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Potential of Underutilized Wild Edible Plants as the Food for the Future – A Review

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Abstract Today, it has been a big challenge to provide a safe, healthy and nutritious source of food for people, especially for poor income groups and undernourished populations of the developing world. Finding cheap and alternative sources of healthy and nutritious food has become a critical issue due to the food scarcity, high cost and unreliable supply of healthy food in developing and undeveloped countries. Tapping in to the world of Underutilized Wild Edible Plants (UWEP) will allow us to provide a substantial solution for food insecurity. UWEP have been identified as a reliable and long term solution due to the availability of micronutrients, bioactive compounds and their pharmacological importance. UWEP based diet should be expanded around the world, after conducting researches to fill the missing information such as micronutrient bioaccessibility, anti-nutrients, elimination of anti-nutrients and novel trends. The purpose of this paper is to explain the potentials of UWEP to cope up with malnutrition and food insecurity, which are burning issues that needs immediate attention.

Keywords: *food scarcity, food insecurity, malnutrition, micronutrients*

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1. Introduction

Though, 40-100, 000 plant species have been frequently used over the years as food, fiber, shelter and for commercial, cultural and medicinal purposes, only a small number of plants are widely used as food sources world-wide [1]. The remaining plant diversity is considered as underutilized, while global food security and economic growth of rural population totally rely on those limited number of plant species.

Underutilized Wild Edible Plants (UWEP) are identified as minor, neglected, local, orphan, promising species that have been used for centuries for their food, fiber, fodder, oil or medicinal purposes. However, the importance and usage of these UWEP have drastically reduced due to the low supply, poor shelf life, unrecognized nutritional values, poor consumer awareness and reputational problems (famine food or "poor people's food"). Further, modernization of agricultural practices has also resulted in severe genetic erosion of their gene pools resulting them to be 'neglected' or 'lost' crops [2].

In terms of food security, many of the developing countries have been facing the problem of food scarcity due to negative influences of increasing human population, rapid urbanization, environmental degradation and climatic changes [3]. Therefore, it has become a necessity to find out the possibility of use of new plant resources having potential for food, medicine, fodder, energy and other commercial uses with the objective of decreasing the adverse effect of hunger and starvation. Some underutilized crops with good nutritional and medicinal potential and low input requirements have been recognized as a promising solution for this problem [4]. Among Asian countries, Sri Lanka has been identified as one of the countries with very high degree of biodiversity. In Sri Lanka, around 240 wild relative species have been identified as underutilized root and tuber crops, leafy vegetables, fruit crops which are highly tolerant to adverse environmental conditions [5]. For example, 55 underutilized root and tuber crop species have been identified as harmless food sources in Sri Lanka [6]. However, only a limited number of researches have been carried out to investigate nutritional value of UWEP available in Sri Lanka [7].

Micronutrient deficiency is an identified health issue and approximately over two billion people are directly affected world-wide. Lack of essential vitamins and minerals, which are demanded in small quantities by the body for proper growth and development is identified as the micro nutrient deficiency and referred as 'hidden hunger' [8]. Among different micro nutrient deficiency disorders, iron (Fe) deficiency is a widespread nutritional disorder in developing countries, where a large number of women and children are affected annually. Moreover, it is the only nutrient deficiency, significantly prevalent in developed countries as well [9]. According to Kennedy *et*

al., [8], the majority of the people in developing countries do not receive enough energy and micronutrients from their diet to fulfill their nutritional requirements. Iron, vitamin A, iodine and energy deficiencies have been recognized as major nutritional problems also in Sri Lanka. However, with reference to the available data on nutritional status at the community level in Sri Lanka, it indicates that the micro nutrient deficiencies or the hidden hunger may be a more serious problem that must be prioritized as a nation.

The erosion of these UWEP species can have an immediate consequence on the nutritional status and food security of rural population, since the enhanced use of these plants can provide a better nutritional value and help the less fortunate to fight against hidden hunger and food insecurity [4]. Available information on UWEP reveal that there are a number of underutilized fruits, vegetables, herbs, roosts, yams, leaves, tubers, flowers and other plant parts that remain untapped even though they are rich in various functional properties. Worldwide local communities have used these plant species for generations, but recently their traditional uses are being forgotten due to the loss of local knowledge, awareness and modern life style of man. Available limited resources clearly indicate that proper authentication, scientific analysis for functional properties and traditional knowledge of UWEP have to be recorded since these species are a promising solution for global food security. This review provides a comprehensive summary of recently published literature on UWEP, their functional properties (nutritional potential, genetic and physical tolerance, pharmacological importance) and future trends which will facilitate more research awareness among researches around the world for combating hidden hunger and food insecurity.

