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A survey on underutilized vegetables in Kandy District Sri Lanka and a study on nutritional properties of selected underutilized vegetables

K.M.R.V Kapilarathne , *R. Wimalasekara

Faculty of Applied Sciences, University of Sri Jayewardenepura, Sri Lanka
*rinukshi@sci.sjp.ac.lk

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Abstract - Sri Lanka is home to a diverse array of nutritionally rich vegetables, many of which are underutilized due to limited public awareness of their health benefits. This study aimed to assess the level of awareness regarding underutilized vegetables (UUVs) within the Ranawana West Grama Niladhari Division of the Harispattuwa Divisional Secretariat in the Kandy District Sri Lanka and to evaluate the nutritional composition of the selected UUVs. A structured questionnaire was administered to fifty households, focusing on three key areas: awareness, consumption frequency, and perceptions of the nutritional value of UUVs. Five UUVs *Bauhinia racemosa* ("Maila"), *Colocasia esculenta* ("Kalu ala kola"), *Acrostichum aureum* ("Karan koku"), *Canthium coromandelicum* ("Kara"), and *Olax zeylanica* ("Malla") were identified as infrequently consumed, with response rates of 2%, 4%, 4%, 6%, and 6% respectively. Standard analytical procedures were employed to quantify macronutrients and key micronutrients. Among the samples, *C. esculenta* exhibited the highest protein (8.11%) and vitamin C content (65.93 mg/100g), while *A. aureum* had the highest carbohydrate content (18.51%). *O. zeylanica* recorded the highest crude fiber level (68.75%), and *B. racemosa* showed the greatest calcium concentration (488.5 mg/100g). In terms of micronutrients, *C. esculenta* and *A. aureum* had the highest iron (295.6 mg/100g) and potassium (192.0 mg/100g) levels, respectively. These findings highlight the significant nutritional potential of UUVs. Enhancing public knowledge, improving market accessibility, and promoting home cultivation are recommended strategies to increase the integration of these vegetables into local diets.

Key words— Nutritional properties, Sri Lanka, Survey, Underutilized vegetables.

1 Introduction

According to the International Centre for Underutilized Crops (ICUC), underutilized crops are defined as species with under-exploited potential for contribution to food security, health, income generation and environmental services. These crops are also known as “indigenous” or “underexploited” crops [1] as they are cultivated mainly by the local communities or the rural population in most of the countries in the world. The change in the lifestyle pattern of the modern man has increased the demand for commercialized crop varieties which have ultimately led to an increase in cultivation of them while most of the traditional varieties remained underutilized. Hence the cultivation of underutilized crops has drastically decreased as they have failed to compete with these commercial crops which has identified as one of the critical reasons for these crops to become underutilized [2]. Apart from this, the lack of awareness on underutilized crops and their immense nutritional value by major communities; farmers, cultivators, policy makers, researchers as well as the public in a country, has become another limitation for these crops to be underexploited [3]. Even though underutilized crops are considered as abandoned crops with minimum cultivation and consumption, their importance addresses many aspects prioritizing; ecological, nutritional and economic importance. The ongoing research and existing evidence show the food production is challenging with the changing climatic conditions which will directly influence the growth, nutritional quality and yield of a crop [4]. Therefore, it is essential to have climate resilient crops which can adapt to the changing climatic conditions. In this context, underutilized crops offer a promise in fulfilling this gap as the wild and local varieties can overcome the climatic changes being tolerable and adaptable to various ecological conditions, than modern crop varieties [5]. Sustainable food production is one of the important aspects needed to avoid any food scarcities in future. However, still most of the global population rely on limited number of cash crops such as maize and wheat regardless of their nutritional properties [6]. To avoid this sole reliance on limited crops and to overcome food scarcity the focus must be dragged more towards these valuable and widely available underutilized crops. Since these underutilized crops are rich in essential nutritional components both macro and micronutrients and being precious crops for diversification in dietary pattern [7], it is far more important to assess the nutritional properties of them to convince the people about their nutritional value.

Sri Lanka is a developing country with lower-middle-income earning nation where approximately 21.8 million people living in a total area of 65, 610 km^2. Being a tropical country Sri Lanka is divided into three main climatic zones namely, wet, intermediate and dry zones, based on the spatial distribution of the annual rainfall. Sri Lanka, despite of its relatively small land mass has been identified as a country rich in biodiversity with a wide range of agro biodiversity including underutilized and neglected crop genetic resources [8], majority of plant crop species being nutritious, yet neglected in terms of cultivation and use. The underutilized crops, which are predominantly fruits and vegetables, are sources of vital micronutrients with many health benefits. Despite their diversity and importance in diet, there is a lack of information on their geographical distribution, nutritional and medicinal properties as well as their availability in the environment [9]. However, there is considerable number of documentation available on the underutilized fruits in Sri Lanka, but research attention seemed to be much less towards the “underutilized vegetables”. Nevertheless, some of the research studies have addressed various socio-economic aspects related to UUVs in Sri Lanka [10],[11] while their nutritional analysis is yet to be fulfilled. Hence the present study has carried out with the major objective of identifying some of the UUVs in Harispattuwa Divisional Secretariat (DS) of Sri Lanka and assessing their nutritional properties which will contribute enormously to uplift the sustainable food production in the country.

