± 0.7^{mn}	22.4 ± 0.8^{ij}	7.8	0.4 ± 0.1
S. cumini	33.3 ± 1.9^{klm}	13.4 ± 0.5^{de}	NA	26.6	0.4 ± 0.0
S. oleosa	22.7 ± 1.6^{hi}	19.6 ± 2.4^{ghij}	17.4 ± 0.7^{gh}	4.3	0.4 ± 0.1
T. zeylanicus	9.9 ± 2.3^{b}	7.3 ± 1.3^{c}	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-I_2 – Ascorbic acid content determined by iodine titrimetric method, Asc-DCPIP – Ascorbic acid content determined by 2,6-dichlorophenolindophenol titrimetric method, AscE – Ascorbic acid equivalent.

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 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 of pectin due to degradation of cell wall during ripening may provide more supply of D-galacturonate, 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 Ercisli 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

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 fruits with TF higher than 100 mg QE/100 gm FW. The MF, *F. indica* is with 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 IC_{50} values (Table 3). Accordingly, the IC_{50} varied in between 1.2 to 245.4 mg/ml giving the highest AOC (lowest IC_{50}) in *M. malabathricum* followed by *A. willisii*, *C. hirta*, *M. calabura*, *A. pedunculata* and *A. alexiteria*. The lowest AOC (highest IC_{50}) was observed in *T. zeylanicus* followed by *B. flabellifer* 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 $FeSO_4$/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 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 TP and TF contents. The higher TP and TF can be responsible for the high AOCs. Some contradict results has been

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

Fruits	TP (mg GE/100 gm FW)	TF (mg QE/100 gm FW)	DPPH - IC_{50} (mg/ml)	FRAP (μmol $FeSO_4$/gm FW)
Commonly consumed fruits (CFs)				
C. papaya	57.4 ± 1.1[a]	17.3 ± 0.4[a]	120.0 ± 10.0[b]	108.3 ± 7.6[a]
M. indica	103.8 ± 15.4[b]	62.2 ± 2.8[b]	12.9 ± 2.1[a]	950.0 ± 78.1[b]
P. guajava (white flesh)	180.6 ± 4.3[c]	92.0 ± 0.3[c]	9.8 ± 0.1[a]	131.5 ± 0.5[a]
Minor fruits (MFs)				
A. alexiteria	580.6 ± 65.1[nop]	35.3 ± 4.6[hij]	5.0 ± 1.0[lm]	152.7 ± 9.3[p]
A. nobilis	89.7 ± 11.5[def]	44.0 ± 1.0[ijkl]	69.1 ± 5.2[cd]	12.3 ± 2.5[ab]