2. World of UWEP and Their Importance as the Future Food

2.1. Underutilized Wild Edible Plants Available in the World

From the millions of known plant species around the world, roughly 120 are cultivated as a food source, and out of those, nine species supply over 75% of the global plant-derived energy. Apart from that, wheat, rice and maize are used as staple food crops around the world while more than one hundred UWEP species remain neglected [10,11]. Referring to above findings, many countries around the world are suitable for cultivation of traditional food crops such as wild vegetables, fruits grain, leafy vegetables, spices and medicinal plants [12,13].

Throughout the world, there are a number of UWEP species with a potential to help against the global food crisis. Most of these unaccustomed assets are either partly or fully domesticated, stay silent and unevaluated. Instead of meeting the food needs of seven billion people around the world with staple food crops alone, now the focus is shifting towards the UWEP based food diet [14]. Since a basic diet of carbohydrates, fats, and proteins alone cannot meet the challenge of malnutrition, it is essential to include micro nutrients in the diet as well. Therefore, UWEP can be used as a potential solution for the prevailing micronutrient deficiencies.

More than 100 UWEP around the world have been identified. India, Malaysia, Nepal and Philippines are reported as the countries that are highly utilizing UWEP while Indonesia, Papua New Guinea and Sri Lanka are known as countries that are moderately using UWEP for food and medicinal purposes [15]. According to Adebowale and Adedire [16], over 770 taxa from various groups and less-known species were identified in tropical and subtropical regions and can be categorized as pseudo cereals and millets (22), grain legumes/pulses (14), root/tuber types (55), vegetables (213), fruits (261), nuts (34), industrial crop (25) and others (148), which have a major impact for nutrition, health security and climate resilience.

Several researches have explored different UWEP, especially on food herbs and wild woody plants in Pakistan, West Africa, Nigeria and northwestern Ethiopia [4,17,18,19,20] and authenticated and scientifically evaluated nearly hundred plant species. Among those, *Adhatoda vasica*, *Artemisia scoparia*, *Galium aparine*, *Amaranthus viridis*, *Hedera nepalensis* and *Urtica dioica* etc. were considered as species which are rich with bioactive compounds. On the other hand, *Cleome gynamandra* (spider plant) was identified as UWEP species after conducting a survey on documented traditional knowledge of these species in western and Nyaza provinces in Kenya [21]. Based on the findings, spider plant is a highly consuming plant as a vegetable and used for recuperating patients, treat diabetes and gastro-intestinal infections. *Indigofera glandulosa* (Barbada) is a wild weed distributed in India, Indonesia and North Australia and *Eryngium foetidum* L. (Spiny coriander) is another leafy spice herb in tropical regions in India. These plants are used as vegetables, since they are enriched with more minerals and vitamins as discussed by Savaliram *et al*., [22]. Moreover, medicinal properties and importance of these species as spices were lately found by Sing *et al*., [23]. Batt *et al*., [24] reported another wild species, *Gratlaria tetragana* (Tum-thang) a little known wild edible plant in the north hill region of India. Historically people in those hill regions used to consume bud and flowers of the *Gratlaria tetragana* as a vegetable, which was rich with micronutrients.

Nutritionally rich and medicinally important Underutilized Wild Edible Fruit (UWEF) crops at eastern Himalayas have been analyzed by Rymbai *et al*., [25]. These UWEF crops namely, *Padus napaulensis*, *Elaeagnus latifolia*, *Myrica esculenta*, *Baccaurea ramiflora Lour*, *Pyrus pashia*, *Calamus meghalayensis*, *Gynocardia odorata*, *Prunus undulata*, *Docynia indica*, *Rhus chinensis* and *Viburnum foetidum* were studied for their habitat and distribution, morphology and quality parameters. According to the study, these fruits were identified as nutritionally rich with minerals, essential fatty acids and antioxidants. Similarly, Pande *et al*., [26], evaluated nutritional availability of UWEF crops in Georgia as; loquat (*Eriobotrya japonica*), mayhaw (*Crataegus* sp.), fig (*Ficus carica*), and pawpaw (*Asimina triloba*) and reported that these fruits are rich in various bioactive compounds as: malic acid, phenolic compounds

(gallic acid and catechin) linoleic acid, which has psychological and industrial benefits. Furthermore, the study reveals that these crops can be used for both food and nonfood applications by monitoring physical properties, oxidative stability and physical activities. On the other hand, Japanese persimmons (*Diospyros kaki*), pomegranates (*Punica granatum*) and barbary figs (*Opuntia figus-indica*) also have been identified as UWEF species and investigated their commercial value and cultivation requirements to promote these species among community [27,28].