2 MATERIALS AND METHODOLOGY

2.1 Collection of data through a survey

Kandy District of Central province of Sri Lanka was randomly selected as the study area for this study. Discussions were held with the local agricultural officers, village development officers, "Samurdhi" officers and, "Grama Niladaries" in the selected area by briefing the objective of the study and advice were sought to collect in depth information about the availability of UUVs in the Harispattuwa DS. Primary data were collected by distributing a paper-based questionnaire with both close ended and open-ended questions, among fifty (n=50) randomly selected families in the Ranawana West Grama Niladari Division (RW-GND). The data was collected for a period of one month. The questionnaire comprised of three major sections: Information on the general background of the respondent, Specific details on awareness and consumption of UUVs according to the consumption frequencies and information on attitude of the respondents on nutritional quality of UUVs. Here persons with reading and writing disabilities were excluded in participating to the survey. Furthermore, a few group discussions were also carried out with the villagers to gather more information on UUVs. In the questionnaire in the section of specific details on awareness and consumption of UUVs, a list of (35) commonly cultivating UUVs were given for the respondents to mark according to the relevant heading of consumption frequencies. This UUVs list was prepared based on previous research publications on commonly cultivating UUVs and other various aspects of underutilized crops in Sri Lanka [9],[11]. Data collected through the survey was analyzed and, the first five UUVs with lowest number of responses (2%-6%), under the category "Rarely consumed" were selected for the nutritional properties analysis. The selected UUVs were initially identified using plant specimens and indigenous knowledge. The common and familiar species were identified at the field itself and further by referring to the relevant literature of underutilized crops of Sri Lanka. Further taxonomical identification of the selected plant species was done at the National Herbarium of Royal Botanical Gardens Peradeniya, referring to the Flora of Ceylon, volume VII [12].

2.2 Analysis of Nutritional Properties

Sample collection: The selected UUVs were freshly procured from field locations and were taken to the laboratory inside sealed polythene bags in an insulated ice box. Five species namely, *Bauhinia racemosa* ("Maila kola"), *Colocasia esculenta* ("Kalu Ala kola"), *Acrostichum aureum* ("Karan Koku"), *Canthium coromandelicum* ("Kara kola") and *Olax zeylanica* ("Malla kola) were used for the nutrient analysis according to the results obtained from the survey.

Sample preparation: The relevant edible parts of the UUVs were washed and cleaned using running potable water, followed by double glass distilled water to remove visible dirt and dried under breeze. The dried plant species were cut into small pieces and were oven dried at 45-55 °C to a consistent moisture level. Then the dried plant species were pulverized, ground and sieved to get a fine powder. The prepared sample powders were then packaged in five separate airtight sterile bottles, labeled and stored in a refrigerator (4°C) for further use [13].

Proximate Analysis: Proximate analysis was done for macronutrients; total protein, total carbohydrate and crude fiber. For micronutrients; total Vitamin C, minerals – Calcium (Ca^{2+}), Potassium (K^+) and Iron (Fe). The powdered samples were subsequently used for nutritional properties analysis. However, fresh samples within 24-48 hours of collecting were used for the determination of proteins and vitamins using relevant extraction techniques.

Quantification of total protein content- The total protein content of all five vegetable samples was quantified using the Bradford Assay method [14]. The standard curve was prepared with reference to the absorbance values obtained for Bovine Serum Albumin (BSA) concentration series. From each of the fresh five UUV samples, 1 g each was weighed and chopped well in a mortar and pestle with approximately 50 ml of freshly prepared phosphate buffer saline of pH 7.4. Then the solutions were centrifuged at 2500 rpm for 10 minutes and final supernatants were collected in labeled tubes. The supernatant obtained was mixed with the Bradford reagent. Absorbance was measured at 595 nm against the blank (Phosphate buffer) using a double beam UV spectrophotometer (ChromeTech, CT-8200). The test was triplicated for all five vegetable samples, and the unknown protein content was determined referring to the BSA standard curve.

Quantification of total carbohydrate content- The total carbohydrate content of all five UUVs samples was quantified using Phenol-Sulfuric acid method, following the standard procedure described by [15]. From each of the five UUV samples, 50 mg powder was used for extractions. Each sample was extracted three times with 5 ml of 80% ethanol by boiling the sample in stoppered boiling tubes in a water bath at 95 ^{0}C for 15 minutes. After the final extraction the samples were centrifuged at 2500 rpm for about 5 minutes, and the supernatant was obtained. One ml of each of the supernatant was mixed with 1 ml of freshly prepared 5% Phenol and 5 ml of Conc: H_2SO_4 (98%). The solutions were placed in a water bath at 100 °C for 5-10 minutes and vortexed for 30 seconds. Blank was set using the solvent; 80% ethanol. The absorbance was measured at 490 nm using a double beam UV spectrophotometer (ChromeTech, CT-8200). The test was triplicated for all the vegetable species, and the carbohydrate content was determined referring to the glucose solution standard curve.

Quantification of total crude fibers- The total crude fibers of all five UUVs samples were quantified following AOAC 978.10 - Wende method [16]; [17] Two grams of each of five UUV samples were extracted in 200 ml of 1.25% H_2SO_4. The solutions were boiled for 30 minutes in a hot plate with periodic stirring. After 30 minutes the solutions were filtered, and the residues were washed well with near boiling water until no more acid remained. The washed residues were taken and again washed with 200 ml of 1.25% NaOH. These solutions were again boiled for 30 minutes with periodic stirring. After 30 minutes the solutions were filtered, and the residues were washed well using near boiling water until no baser remained. The remaining were carefully taken into a porcelain crucible separately and they were kept on a hot plate to remove any excess water remaining. After that the crucibles were kept in hot air oven at 105 °C for 2 hours. The weight of the crucibles with the fiber (W1) was measured after 2 hours. The crucibles were then placed in the muffle furnace at 550 °C for 4 hours. After 4 hours the crucible was taken out from the muffle furnace and kept in a desiccator for about 10 minutes. The final weight of the crucibles with ash (W2) was measured. The total crude fiber content was measured for all five UUV samples using the Eq.1 and the test was triplicated for all five vegetable samples.

$$\text{Total Crude Fiber Content (\%)} = \frac{W_1 - W_2}{W_S} \times 100\% \qquad \text{(Eq.1)}$$

Where: W_1 = Weight of the crucible with fiber (g), W_2 = Weight of the crucible with ash (g), W_S = Weight of the original sample (g)

This calculation measured the weight difference between the residue after digestion and the remaining ash after incineration. This difference represents the crude fiber, expressed as a percentage of the original sample weight.