A. pedunculata	493.3 ± 95.0[lmno]	57.3 ± 2.4[lmno]	4.4 ± 0.4[m]	115.0 ± 15.0[nop]
A. willisii	716.0 ± 121.8[op]	66.0 ± 3.6[mnop]	1.3 ± 0.2[o]	330.0 ± 26.5[q]
B. flabellifer	41.2 ± 9.3[abc]	17.8 ± 1.9[de]	228.7 ± 28.0[a]	27.3 ± 2.5[de]
C. hirta	974.3 ± 31.0[p]	181.7 ± 23.6[r]	1.5 ± 0.5[o]	310.1 ± 10.0[q]
D. hebecarpa	27.8 ± 2.6[ab]	20.5 ± 3.9[ef]	9.5 ± 0.5[k]	121.7 ± 7.6[nop]
D. retusa	122.7 ± 11.9[efgh]	31.0 ± 5.0[ghi]	81.9 ± 1.9[bc]	35.2 ± 4.8[efgh]
E. moonii	294.9 ± 47.2[jklm]	55.3 ± 4.3[lmno]	25.2 ± 0.4[gh]	67.3 ± 2.5[jkl]
F. indica	112.0 ± 26.2[efg]	6.2 ± 1.3[a]	107.0 ± 8.0[b]	42.7 ± 2.5[fghi]
G. quaestia	155.3 ± 10.3[fghij]	52.7 ± 2.5[klm]	53.2 ± 2.8[de]	47.0 ± 2.6[ghij]
G. zeylanica	126.4 ± 8.4[efgh]	8.5 ± 1.3[ab]	205.3 ± 12.9[a]	9.6 ± 0.5[a]
I. coccinea	270.2 ± 27.8[ijkl]	99.0 ± 18.2[q]	11.0 ± 1.0[jk]	77.0 ± 14.7[klm]
L. camara (unripe)	93.2 ± 6.1[def]	79.5 ± 5.2[opq]	10.8 ± 0.3[k]	91.9 ± 12.7[lmno]
L. camara (ripe)	330.7 ± 26.9[klmn]	89.0 ± 10.1[pq]	198.3 ± 12.6[a]	32.9 ± 2.6[defg]
M. alba (unripe)	97.4 ± 10.9[def]	ND	96.1 ± 3.9[bc]	18.1 ± 1.1[c]
M. alba (ripe)	141.0 ± 9.9[fghi]	33.3 ± 2.1[hi]	50.5 ± 5.1[de]	85.0 ± 5.0[lmn]
M. calabura	597.5 ± 55.7[nop]	76.5 ± 3.1[nopq]	2.3 ± 0.4[n]	272.0 ± 65.8[q]
M. maderaspatana	204.4 ± 41.9[ghijk]	63.6 ± 1.2[mnop]	12.0 ± 1.0[jk]	34.3 ± 5.1[efgh]
M. malabathricum	**1613.3 ± 126.6[q]**	**228.0 ± 27.1[r]**	**1.2 ± 0.3[o]**	**486.7 ± 15.3[r]**
M. paniculata	937.5 ± 54.5[op]	36.9 ± 5.6[hijk]	68.4 ± 2.9[cd]	34.1 ± 5.1[efg]
O. berrelieri	24.9 ± 5.0[a]	16.8 ± 2.8[cde]	15.4 ± 1.0[ij]	101.8 ± 16.0[mno]
O. dillenii	128.0 ± 24.4[efgh]	12.0 ± 1.8[bc]	NA	34.1 ± 3.3[efg]
P. foetida	91.5 ± 10.6[def]	26.0 ± 4.0[fgh]	86.8 ± 2.8[bc]	17.0 ± 2.6[bc]
P. guajava (wild)	227.8 ± 59.2[hijk]	14.0 ± 1.0[cd]	10.4 ± 0.5[k]	75.2 ± 4.2[klm]
P. korintii	52.3 ± 3.1[bcd]	16.9 ± 1.6[cde]	76.4 ± 5.1[bc]	31.2 ± 2.3[def]
S. americanum	536.7 ± 32.1[mnop]	51.2 ± 1.1[klm]	40.8 ± 0.9[ef]	53.7 ± 5.5[ijk]
S. capsicoides	207.1 ± 32.9[ghijk]	49.5 ± 1.7[jklm]	43.8 ± 3.8[e]	23.0 ± 2.1[cd]
S. cumini	258.2 ± 20.1[ijkl]	53.7 ± 1.7[lmn]	18.3 ± 1.8[hi]	107.7 ± 8.1[mnop]
S. oleosa	213.7 ± 30.2[ghijk]	21.1 ± 2.1[ef]	30.3 ± 3.0[fg]	49.2 ± 0.7[hij]
T. zeylanicus	71.3 ± 18.2[cde]	21.7 ± 1.5[efg]	245.4 ± 13.6[a]	12.3 ± 2.5[ab]