There are a number of grain legumes also remain underutilized as grass pea, bambara groundnut (*Vigna subterranea* (L.), itching bean (*Mucuna pruriens* (L.), rice bean, moth bean, and Adzuki bean. However, proximate compositions, mineral and vitamin contents, lipids, fatty acids and amino acid profile were analyzed in these legumes for understanding their contribution as a food source. Moreover, anti-nutritional compounds were also analyzed in these species to evaluate whether they contain heavy metal or toxic compounds. Apart from nutritional benefits these crops are important since they are highly vulnerable to adverse environmental conditions [29,30,31,32].

Among UWEP there are several oil seeds such as *Telfairia occidentalis, Andenopus breviflorus, cucumeropsis edulis, Antiaris africana* and *Moanodora tenuifolia* which contain sterols, triterpene alcohols and hydrocarbons [33]. Chemical composition of *Jatropha curcas* L. seeds have been evaluated and 66.4% oil content have been reported [34]. Therefore, commercial oil seeds can be substituted by this wild species, since these seeds contain linolenic acid and ten sterols and thirteen tritepene alcohol in the unsaponifiable fraction of the oil. Fairly high oil content (34.7-68.8%) was found out in *Telfairia occidentalis*, *Andenopus breviflorus*, *Cucumeropsis edulis*, *Antiaris africana*, and *Monodora tenuifolia* which remain neglected in Nigeria.

2.2. Underutilized Wild Edible Plants Available in Sri Lanka

Food requirement in Sri Lanka is mainly filled by few general crops mainly with rice, pulses, vegetables and fruits, resulting in less diversification of human diet and leading the country to risk of health and food insecurity. Sri Lanka is a natural hot spot of edible plant species which are remaining as neglected or underutilized [35]. Most of these unaccustomed assets are either partly or fully domesticated and stay silently and unevaluated. Several identified underutilized plant species are listed in Table 1. Low input requirement, tolerance to adverse environmental conditions and potential income source for rural people are the major reasons for cultivating these species in Sri Lanka.

Table 1. Commonly Cultivating Underutilized Plats in Sri Lanka

No	Category	Common name	Botanical name	Reference
01	Vegetables	Long bean	*Vigna unguiculata*	[36]
		pumpkin	*Cucurbita maxima*	
		Ridge gourd	*Luffa acutangula*	
		Bitter gourd	*Momordica charantica*	
		Snake gourd	*Trichosathes anguina*	
		Ceylon spinach	*Basella alba*	
		Kathurumurunga	*Sesbania grandiflora*	
		Thampala	*Amaranthus* spp	
		Drumstick	*Moringa oleifera*	
		Kohila	*Lasia spinosa*	
		Kapukinissa	*Abelmoschus moschatus*	[37,38]
		Katu thampala	*Amranthus spinosus*	
		Ahu kola	*Chenopodium*	
		Kiri henda	*Celosia argentea*	
		Heen gotukola	*Centella asiatica*	
		Thitta labu	*Citrullus colocynthis*	
		Alupuhul	*Beninca sahispida*	[39]
		Kekiri	*Cucumis sativus*	
		Thibbatu	*Solanum torvum*	
		Diyalabu	*Lagenaria siceraria*	
		Sarana	*Boerhavia diffusa*	
		Thebu	*Costus speciosus*	
		Kirihenda	*Celosia argentea*	
		Aguna kola	*Dregea volubilis*	
		Kowakka	*Coccinia grandis*	
		Thebu kola	*Costus speciosus*	
		Sweet Leaf or Japan Batu	*Sauropus androgynous*	
		Madatiya	*Adenanthera pavonina*	
		Geta thumba	*Leucas zeylanica*	
		Vatha banga	*Pisonia alba*	