Quantification of total vitamin C- The total vitamin C content was quantified using the UV spectrophotometric method following the procedure described by [18]; [19]. From each of the five UUV samples, 10 g of fresh samples were weighed. They were blended with 50 ml of 5% TAA and extracted in a solution. The solutions were transferred into 250 ml conical flasks separately, and another 50 ml of 5% Tri-chloro Acetic Acid (TAA) was added to each. The solutions were filtered using Whatman filter papers (No: 1), and filtrates were collected for Vitamin C analysis. (The filtrates were stored at (-10 °C) until use). From each of the filtrates, 8 ml was transferred into boiling tubes, into which a few drops (0.5 ml) of 3% (v/v) Bromine water were added and mixed well. To the same solutions, another few drops (0.25ml) of 10% (w/v) Thiourea solution was added along with 1 ml of 2,4-DNP solution. All the samples were kept in a thermostatic water bath at 37 °C for 3 hours to complete the reaction. After 3 hours, the solutions were cooled in an ice bath for 30 minutes. After cooling, 5 ml of 85% (v/v) H_2SO_4 was added to each of the samples with constant stirring. Finally, the absorbance was measured at 521 nm using double-beam UV spectrophotometer (ChromeTech, CT-8200). The test was triplicated for all five UUV samples. The total vitamin C content of each sample was expressed as mg per 100 g of fresh weight of the UV sample, using the standard curve prepared with L-AA standard solution.

Quantification of Minerals- The mineral ions; Calcium (Ca^{2+}), Potassium (K^{+}) and Iron ($Fe^{2+}/^{3+}$) of all five UUV samples were quantified using the Atomic Absorption Spectrophotometric (Thermo Scientific iCE 3500 AAS) method according to the procedure in [20]. Quantification was accomplished by comparison with standard curves. From each of the dried powdered UUV samples, 1g was measured and placed in a porcelain crucible. The samples were kept in a hot air oven at 105 °C for 24 hours for the samples to be charred. The charred samples were taken and placed in the muffle furnace at 550 °C overnight to obtain the ash. The ash samples were then taken and cooled in a desiccator. Each of the ash samples was dissolved in 5 ml of 20% HCl separately while warming the solutions to fully dissolve the ash residues. The solutions were filtered twice through the nylon micro-filters of 0.2 µm pore size. The filtrates were separately obtained in well-cleaned 50 ml volumetric flasks, and each was diluted (×10) up to 50 ml by adding distilled water. Finally, the absorbance was measured using AAS against a standard. The test was triplicated for each of the UUV samples.

2.3 Statistical Analysis

The data collected through the survey and the nutrient analysis were analyzed using Microsoft Excel 2010 (MS EXCEL 2010) and Minitab® version 16 software packages. MS EXCEL software package was used to analyze the data collected from survey. All measurements in nutritional analysis were performed in triplicate and recorded as mean ± standard deviation 29 (SD). One way Analysis of Variance (ANOVA) and Tukey's test were used for descriptive statistics and to determine the significant differences between the nutritional properties of five underutilized vegetables at p-values ≤0.05.

3 RESULTS AND DISCUSSION

The results obtained from the analysis of the data collected via the survey are tabulated in Table 1.

Table 1. Number of UUV species listed by people in RW-GND

Respondents %	No: of UUVs listed
0-10	2
10-20	5
20-30	5
30-40	8
40-50	12
>50	7

According to the above results an average of 40–50% of respondents demonstrated awareness of the majority (12) of the commonly cultivated underutilized vegetables (UUVs). In contrast, a significantly lower proportion (0–10%) of participants reported awareness of a few (2) UUVs. Additionally, over 50% of the surveyed population were familiar with an intermediate number of UUVs (approximately 7 varieties). These results suggest that the population in the selected study area possesses a moderate level of knowledge and awareness regarding most of the commonly cultivated UUVs in Sri Lanka.

The consumption frequency of underutilized vegetables (UUVs) among residents of the RW-GND was assessed using four defined consumption categories. Emphasis was placed on the "rarely consumed" category, as the vegetables selected for nutritional analysis were drawn from this group. Despite their substantial but often overlooked nutritional value [21], many underutilized crops remain infrequently consumed due to limited public awareness [8]. Therefore, identifying the specific UUVs that, although rarely consumed, are still occasionally included in local diets is essential for promoting their nutritional benefits and encouraging greater dietary integration.

Table 2. Consumption frequency of rarely consuming UUVs by people in RW-GND

Plant species	Frequency	Percentage %
• *Benincasa hispida (*"Alupuhul")	18	36
• *Cucumis melo* ("Kekiri")	21	42
• *Solanum trovum* ("Thibbatu")	16	32
• *Momordica charantia* ("Karawila")	16	32
• *Tetrameles nudiflora* ("Diyalabu")	10	20
• *Vincetoxicum bracteatum* ("Kiri anguna")	22	44
• *Olax zeylanica L* ("Malla kola")	3	6
• *Dovyalis hebecarpa* ("Madu")	6	12
• *Causonis trifolia* ("Ikiriya")	7	14
• *Careya arborea* ("Kahata")	9	18
• *Bacopa monnieri* ("Lunuwila")	8	16
• *Monochoria vaginalis* ("Diya habarala")	9	18
• *Vigna unguiculata* ("Kollu")	14	28
• *Mucuna pruriens* ("Wanduru mae")	11	22
• *Vigna unguiculata* ("lea maa")	6	12
• *Colocasia esculenta L* ("Kalu Ala kola")	2	4
• *Acrostichum aureum L* ("Karan Koku"),	2	4
• *Canna indica L* ("Buthsarana")	15	30
• *Basella alba L* ("Gas niwithiya")	14	28
• *Artocarpus nobilis* ("Wal del")	12	24
• *Bauhinia racemosa* ("Maila")	1	2
• *Canthium coromandelicum* ("Kara kola")	3	6
• *Plectranthus rotundifolius* ("Innala")	15	30
• *Coccinia grandis* ("Kowakka")	15	30
• *Lasia spinosa* ("Kohila")	15	30
• *Amorphophallus paeoniifolius* ("Akkapana")	6	12
• *Caesalpinia bonduc* ("Katu eramudu")	4	8
• *Alternanthera sessilis* ("Genda kola")	7	14
• *Solanum melongena* ("Japan batu")	14	28
• *Talinum triangulare* ("Miyena kola")	4	8
• *Momordica dioica* ("Thumba karawila")	19	38
• *Vigna sesquipedalis* ("Dambala")	14	28
• *Moringa oleifera* ("Murunga")	13	26
• *Maranta arundinacea* ("Hulankeeriya")	10	20

The local name of the plant species is given within the brackets

The above Table 2. shows the respondent percentage (%) consuming different UUVs rarely in their meal and Table 3. summarizes the number of UUVs rarely consumed under each range of respondent %. The graphical representation relevant to Table 3. is depicted in Fig. 1. The number of respondents is given as the frequency, and percentages are given as a value of total number of respondents (n=50).