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.

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 Fe^{2+} 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.

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 $FeSO_4$/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 – antiradical power; FRAP – ferric reducing antioxidant power.

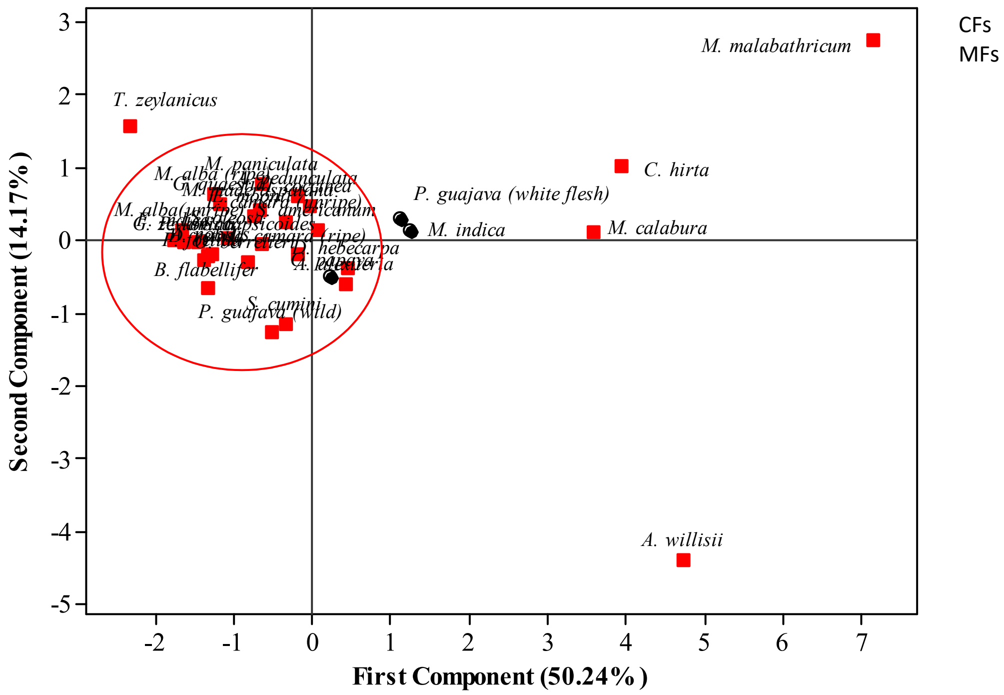

Fig. 1. Score plot for principal component analysis.

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.

References

1. Ashton MS, Gunatilleke S, Zoysa ND, Dassanayake M, Gunatilleke N, Wijesundera S. A Field Guide to the Common Trees and Shrubs of Sri Lanka. Sri Lanka: WHT Publications (Pvt.) Limited; 1997.

2. Bandula A, Jayaweera C, Silva AD, Oreiley P, Karunarathne A, Malkanthi SHP. Role of underutilized crop value chains in rural food and income security in Sri Lanka. Procedia Food Sci. 2016;6:267-70. http://doi.org/10.1016/j.profoo.2016.02.049

3. Malkanthi SHP, Karunaratne AS, Amuwala SD, Silva P. Opportunities and challenges in cultivating underutilized field crops in Moneragala district of Sri Lanka. Asian Journal of Agriculture and Rural Development. 2014;4(1):96-105. http://doi.org/10.4038/tar.v30i3.8315

4. Weerahewa J, Rajapakse C, Pushpakumara G. An analysis of consumer demand for fruits in Sri Lanka. Appetite. 2013;60(1):252-58. https://doi.org/10.1016/j.appet.2012.09.017

5. Mayes S, Massawe FJ, Alderson PG. The potential for underutilized crops to improve security of food production. Journal of Experimental Botany, 2012;63(3):1075-79. https://doi.org/10.1093/jxb/err396

6. Pushpakumara DKNG, Heenkenda HMS, Marambe B, Ranil RHG, Punyawardena BVR, Weerahewa J et al. Kandyan home gardens: a time-tested good practice from Sri Lanka for conserving tropical fruit tree diversity. In: Tropical fruit tree diversity: good practice for *in-situ* and on-farm conservation. Abingdon, Oxon: Routlendge; 2016:127-46.

7. Senaratna LK. A check list of the flowering plants of Sri Lanka. Sri Lanka: National Science Foundation; 2001.

8. Yasapalitha TA, Rupasinghe RS. Sri Lankave Wana Palthuru. Sri Lanka: Wasana Publishers; 2016.

9. Piyathunga A, Mallawaarachchi M, Madhujith W. Phenolic content and antioxidant capacity of selected underutilized fruits grown in Sri Lanka. Trop Agric Res. 2016;27(3):277-86.

10. Bopitiya D, Madhujith T. Antioxidant potential of pomegranate (*Punica granatum* L.) cultivars. Trop Agric Res. 2012;24(1):71-81.

11. Hewage S., Premakumara G., Madhujith T. Study on antioxidant activity of mangosteen (*Garcinia mangostana*). Paper presented at: 64th Annual Sessions, Sri

Lanka Association for the Advancement of Science; Sri Lanka; 2008 Dec 1-6.