No	Category	Common name	Botanical name	Reference
02	Fruits	Durian	*Durio zibethinus*	[36]
		Nelli	*Phyllanthus emblica*	
		Wood apple	*Limonia*	
		Beli	*Aegle marmelos*	
		Lovi	*Flacourtia inermis*	
		Veralu	*Elaeocarpus serratus*	
		Jackfruit	*Artocarpus heterophyllus*	
		Tamarind	*Tamarindus indica*	
		Goraka	*Garcinia quaesita*	
		Guava	*Psidium guajava*	
		Naran	*Citrus* spp.	
		Mangosteen	*Garcinia mangostana*	
		Biling	*Averrhoa bilimbi*	
		Gaduguda	*Baccaurea motleyana*	
		Rata nelli	*Phyllanthus acidus*	
		Uguressa	*Flacourtia indica*	
		Sapodilla	*Manilkara zapota*	
		Katuanoda	*Annona muricata*	
		Madan	*Syzigium cumini*	
		Lavalu	*Pouteria campechiana*	
		Pomegranate	*Punica granatum L.*	
		Kon	*Schleicheraa oleosa*	
		Rose apple	*Zyzygium jambos*	
		Uguressa	*Flacourtia indica*	
		Emberella	*Sondias Dulcis*	
		Palu	*Menilkara hexandra*	
		Namnan	*Cynometra cauliflora*	
		Ceylon durian	*Durio ceylanicus*	
		Wal dhel	*Artocarpus nobilis*	[40]
		Heen Ebilla	*Antidesma alexiteria*	
		Heen Karamba	*Carissa spinarum*	
		Veera	*Drypetes sepiaria*	
		Kalu mediriya	*Diospyros quaesita*	
		Veralu	*Elaeocarpus serratus*	
		Damina	*Grewia damine*	
		Mee	*Madhuca longifolia*	
		Indi	*Phoenix pusilla*	
		Masan	*Zizyphus mauritiana*	
		Udahalu	*Passiflora* foetida	
03	Legumes	Black gram	*Vigna mungo*	[36]
		Cowpea	*Vigna unguiculata*	
		Horse gram	*Macrotyloma uniflorum*	
		Wal kollu	*Atylosia scarabaeoides*	[38]
		Avara	*Canavalia rosea*	
		Black gram	*Vigna mungo (L.)*	
04	Cereals	Little millet	*Panicum sumatrense*	[36]
		Finger millet	*Eleusine coracana*	
		Sorghum	*Sorghum bicolor*	
		Kodo millet	*Paspalum scrobiculatum*	
		Foxtail millet	*Setaria italic*	
		Proso millet	*Digitaria ciliaris*	
		Gira thana	*Echinochloa colona*	[37,38,42]
		Ahu	*Hygroryza*	
		Perl millet	*Pennisetum glaucum*	
		Heen meneri	*Panicum sumatrense*	
		Thana hal	*Setaria italic*	
05	Oilseeds	Groundnut	*Arachis hypogaea*	[36]
		Soybean	*Glycine max*	
		Sesame / Gingili	*Sesamum indicum*	[38]
		Mustard	*Brassica juncea*	

No	Category	Common name	Botanical name	Reference
06	Roots and Tubers	Sweet potato	*Ipomoea batatas*	[36]
		Cassava	*Manihot esculenta*	
		Innala	*Plectranthus rotundifolius*	
		Dioscorea yams	*Colocasia esculenta*	
		Rata ala	*Xanthosoma* spp.	
		Habarala	*Alocasia macrorrhiza*	
		Buthsarana	*Canna indica*	
		Welala	*Colocasia nymplimfolia*	[38]
		Kiri ala	*Dioscorea alata*	
		Gahala	*Colocasia esculenta*	[41]
		Rajala	*Dioscorea alata*	
		Elephant foot yam	*Amorphophallus paenoiifolius*	
07	Spices and condiments	Alan	*Alpinia nigra*	[37,42]
		Kurundu	*Cinnamomum*	
		Termeric	*Curcuma longa*	
		Inguru piyali	*Kaempferia galanga*	
		Nut meg	*Myristica fragrans*	
08	Herbal crops	Ginger	*Zingiber officinale*	[38]
		Endaru	*Ricinus communis*	
		Welpenela	*Cardiospermum halicacabum*	
		Polpala	*Aerva lanata*	
		Hathavariya	*Asparagus officinalis*	
		Wel penela	*Cardiospermum halicacabum*	
		Rathmal	*Icora coccinea*	
		Muna mal	*Mimusop elengi*	
		Pitawakka	*Phyllanthus amarus*	
		Waduru mee/Avariya Pala	*Mucuna pruriens*	

According to survey study done by Malkanthi *et al*., [38], Thanamalvila divisional secretariat in Monaragala district is reported as the most cultivated underutilized cereals and vegetables in Sri Lanka, including *Eleusine coracana*, *Panicum sumatrense*, *Cucumis sativus*, *Solanum torvum* etc. and nearly 30 to 106 farming families are cultivating these species. Contribution of these species to the food requirements of rural farming families in Sri Lanka range 5% to 63%. Furthermore, farming families of Uva and Eastern provinces highly rely on rural food requirement and income security on 60% of underutilized vegetables, 30% of underutilized cereals and pulses and 10% of underutilized fruits [35].

3. Functional Properties of UWEP and Importance

3.1. Resistance for Adverse Environmental Conditions and Pest and Disease Attacks

Generally, UWEP are growing all over the world including Asian, African and European countries. Climatic conditions, environmental factors (soil, water requirement, nutrient availability) and other inputs (water, fertilizer) are not huge barriers for growth of UWEP species in any country around the world [43,44]. UWEP have created a wide spread awareness among researchers because of vulnerability to unfavorable climactic and environmental factors.

Underutilized *Oryza* and millet species (*Pennisetum glaucum*) grown in poor soil and hard environment conditions around the world have been reported to have a high yield [45]. On the other hand, low input requirement and minimum management practices lead to low cost of production and high profit margins for local farmers [46]. Modified green houses and protected agriculture are high cost solutions for farmers in developing countries. Therefore, providing better knowledge and awareness about these UWEP will motivate farmers to use these plants in a large scale manner while making it an alternative income source.