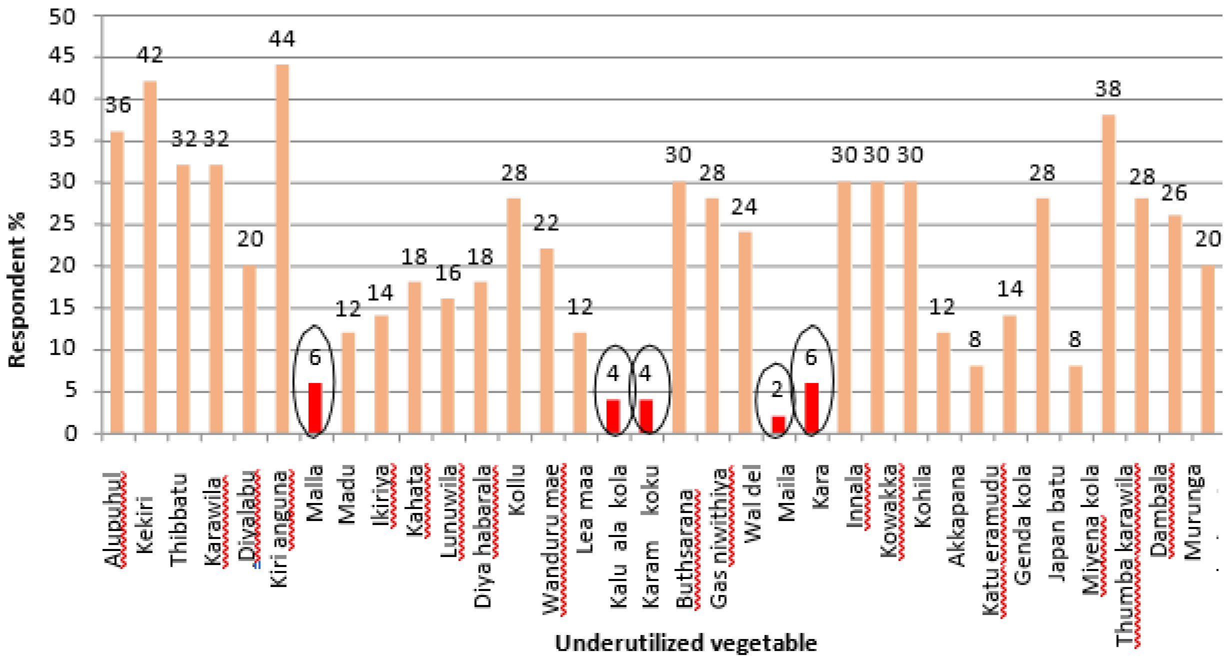


Fig 1. Consumption frequency of rarely consuming UUVs by people in RW-GND.
The five UUVs; *Bauhinia racemosa* ("Maila kola"), *Colocasia esculenta L* ("Kalu Ala kola") ,*Acrostichum aureum L* ("Karan Koku"), *Canthium coromandelicum* ("Kara kola"), *Olax zeylanica L* "Malla kola" with the lowest respondent percentages, which have been used for nutritional properties analysis, are highlighted in red and are circled with their data labels.

Table 3. Number of UUVs rarely consumed by people

Respondent %	**No: of UUVs rarely consume**
0-10	7
10-20	10
20-30	11
30-40	4
40-50	2
>50	0

As presented in Table 2. and Fig. 1., the highest proportion of respondents (44%) reported consuming *Vincetoxicum bracteatum* ("Kiri anguna") at a frequency of 1–2 times per week, whereas *Bauhinia racemosa* ("Maila") was consumed at the same frequency by only 2% of the population. The vegetables *Bauhinia* *racemosa* (“Maila”) (2%), *Colocasia esculenta* (“Kalu ala kola”) (4%), *Acrostichum aureum* (“Karan koku”) (4%), *Canthium coromandelicum* (“Kara”) (6%), and *Olax zeylanica* (“Malla”) (6%) recorded the lowest frequencies of weekly consumption, indicating that these are the least UUVs in local diets, even among those considered "rarely consumed." Consequently, these five UUVs were selected for laboratory-based nutritional analysis, based on the criterion of minimal consumption within the study population. Furthermore, the data in Table 3. indicate that only two UUVs are consumed by a moderate proportion (40–50%) of respondents, while a greater number of UUVs (10 or 11 types) are consumed by a markedly smaller percentage (10–30%) of the population at least 1–2 times per week. Notably, none of the UUVs are consumed by more than 50% of respondents, underscoring their overall limited dietary inclusion and supporting their classification as underutilized within the study area.

Attitudes reflect the behavioral intention of people in general [22]. Understanding the attitudes of people in RW-GND towards UUVs is important to understand the response and behavior of them on UUVs, and the reasons for their behavior or the practices. Table 4. summarizes the results obtained on the attitude of the people in the questionnaire.