12. Mallawaarachchi MALN, Madhujith WMT, Pushpakumara DKNG. Antioxidant potential of selected underutilized fruit crop species grown in Sri Lanka. Trop Agric Res. 2019;30(3):1-12. http://doi.org/10.4038/tar.v30i3.8315
13. Manuha M, Iqbal N, Nageeb B, Paranagama P. Determination of vitamin C (ascorbic acid) in lime and lemon. Paper presented at: 2nd International Conference on Ayurveda, Unani, Siddha and Traditional Medicine (iCAUST); Sri Lanka; 2014 Dec 16-18.
14. Nadeesha M, Bamunuarachchi A, Edirisinghe E, Weerasinghe W. Studies on antioxidant activity of Indian gooseberry fruit and seed. Journal of Science of the University of Kelaniya, Sri Lanka. 2007;3:83-92.
15. Padmini S, Samarasekera R, Pushpakumara D. Antioxidant capacity and total phenol content of Sri Lankan *Annona muricata* L. Trop Agric Res. 2014;25(2):252-60. http://doi.org/10.4038/tar.v25i2.8146
16. Sarananda KH, Thillakawardane TU, Alexander B. Production of health-friendly, ready-to-serve fruit drinks from under-utilized local fruits from Sri Lanka. Sri Lanka Journal of Food and Agriculture. 2017;3(2):37-48. http://doi.org/10.4038/sljfa.v3i2.50
17. Sirasa MSF, Rukiya MJF, Silva KDRR. Antioxidant properties of selected commonly consumed and underutilized fruits in Sri Lanka. Paper presented at: Peradeniya Univ. International Research Sessions; Sri Lanka; 2014 Jul 4-5.
18. Silva KDRR, Sirasa MSF. Antioxidant properties of selected fruit cultivars grown in Sri Lanka. Food Chem. 2018;238:203-08. https://doi.org/10.1016/j.foodchem.2016.08.102
19. Abeysuriya HI, Bulugahapitiya VP, Jayatissa LP. Total vitamin C, ascorbic acid, dehydroascorbic acid, antioxidant properties and iron content of underutilized and commonly consumed fruits in Sri Lanka. Int J Food Sci [Internet]. 2020 [cited 2021 Apr 12] https://www.hindawi.com/journals/ijfs/2020/4783029/
20. Nielsen SS. Food Analysis. 4th ed. New York, USA: Springer Science and Business Media, Inc.; 2010:55-60.
21. Ikram EHK, Eng KH, Jalil AMM, Ismail A, Idris S, Azlan A et al. Antioxidant capacity and total phenolic content of Malaysian underutilized fruits. J Food Compost Anal. 2009;22:388-93. https://doi.org/10.1016/j.jfca.2009.04.001
22. Ranganna S. Hand book of analysis and quality control for fruit and vegetable products. New Delhi, India: Tata McGraw-Hill Publishing Company Limited; 1999.
23. Suntornsuk L, Gritsanapun W, Nilkamhank S, Paochom A. Quantitation of vitamin C content in herbal juice using direct titration. J Pharm Biomed. 2002;28(5):849-55. https://doi.org/10.1016/S0731-7085(01)00661-6
24. Lim YY, Lim TT, Tee JJ. Antioxidant properties of several tropical fruits: A comparative study. Food Chem. 2007;103(3):1003-08. https://doi.org/10.1016/j.foodchem.2006.08.038
25. Yadav RNS, Agarwala M. Phytochemical analysis of some medicinal plants. J Phytol. 2011;3(12):10-14.
26. Brand-Williams W, Cuvelier M, Berset C. Use of free radical method to evaluate antioxidant activity. LWT-Food Sci Technol. 1995;28(1):25-30. https://doi.org/10.1016/S0023-6438(95)80008-5
27. Benzie IF, Strain J. Ferric reducing/ antioxidant power assay: Direct measure of total antioxidant activity of biological fluids and modified version for simultaneous measurement of total antioxidant power and ascorbic acid concentration. Meth Enzymol. 1999;299:15-27. https://doi.org/10.1016/s0076-6879(99)99005-5
28. Jorhem L. Determination of metals in foods by atomic absorption spectrometry after dry ashing: NMKL1 collaborative study. J AOAC Int. 2000;83(5):1204-11.
29. Fenech M, Amaya I, Valpuesta V, Botella MA. Vitamin C content in fruits: biosynthesis and regulation. Front Plant Sci [Internet]. 2019 [cited 2021 Apr 1];9:1-21. https://www.frontiersin.org/articles/10.3389/fpls.2018.02006/full.
30. Banoo A, Dolkar T, Ali M. Role of physical and chemical performance during storage of apple cultivar. J Pharmacogn Phytochem. 2018;7(2):1332-38. http://www.phytojournal.com/archives/2018/vol7issue2/PartS/7-2-26-148.pdf
31. Ercisli S, Orhan E. Chemical composition of white (*Morus alba*), red (*Morus rubra*) and black (*Morus nigra*) mulberry fruits. Food Chem. 2007;103(4):1380-84. https://doi.org/10.1016/j.foodchem.2006.10.054