Soil and climate variations, hard pan of the soil and drought condition in Sri Lanka, India and many African countries will not affect the growth of UWEP. For example, pearl millet, amaranth and many other wild cereal species can be grown under the heavy drought conditions in Sub-Saharan Africa.

In Sri Lanka also most of the identified UWEP species are highly adaptive to drought, salinity, extreme temperatures, mineral toxicity and acidity. For instance, *Dimocarpus longan* (Mora), *Salacia chinensis* (Himbutu), *Ziziphus mauritiana* (Masan), *Calophyllum walkeri* (Keena), *Zyzygium caryophyllatum* (Dan), *Phyllanthus emblica* (Nelli) etc. are abundant in arid lands, scrublands or forest edges [47]. Apart from these fruits, leafy vegetables such as, *Trianthema portulacastrum* (Heen sarana), *Trianthema decadra* (Maha srana), *Polyscias fruticosa* (Koppa kola), Commelina diffusa (Gira pala), `*Talinum paniculatum* (Gas nivithi), Acrostichum aureum (Keren koku) etc. also can be seen in marshy places, low country ditches or saline soil (coastal area) [48]. These plants are well adopted to unfavorable environmental conditions and some of them can even be grown in

marginal lands. Moreover, these species have good resistance to pests and diseases as well.

3.2. Chemical and Nutritional Properties

The global population is increasing day by day and according to the FAO [11], poor dietary patterns among people have resulted due to the over dependence on staple crops or moving to commercial cereals, soil infertility and degradation of natural resources. In this context, nutrition availability in UWEP around the world, provides many valuable scientific facts regarding the potential of providing healthy, nutritious and wholesome food for poor and undernourished developing nations.

Legumes are one of the leading, valuable plant sources for human diet and investigations on underutilized wild legume species have been reported around the world including North America, Africa, Korea, China, India, Mexico and Nigeria. A study was conducted to investigate the nutritional availability of 19 underutilized legumes in Africa and results revealed that they were used as bio-fortification sources since they are enriched with proteins, essential amino acids, minerals and energy values. Moreover, lauric, myristic, palmitic, arachidic, lignoceric, myristoleic, elaidic and heneicosanoic acids were also screened in these legumes. Various functional properties as foaming capacity, gelation property and bioactive compounds such as antioxidants, phenols were identified. However, trypsin inhibitors, saponins, oligosaccharides like anti-nutrients were also identified and researches concluded that processing methods (cooking, thermal treatments, soaking) can detoxify these compounds to convert legumes into edible form [24]. Another weed legume, *Indigofera glandulosa* (Babara), was identified from India, Indonesia and North Australia and it is a commonly consumed famine food by Indians. Lately, researchers investigated that the species is enriched with vitamin B, essential amino acids, proteins and high energy [22].

As Adhikari *et al*., [49] reported, household food baskets of local population in mountain areas at Himalya were filled with wild species as amaranthus (*Amaranthus caudatus*), naked barley (*Hordeum vulgare*), black gram (*Vigna radiate*), horse crop (*Macrotyloma uniflorum*), olarum (*Amorphophallus campanulatus*), yam (Dioscorea spp.), rayo (*Brassica juncea*), sesame (*Sesamum indicum*), niger (*Guizotia abyssinica*), kaphal (*Myrica esculenta*), chiuri (*Aesandra butyracea*), amala (*Phyllanthus emblica*), pumello (*Citrus maxima*) and jammun (*Syzygium cumini*). However, these species were lately replaced by commercial cereals, such as wheat, rice and maize. The studies on nutritional comparison of these two groups has shown that calcium, iron, zinc, riboflavin and folic acid like micronutrients are rich in underutilized cereals reference to the commercial species. Moreover, findings were revealed that pearl millet also contain higher amount of micronutrients (excluding calcium) than wheat.

UWEF species are referred as important source of supplementing essential nutrients in human diet. In India, people used to consume more wild fruit species before exotic fruit species have been introduced [50]. The literature reported that the UWEF species are more nutritious based on the investigation conducted for11wild edible fruits namely, *Capparis zeylanica L.* (Wagati), *Carrisa congesta* (Karwand), *Cordia dichotoma* (Bhokar) etc. The analyzed nutrient profile concluded that the species contain 0.4-18% - protein, 0.5-5%-fat, 0.5-6%-fiber, 1.45% amino acids and satisfactory levels of beta-carotene, vitamin C, sugars and minerals (Cu, P, Zn, Fe, Mn) [51]. Furthermore, malnutrition along with multiple nutrient deficiency disorders were observed among those tribal people who discontinued consuming locally available underutilized fruits and clinical symptoms of protein energy malnutrition (14.4%), anemia (33.0%), iodine deficiency disorder (17.0%), vitamin A deficiency (7.4%), vitamin C deficiency (12.40%), calcium deficiency (18.0%) and zinc deficiency (19.20%) were observed among this group. In contrast, the other groups consuming underutilized fruits regularly showed healthier and nutritionally secure [52].