Table 4. Attitude of people in RW-GND on nutritional quality of UUVs (n=50)

Attitudinal statement	Respondents	
	Frequency	**Percentage (%)**
Highly nutritious	27	54
Moderately nutritious	14	28
Not nutritious	-	0
No idea on nutritional quality	9	18

The findings indicate that a majority of respondents (54%) hold a positive attitude toward the nutritional value of underutilized vegetables (UUVs), recognizing them as highly nutritious. This highlights the importance of further disseminating detailed information on the nutrient composition of UUVs to the public. Accordingly, one of the specific objectives of the present study was to conduct a nutritional analysis of selected UUVs. Notably, none of the participants (0%) expressed the belief that UUVs lack nutritional value, suggesting that there is at least a minimal level of perceived nutritional benefit among the entire study population. However, a significant proportion (18%) reported having no clear understanding of the nutritional qualities of UUVs. This lack of awareness may contribute to their infrequent consumption, reinforcing their classification as underutilized crops [8]. The presence of such a knowledge gap among a notable segment of the population warrants attention. A lack of understanding regarding the nutritional properties of food items can result in hesitancy or disinterest in incorporating them into regular diets [23]. This further justifies the need for comprehensive nutritional profiling of UUVs as a strategy to support their promotion and greater inclusion in local dietary practices.
Fig 2. and Table 5. respectively shows five vegetables which were selected for nutritional properties analysis and their edible parts, which is generally consumed by people as a vegetable.

Table 5. List of selected UUVs from the survey and their edible parts

Scientific name	Edible portion
Bauhinia racemosa (L.) ("Maila")	leaves
Colocasia esculenta (L.) ("Kalu ala kola")	leaves and tender stem
Acrostichum aureum (L.). ("Karan koku")	tender leaves
Canthium coromandelicum (Burm.f.) ("Kara")	leaves
Olax zeylanica (L.) ("Malla")	leaves

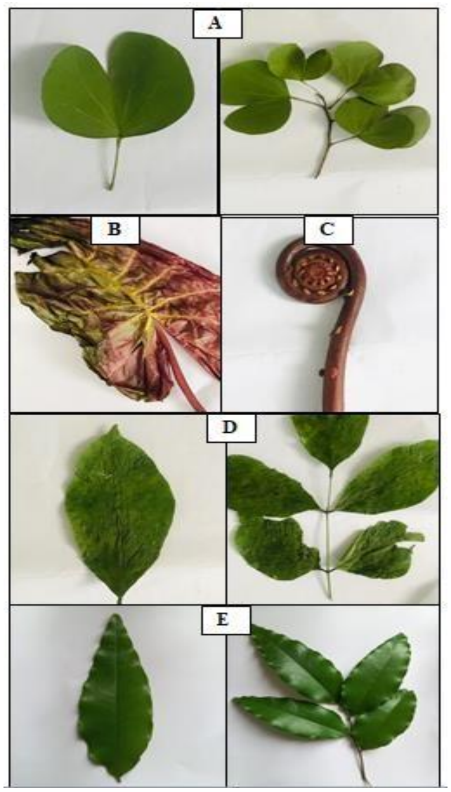
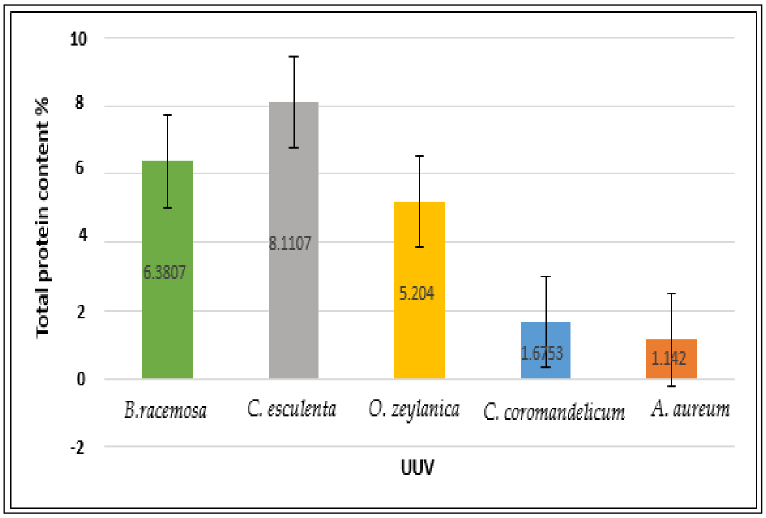


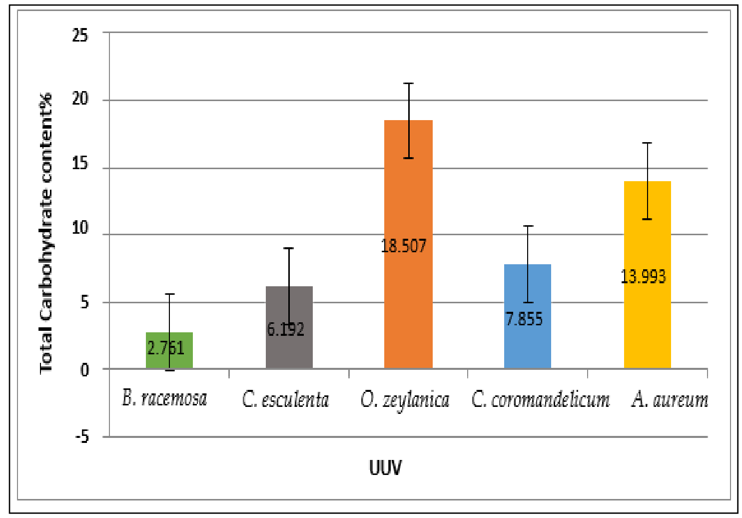
Fig 2. Underutilized vegetables selected for the nutritional properties analysis

A: *Bauhinia racemosa* ("Maila kola") **B:** *Colocasia esculenta* **(**"Kalu Ala kola") **C:** *Acrostichum aureum* **(**"Karan Koku") **D:** *Canthium coromandelicum* **(**"Kara kola") **E:** *Olax zeylanica* **(**"Malla kola")

Underutilized species provide valuable macronutrients such as carbohydrates, proteins, fiber and fats, micronutrients such as vitamins and minerals, as well as bioactive non-nutrients that contribute to dietary health. The results of the proximate analysis (proteins, carbohydrate, crude fiber) and micronutrients (minerals: Ca, Fe, K), vitamin C of the five selected UUVs are discussed in this section.