32. Gungor N, Sengul M. Antioxidant activity, total phenolic content and selected physiochemical properties of white mulberry (*Morus alba* L.) fruits. Int J Food Prop. 2008;11:44-52. https://doi.org/10.1080/10942910701558652
33. Guofang X, Xiaoyan X, Xiaoli Z, Yongling L, Zhibing Z. Changes in phenolic profiles and antioxidant activity in rabbiteye blueberries during ripening. Int J Food Prop. 2019;22(1):320-29. https://doi.org/10.1080/10942912.2019.1580718
34. Anton D, Bender I, Kaart T, Roasto M, Heinonen M, Luik A, et al. Changes in polyphenols contents and antioxidant capacities of organically and conventionally cultivated tomato (*Solanum lycopersicum* L.) fruits during ripening. Int J Anal Chem [Internet]. 2017 [cited 2021 Feb 28]. https://www.hindawi.com/journals/ijac/2017/2367453/
35. Bashir HA, Abu-Goukh AA. Compositional changes during guava fruit ripening. Food Chem. 2003;80(4):557-63. https://doi.org/10.1016/S0308-8146(02)00345-X
36. Ibrahim KE, Abu-Goukh AA, Yusuf KS. Use of ethylene, acetylene and ethrel on banana fruit ripening. University of Khartoum Journal of Agricultural Sciences. 1994;2(1):73-92.
37. Abu-Goukh AA, Abu-Sarra AF. Compositional changes during mango fruit ripening. University of Khartoum Journal of Agricultural Sciences. 1993;1(1):33-51. https://doi.org/10.1111/j.1365-2621.1985.tb10555.x.
38. Arena E, Fallico B, Maccarone E. Evaluation of antioxidant capacity of blood orange juices as influenced by constituents, concentration process and storage. Food Chemistry. 2001;74:423-27. http://dx.doi.org/10.1016/S0308-8146(01)00125-X
39. Narayana SD, Wedamulla NE, Wijesinghe WA, Rajakaruna RA. Extraction of anthocyanin from Hinembilla (*Antidesma alexiteria*) fruit as a natural food colorant. Paper presented at: International Research Conference of Uva Wellassa University; International Research Conference of Uva Wellassa University; Sri Lanka; 2019 Feb 08.
40. Sánchez-Salcedo EM, Mena P, García-Viguera C, Martínez JJ, Hernández F. Phytochemical evaluation of white (*Morus alba* L.) and black (*Morus nigra* L.) mulberry fruits, a starting point for the assessment of their beneficial properties. J Funct Foods. 2015;12:399-408. https://doi.org/10.1016/j.jff.2014.12.010
41. Kubola J, Siriamornpun S, Meeso N. Phytochemicals, vitamin C and sugar content of Thai wild fruits. Food Chem. 2011;126(3):972-81. https://doi.org/10.1016/j.foodchem.2010.11.104
42. Rufino MSM, Alves RE, Brito ES, Pérez-Jiménez J, Saura-Calixto F, Mancini-Filho J. Bioactive compounds and antioxidant capacities of 18 non-traditional tropical. Food Chem. 2010;121(4):996-1002. https://doi.org/10.1016/j.foodchem.2010.01.037
43. Lim TK. Edible medicinal and non-medicinal plants: Fruits (Vol. I). New York, USA: Springer; 2012.
44. Bochi VC, Barcia MT, Rodrigues D, Speroni CS, Giusti MM, Godoy HT. Polyphenol extraction optimisation from Ceylon gooseberry (*Dovyalis hebecarpa*) pulp. Food Chem. 2014;164(1):347-54. https://doi.org/10.1016/j.foodchem.2014.05.031

45. Bochi VC, Barcia MT, Rodrigues D, Godoy HT. Biochemical characterization of *Dovyalis hebecarpa* fruits: A source of anthocyanins with high antioxidant capacity. J Food Sci. 2015;80(10):127-33. https://doi.org/10.1111/1750-3841.12978

46. Rotili MC, Villa F, Braga GC, França DL, Rosanelli S, Laureth JC, da Silva DF. Bioactive compounds, antioxidant and physic-chemical characteristics of the dovyalis fruit. Acta Sci Agron. 2018;40:1-8. https://doi.org/10.4025/actasciagron.v40i2.35465

47. Huang W, Cai Y, Corke H, Sun M. Survey of antioxidant capacity and nutritional quality of selected edible and medicinal fruit plants in Hong Kong. J Food Compost Anal. 2010;23(6):510-17. https://doi.org/10.1016/j.jfca.2009.12.006

48. Zimmermann MB, Hurrell RF. Nutritional iron deficiency. Lancet. 2007;370:511-20. https://doi.org/10.1016/s0140-6736(07)61235-5

49. Pituch KA, Stevens JP. Applied Multivariate Statistics for the Social Sciences. New York: Routledge; 2016.

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