Underutilized fruit cultivars in Sri Lanka such as bilimbi (*Averrhoa bilimbi* ‘local’), ceylon date palm (*Phoenix pusilla* ‘local’), ceylon olive (*Elaeocarpus serratus* ‘local’), sugar apple (*Annona squamosa* ‘local’), miracle berry (*Synsepalum dulcificum* ‘local’), bullock’s heart (*Annona reticulata* ‘local’), soursop (*Annona muricata* ‘local’), jamaica plum (*Spondias dulcis* ‘local’), gooseberry (*Phyllanthus emblica* ‘local’), governor’s plum (*Flacourtia indica* ‘local’) and rose apple (*Syzygium jambos* ‘Malaysian’) were analyzed for their nutrient profile. Significantly high amounts of vitamin C (3.8-136.8 mg AAE/100 g fresh fruit), total phenol contents (30.9 - 915.7 mg GAE/g of fresh fruit), total flavonoids (242.5-873.2 mg CE/100 g) and antioxidants (0.69 - 1022.05 lmol FeSO4/g fresh fruit) were available in these underutilized species compared to commonly consumed fruits [53].

Laboratory nutritional assessment of many underutilized vegetable (fruit vegetables and leafy vegetables) species have been carried out to estimate and determine their nutritional constituents [12,54,55,56,57,58] and resulted data revealed that these species were enrich with phytochemicals and minerals. Apart from nutritional benefits, it has been observed that tribal people who still live in forest areas and, consume traditional foods are healthy and free from most of the diseases. For example, tribes in Bastar, India frequently consume UWEP such as *Cassia tora*, *Celosia argentea*, *Bauhinia variegata*, *Cordia myxa*, *Amaranthus* spp., *Costus speciosus*, *Ficus* spp. and *Moringa oleifera* as vegetables [59,60,61] and these species act as a nutrient source specially for pregnant tribal women in this area [59]. Freiberger *et al*., [54] has studied nutrient content of wild edible leaves which are consumed widely as leafy vegetables in Nigeria. Minerals, amino acids in *Ximenia Americana*, *Amaranthus viridus*, *Corchours iridens*, *Hibiscus sabdarifa*, *Maerua crassifolia*, *Moringa oleifera* and *Leptadenia hastate* were analyzed to test the impact of these leaves in improving human diets. Trace minerals of Ca (10–20 mg/g), Fe (107 - 687 µg/g), Mg (3.5 - 14 mg/g), Cu (8.5 - 12.8 µg/g), Mn (29.9 - 151 µg/g), P (1.43 - 4.35 mg/g), Zn (17.3 - 19.7 µg/g) and Se (below 5 µg/g) were detected contained in significant amounts in these leaves. Amino acids of aspartate, glycine, methionine, leucine, cysteine also identified and *Moringa oleifera* contains the highest protein (17.1 mg/g dry weight) content compared to other

species. Further essential amino acids content in studied wild species of *Maerua crassifolia*, *Moringa oleifera* and *Ximenia Americana* was exceptionally high with reference to the standards of the World Health Organization (WHO). The nutrient profile of underutilized wild species, *Moringa stenopetala* (Haleko) and *Moringa oleifera* (Murunga), collected from Southern Ethiopia and Sri Lanka were analyzed [62,63] and the findings reported that *M. stenopetala* leaves are rich with vitamin C (28.07 (mg/100g), which is seven times higher than oranges and vitamin A availability which is higher than carrots. Moreover, protein (9.0 mg/100g) and Ca (729.8 mg/100g) availability of leaves are significantly higher than yoghurt and milk [64]. Different minerals such as Na (403.5 mg/100g), K (453.0 mg/100g), P (65.6 mg/100g), Ca (792.8 mg/100g), Fe (3.08 mg/100g) and Zn (0.53 mg/100g) were screened in also identified with considerable amount of β-carotene (160 mg/100g) and α-carotene (54 mg/100g). With reference to the species of *M. oleifera*, minerals of K (1839.56.0 mg/100g), Mg (456.13mg/100g), Ca (1532.04mg/100g), Fe (10.54 mg/100g) and Zn 3.29 mg/100g) were screened in leaves. Therefore, *Moringa stenopetala* and *Moringa oleifera* leaves can be recommended as food supplements, combating micronutrient malnutrition. Another study was conducted to investigate the antioxidant availability and proximate composition of wild leafy vegetable species (*Coccinia grandis* (Kowakka), *Dregea volubilis* (Agunu kola) and *Costus specious* (Thebu kola). Considerable amount of crude protein (1.75-7.17% fresh weight basis) and twenty-four minerals including Na, K, Ca, and Fe were identified in these wild species. Furthermore, they have suggested that nutritional requirements of a person can be facilitated with these species by having proper identification of bioavailability of minerals [39].