A)



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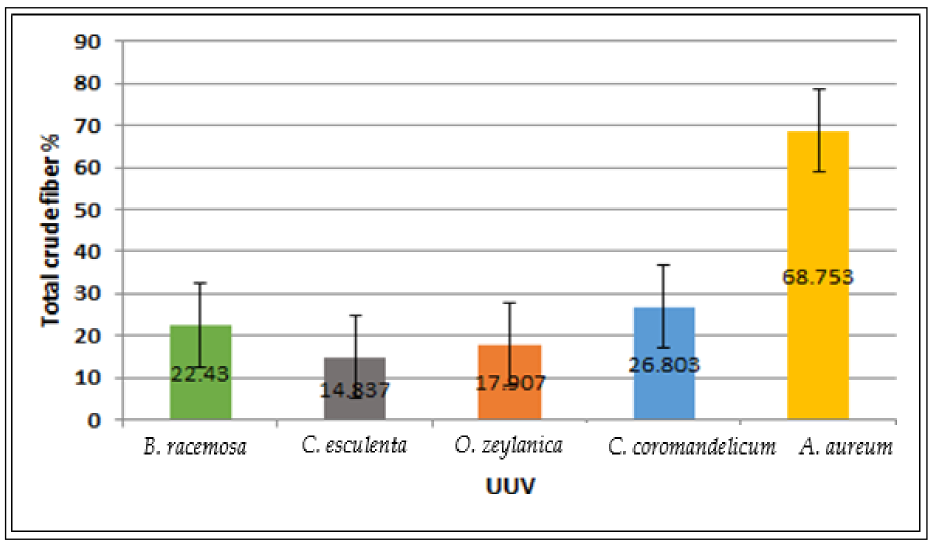

C)

Fig. 3 Comparison of total carbohydrate, total protein, and total crude fiber content in the samples analyzed. A) Total carbohydrate content, B) Total protein content, C) Total crude fiber content. (Bars represent mean values of three independent experiments ± standard deviation. Statistically significant differences between samples within each nutrient category ($p < 0.05$) were determined using one-way ANOVA followed by Tukey's post hoc test.)

Protein was determined as the first proximate in all five UUVs, and the results are shown in Fig.3(A. The amount of protein is given as mean ± per 100 g of fresh weight. According to Fig 3. (A), *Colocasia esculenta* ("Kalu ala kola") exhibited the highest protein content among the UUVs with a value of 8.11%, while Karan koku recorded the lowest protein content at 1.14%. Statistical analysis further revealed no significant difference in the mean protein contents between *Canthium coromandelicum* ("Kara") (1.68%) and *Acrostichum aureum (*"Karan Koku") (1.14%), suggesting that both vegetables contain comparable protein levels. Protein is a vital macronutrient required across various stages of the human life cycle for growth, tissue repair, and physiological development [24]. Dietary proteins contribute to the synthesis and maintenance of essential biomolecules critical to the proper functioning of the human body [25]. Numerous studies have reported that leafy vegetables serve as valuable sources of plant-based proteins, offering a cost-effective and locally accessible means of meeting protein needs, particularly in rural populations [26]. Notably, the protein content in three of the UUVs studied, *Bauhinia racemosa* ("Maila kola"), *Colocasia esculenta* ("Kalu Ala kola") and *Olax zeylanica* ("Malla kola") was higher than that found in several commonly consumed leafy vegetables in Sri Lanka, including *Alternanthera sessilis* ("Mukunuwenna"), *Centella asiatica* ("Gotukola"), and *Trianthema portulacastrum* ("Sarana") [27]. Furthermore, when compared to commonly consumed vegetables such as pumpkin (1.24%), leeks (1.57%), green beans (1.83%), and beetroot (1.61%), these UUVs demonstrate a relatively higher protein content, reinforcing their potential as nutrient-dense dietary options [28]. According to the recommended daily allowance (RDA) for protein, a 100 g portion of most of the selected UUVs could contribute approximately 4% to the daily protein requirement of an average adult [29]. Therefore, the incorporation of these UUVs into regular diets could significantly enhance daily protein intake, especially in resource-limited settings where access to animal-based protein sources is constrained.

The amount of Carbohydrate is given as mean ± per 100 g of dry weight in Fig.3 (B. The total carbohydrate content among the five selected underutilized vegetables (UUVs) ranged from 2.76% to 18.51%. *Acrostichum aureum* ("Karan Koku") exhibited the highest carbohydrate concentration (18.51%), while *Bauhinia racemosa* ("Maila kola") contained the lowest (2.76%). Carbohydrates serve as the primary source of energy for the human body and are involved in a range of essential physiological processes, including cellular communication, inflammation, immune responses, and the progression of certain diseases [30]. According to the Institute of Medicine (IOM), RDA for carbohydrates in a healthy adult is 130 grams per day [29]. Based on the present findings, a 100 g serving of the selected UUVs contributes approximately 2–15% (ranging from 2.0 g to 19.0 g per 100 g) of the daily carbohydrate requirement. Although this contribution is modest in comparison to other macronutrients found in UUVs, it is noteworthy that *Acrostichum aureum* ("Karan Koku") (18.51%) and *Malla* (13.99%) possess higher carbohydrate levels than several widely consumed leafy vegetables in Sri Lanka, such as *Centella asiatica* ("Gotukola") at 7.03%, *Sesbania grandiflora* ("Katuru Murunga") at 9.81%, and *Alternanthera sessilis* ("Mukunuwenna") at 10.76% [31].These findings are consistent with earlier studies [32, 33] that reported higher carbohydrate contents in certain UUVs compared to commonly consumed leafy vegetables. Thus, UUVs can be considered as valuable dietary sources of carbohydrates and may serve as effective supplements in improving carbohydrate intake, particularly in populations with limited access to diverse food sources.