Wild edible species of *Glebionis coronaria*, *Polygonum cognatum*, *Smilax excels*, *Eremurus spectabilis* and *Chenopodium album* were also studied in Turkey and results highlighted that all species are enriched with K at significant level, ranging from 256 to 709 mg/100g. Apart from K, other micronutrients such as Ca, Fe, Mg and Cu are also available at considerable levels. With reference to the dietary fiber availability, few species of *Polygonum cognatum*, *Smilax excels* and *Eremurus spectabilis* considered as good sources of dietary fiber. Moreover, it was mentioned that geography, genetic factors, climate, agricultural practices and preparation methods may create an impact on nutrition availability of these species [65].

Dioscorea alata (Rajala) and *Amorphophallus paenoiifolius* (Elephant foot yam), underutilized root and tubers found in Sri Lanka, were analyzed for proximate composition and minerals [5]. Protein content of selected species are comparatively higher (7.60%) than *Manihot esculenta* (Cassava) which have 1.2 to 1.8 % of protein content [66]. Fe, Cu, K, Zn, Na, Mg and Ca contents were also identified and available amounts ranged as 0.99 - 5.71, 0.74 - 2.29, 328.11 - 114.04, 0.47 - 6.71, 1.45 - 3.25, 11.11 - 44.66 and 1.09 - 61.26 mg/100g respectively. Bhandari *et al*., [67] studied nutritional availability of wild yam tuber species (Dioscorea bulbifera, D. versicolor, D. deltoidea and D. triphylla) available in Nepal. Crude protein, ash, crude fat and crude fiber contents of these yams were reported as 1.6–3.1, 0.5–1.2, 0.2–0.3 and 0.6–1.5% fresh weight basis, respectively. Moreover, the yams are rich in different mineral contents as well (K (250–560), Na (4.15–17.8), P (33.1–61.6), Ca (14.3–46.9), Mg (18.3–27.3), Cu (0.10–0.21), Fe (0.39–2.92), Mn (0.14–0.35) and Zn (0.22–0.53) in mg per 100 g fresh weight). Hence, lesser known wild yam species can be promoted for creating significant improvement in food baskets of developing countries.

3.3. Medicinal Properties and Pharmacological Importance of UWEP

UWEP species were also identified as a potential source of medicine which plays an important role in pharmaceutical production and healthcare system [68]. Most of the local communities have used underutilized wild species in their traditional medicine system [69].

An underutilized edible root, *Maca* is known to contain significant amounts of iodine which is important for thyroid metabolism which leads to health-promoting effects on humans [70,71]. Lee *et al*., [72] also conducted a study on *Maca* and found out that it was an important dietary supplement for several health issues known to women including menopause symptoms such as hot flushes, night sweats, loss of libido and a change in monthly periods. *Cyperus esculentus* (Tigernut) is also a wild species that can be used for colon cancer, coronary heart diseases, obesity, diabetes, and gastrointestinal disorders since it contains high dietary fiber content [4]. Moreover, *C. esculentus* contains quality oil and a higher amount of essential amino acids which improves adult health.

Neela, [73] also described the medicinal value of *Casimiroa edulus*, UWEF species available in Ethiopia. The fruit was reported to be an excellent source of antiepileptic compounds after completing several trails of antiepileptic drugs. Further, ethyl acetate extract of *Casimiroa edulus* seeds have been proven as potential cancer preventive activity since they contain anti mutagenic constituents. Anxiolytic activity, antidepressant properties and antihypertensive activity also can be observed in *Casimiroa edulus* leaves and other plant parts [74]. *Adansonia digitata* L. is another UWEF species available in Africa. Bark of *A. digitata* L is used for relieving shivering, influenza while leaves are used for hyposensitive, antihistamine, treat kidney and the fruit pulp is prepared to combat fevers and treat dysentery [75]. Another African wild fruit species called *Balanites aegyptiaca* (L.) is also used to treat dysentery and constipation while seeds are used to treat tumors and wounds, as laxative [76]. Moreover, *Dovyalis caffra*, *Garcinia livingstonei*, *Mimusops zeyheri*, *Parinari curatellifolia*, *Sclerocarya birrea*, *Strychnos spinose*, *Uapaca kirkiana* and *Vangueria infausta* are used to cure many non-communicable diseases and improve body immunity. Availability of dietary fibers such as pectin, beta-glucans, hemicellulose, cellulose, lignin, fructans and common organic acids such as citric, malic, tartaric, oxalic, lactic, acetic and iso-citric are important constituents that help to cure many non-communicable diseases and also improve body immunity [75]. *Lycium barbarum*, *Clausena lansium* (Lour.) and *Passiflora foetida* L. are identified as UWEF species in Vietnam. Vitamin C and beta carotene in these species possess antioxidant activity which prevents cardiovascular disease and cancers [77].