Crude fiber of the five UUV was determined as the third proximate, and the results obtained are given in Fig.3 (C. The amount of crude fiber is given as mean ± per 100 g of dry weight. The results indicate that the crude fiber content of the five selected underutilized vegetables (UUVs) ranged from 14.84% to 68.75%. The highest crude fiber concentration was recorded in *Olax zeylanica* ("Malla kola") leaves (68.75%), while the lowest was

observed in *Acrostichum aureum (*"Karan Koku") *(*14.84%). Notably, the crude fiber content in all five UUVs was relatively higher than their respective protein and carbohydrate levels, highlighting the prominence of fiber as a major nutritional component in these vegetables. The minimum fiber content observed in the present study (14.84%) is substantially greater than previously reported values for *Colocasia esculenta* ("Kalu Ala kola″), which ranged between 0.3% and 4.8% [34,35]. This discrepancy may be attributed to differences in experimental methodologies, environmental factors, plant maturity, and geographic origin. Such variations are commonly observed in nutritional profiling of plant-based foods. Crude fiber plays a critical role in human nutrition due to its various functional properties. These include enhancing gastrointestinal motility, reducing intestinal transit time, lowering total and low-density lipoprotein (LDL) cholesterol levels, preventing constipation, and improving food stability by modifying texture, structure, and water-holding capacity [36]. Given these benefits, dietary fiber is considered an essential component of a balanced diet. When compared to commonly consumed vegetables such as pumpkin (0.79%), carrot (2.87%), and drumstick (*Moringa oleifera*) (3.30%) [28], all five UUVs examined in this study demonstrated significantly higher fiber content. Therefore, incorporating these UUVs into the regular diet can provide a substantially higher intake of dietary fiber, making them valuable alternatives to conventional vegetables in promoting digestive health and overall well-being.
The total Vitamin C content of each of the five UUV is given in Fig.4. The amount of vitamin C is given as mean ± per 100 g of fresh weight.

According to the above results *Colocasia esculenta* ("Kalu Ala kola") contains the highest vitamin C content among the selected UUVs, with a value of 65.93 mg/100 g, while *Canthium coromandelicum* ("Kara kola") recorded the lowest content at 41.5 mg/100 g. Overall, the vitamin C concentrations among the five UUVs ranged from 40 mg/100 g to 70 mg/100 g, with no statistically significant variation observed between them. These values indicate that the selected UUVs are relatively rich sources of vitamin C. Vegetables are widely recognized as protective foods in human nutrition due to their high concentrations of essential vitamins and minerals, which contribute to a range of health benefits [37]. Among these micronutrients, vitamin C holds a vital role as it supports numerous metabolic functions, including tissue growth and repair, immune system regulation, and the neutralization of free radicals through its antioxidant properties [38]. Micronutrient deficiencies remain a public health concern in many parts of the world, making the identification of alternative and locally available sources of vitamins critically important. Underutilized vegetables have been highlighted as rich sources of various micronutrients, particularly vitamins. For instance, a study by [39] reported that UUVs such as *Momordica foetida* ("Thumba Karawila"), *Vigna vexillata* ("Wal Lee Mae"), *Launea cornuta* (wild lettuce), and *Basella alba* ("Niwitiyā") contain substantial vitamin C content, ranging between 46.0 and 100.0 mg/100 g. These findings are in alignment with the current study, further reinforcing the nutritional potential of UUVs. According to the Food, Nutrition, and Dietetics Guidelines (2005), the RDA for vitamin C in a healthy adult is 90 mg per day. Therefore, the consumption of 100 g of any of the selected UUVs could contribute more than 50% of the daily vitamin C requirement, emphasizing their value as effective dietary sources of this essential micronutrient.

The microelement content (Ca, Fe and K) of each of the five UUV is given in Table 6. The amounts are given as mean ± per 100 g of dry weight.

Table 6. Microelement content of five UUVs

UUV	Total Ca content (mg/100g)	Total Fe content (mg/100g)	Total K content (mg/100g)
Bauhinia racemosa ("Maila")	488.5 ±5.89[a]	56.1 ±0.0103[a]	74.2 ±0.06[a]
Colocasia esculenta ("Kalu ala kola")	439.9 ±2.50[b]	295.6 ±0.0005[b]	124.4 ±0.06[b]
Acrostichum aureum ("Karan koku")	6.9 ±0.16[c]	46.8 ±0.0003[c]	192.0 ±0.04[c]
Canthium coromandelicum ("Kara"),	86.3 ±1.53[d]	52.4 ±0.0025[d]	86.0 ±0.06[d]
Olax zeylanica ("Malla")	23.2 ±0.18[e]	21.8 ±0.0017[e]	15.5 ±0.01[e]

The mineral analysis of the five selected UUVs, *Bauhinia racemosa* ("Maila"), *Colocasia esculenta* ("Kalu ala kola"), *Acrostichum aureum* ("Karan koku"), *Canthium coromandelicum* ("Kara"), and *Olax zeylanica* ("Malla") reveals that these species are valuable sources of micronutrients, particularly calcium (Ca), iron (Fe), and potassium (K). The calcium content varied substantially among the species, ranging from 6.9 mg/100 g to 488.5 mg/100 g.

Bauhinia racemosa ("Maila kola") demonstrated the highest calcium content (488.5 mg/100 g), whereas *Acrostichum aureum* ("Karan Koku") had the lowest (6.9 mg/100 g). Calcium is a critical nutrient in the human diet, essential for the development and maintenance of bones and teeth, and is also involved in blood clotting, muscle contraction, neural function, and various enzymatic processes [40]. The high calcium levels in these UUVs suggest their potential to significantly enhance dietary calcium intake, particularly in populations with limited access to dairy or fortified foods. Iron levels among the UUVs ranged from 21.8 mg/100 g to 295.6 mg/100 g. The highest concentration was observed in *Colocasia esculenta* ("Kalu Ala kola") (295.6 mg/100 g), while the lowest was recorded in *Olax zeylanica* ("Malla kola") (21.8 mg/100 g). Iron is a fundamental component of hemoglobin and myoglobin, and its deficiency is a leading cause of anemia globally [39]. The RDA for iron in healthy adults is 16–18 mg/day [FND, 2005], and the results indicate that a 100 g serving of these UUVs can supply well over 50% of the daily requirement, particularly from *Colocasia esculenta* ("Kalu Ala kola") . This underscores the role of UUVs in combating iron deficiency and enhancing nutritional security [41]. Potassium content in the selected UUVs ranged from 15.5 mg/100 g to 192.0 mg/100 g. *Karan koku* had the highest level (192.0 mg/100 g), while *Olax zeylanica* ("Malla kola") had the lowest (15.5 mg/100 g). Potassium is essential for maintaining electrolyte balance, nerve function, and regulating blood pressure. Adequate potassium intake is linked to reduced risk of hypertension [42]. However, modern dietary shifts away from fruit and vegetable consumption have led to reduced potassium intake globally [43]. Given their relatively high potassium content, UUVs offer an accessible and affordable dietary source of this crucial mineral. Although *Olax zeylanica* ("Malla kola") exhibited the lowest Fe and K levels among the five vegetables, its calcium content was notably high. Importantly, the mineral content of these UUVs was found to exceed that of several commonly consumed vegetables. This observation aligns with previous studies which suggest that wild and underutilized plants frequently possess superior micronutrient profiles compared to cultivated or exotic varieties [44, 45]. The significantly high levels of calcium, iron, and potassium found in these UUVs affirm their potential as key contributors to dietary micronutrient intake. Their inclusion in regular diets could aid in mitigating micronutrient deficiencies, improving immune function, and promoting general health and food security [39]. Nutrient composition in plant foods is subject to variation due to several factors, including geographic location, agro-climatic conditions, plant genotype, maturity stage, and post-harvest handling. The discrepancies observed in the present study, particularly in mineral content, may be attributed to environmental variables such as soil composition, sunlight exposure, temperature, humidity, and growth stages, all of which influence plant metabolism and nutrient biosynthesis [46]. Additionally, genetic variability among species, cultivars, and ecotypes can lead to significant differences in nutritional profiles [47]. Therefore, while this study establishes the nutritional value of the selected UUVs, slight variations in nutrient content should be expected among different varieties or growing conditions

4 Conclusion

The aim of the research study was to conduct a survey on UUVs in a selected study area of Sri Lanka to identify the knowledge of people about underutilized vegetables and to determine nutritional properties of some selected UUVs. The survey conducted, in RW-GND of Harispattuwa DS of Kandy District, concludes that the knowledge and awareness of people in the selected area about UUVs is low, as only 40%-50% of the total respondents are aware of the majority of the UUVs. It can be assumed that this has directly affected their consumption frequencies, as there are no UUVs consumed by more than 50% of the population. Out of the rarely consumed vegetables identified by the survey, the highest consumption percentage was recorded for *Wattakaka volubilis* (“Kiri anguna kola”) whereas lowest was recorded for *Bauhinia racemosa* (“maila kola”). Although the consumption frequencies are at a comparatively lower-level majority of respondents (57%) have a better understanding about the nutritional quality of UUVs, but discussions with them showed that they indispensably require further awareness and elaborations about their nutritional value. Lack of awareness among people (40%) and rare availability of UUVs in the market (62%) were the major reasons identified for the lower consumption of UUVs by the people. Although based on the present study, it is not possible to generalize the results to the whole population of Sri Lanka, it can be presumed that most of the people in the entire country do not have adequate knowledge about these neglected vegetables but can still be consumed and possess a greater nutritional value. Hence, to reassure the nutritional value of UUVs and to disseminate their nutritional importance, the nutritional property analysis was done for; *Bauhinia racemosa* (“Maila”), *Colocasia esculenta* (“Kalu ala kola”), *Acrostichum aureum* (“Karan koku”), *Canthium coromandelicum* (“Kara kola”), *Olax zeylanica* (“Malla”), which showed minimum consumption frequencies 2%,4%,4%,6% and 6% respectively. Regarding the nutritional property analysis, it concludes that the above selected UUVs are potential source of both macro-nutrients and micronutrients. Protein, carbohydrate and crude fiber contents of UUVs were relatively high compared to the common vegetables like pumpkin, leeks, carrot, etc. UUVs were significantly rich in vitamin C and mineral (Ca,Fe,K) contents compared to some common leafy vegetables like *Centella asiatica* (“gotukola”), *Alternanthera sessilis* (“mukunuwenna”), *Sesbania grandiflora* (“kathurumurunga”), etc. In the nutritional property analysis, *Colocasia esculenta*

(“Kalu Ala kola”) showed the highest amounts in three of the nutrients; proteins (8.1%), Vitamin C (65.9%) and iron contents (295.6 mg/100g), which can assume to be nutritionally rich UUV out of five candidates selected for the analysis. However the literature regarding the nutritional evaluation of UUVs in Sri Lanka are hardly ever found, which further concludes that the scientific attention should essentially be paved towards aspects related to UUVs and their nutritional importance, so that the public awareness can also be enhanced. As revealed by this study, it is understandable that knowledge on UUVs and awareness on their nutrient values are of paramount importance and numerous future perspectives are required to familiarize the local people with them. In that regard, people can be encouraged to cultivate UUVs in suitable areas and promote their consumption, expanding the limited list of green leafy vegetables they have already consumed. Conducting well-structured awareness programmes, implementation of projects, and increasing the availability of UUVs in the market can be proposed as some future work to accomplish. As the next steps it can be recommended to promote the consumption of UUVs because of their nutritional excellence and to find out different preparation and cooking techniques of UUVs to ensure safety in their consumption and nutritional composition. Also, it is highly suggested to develop and acquire seeds, breeding techniques and cultivation method of UUVs for domestication while ensuring their wider adoption on a sustainable basis.

5 References

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