Cajanus cajan, Ceratotheca sesamoides, Citrullus lanatus, Cleome gynandra, Corchorus olitorius, Pennisetum glaucum, Sesamum indicum, Sphenostylis stenocarpa, Vigna subterranean are Underutilized vegetable species which contain high amount of micronutrients and antioxidants [4] and important for possessing pharmacological properties. Several human pathologies such as hypertension, headaches, breast cancer, burns, inflammations, injuries, liver complaints, infections, and sexually transmitted diseases can be cured by seeds, leaves and roots of those wild vegetable species [78]. *Portulaca oleracea* L., *Diplazium esculentum, Polygonum aviculare* L., *Musa acuminata* Colla, *Amaranthus spinosus* L, *Melientha suavis* Pierre, *Houttuynia cordata* Thunb and *Polygonum chinense* are another underutilized leafy vegetable species available in Northern mountainous provinces of Vietnam [77]. Since these species are rich in omega-3 fatty acids, they can promote human growth and development. Moreover, P. *oleracea* contains alpha-linolenic acid which prevents diseases and promotes immunity development. Number of cardiovascular diseases also can be cured using these identified species [79].

Chugh *et al*., [80] studied underutilized legumes of *Vicia faba* L., *Vigna umbellata* (Thunb.) and *Lablab purpureus* (L.) Sweet. which can be used as medicinally important UWEP species. Promoting growth and development, inducing the immune system are the major health benefits that can be gained from these species. *Macrotyloma uniflorum* (horse gram), commonly found in Asian and African countries is another wild legume species. Traditional knowledge of medicinal properties regarding *M. uniflorum* remains neglected due to poor awareness [81]. As explained by Pati and Bhattacharjee, [82], excessive perspiration can be cured using horse gram seed flour. Kidney stones, asthma, bronchitis also can be treated using this wild legume species [83] while anthelmintic activity, hypolipidaemic and hypoglycemic actions are important for curing beneficial disease.

Roots and tubers of *Dioscorea hamiltonii*, *Allium chinense*, *Colocasia esculenta* (L.), *Zingiber officinale* Roscoe, *Bambusa* spp. and *Curcuma longa* L. have been used for ancient medicine systems as good appetizer and for treating anemia, wounds, cancer, piles and skin eruptions [84]. Moreover, these species have medicinal value that can be used in the pharmaceutical industry.

Referring to scientific studies and findings, medicinal values and related biological activities of UWEP species play an important role in medical treatments. Traditional knowledge of UWEP species and traditional methods of treatment are still largely ignored. Therefore, it is essential to create social awareness about the medicinal properties of UWEP.

4. Utilization and Value Addition of Underutilized Wild Edible Plants in Sri Lanka

Utilization of UWEP species for new product developments and value addition is an effective method to enhance the nutrition and health status of the society as well as to gain benefits for the economy. As previously discussed, these species have rich nutrient profiles, health benefits, resistance to adverse environmental conditions and low input requirements for cultivation. Considering all these aspects there is a huge potential to develop a new market trend using UWEP species.

Commercialized new products and value added products such as heat processed products (jam, jelly, candy, sauce, dehydrated products), dried fruits or vegetables, fruit juice, confectionaries, preserved products, glazed products, wine, pickle, frozen puree, cane products etc. are currently developing using UWEP species throughout the world. Processing of UWEP is conducted mainly with the objectives of preservation of nutrient value, reduction of post-harvest loss, elimination of waste, prevention of seasonality and improvement of quality [85].

Jam is a highly available product type that uses UWEF species of jamun, karonda, anola, mulberry, soursop, tamarind and wood apple. Anola is a highly perishable underutilized species which has higher medicinal importance [86,87,88] and it is used to produce jam, jelly, candy, toffee, pickle, sauce, squash, juice, RTS beverage, cider, shreds, dried powder, etc. [89]. Moreover, tamarind, jamun, karonda, etc. are used to develop jelly and candy as well. Wine production is conducted basically using mahua, jujube, ber, Indian fig and karonda. Chutney, pickle, sauce and canned products are developed using ber, aonla, jamun, ker, jujube, tamarind, lasora, gonda, karonda, wood apple and pomegranate. Furthermore, bael, karonda, ker, phalsa, tamarind, custard apple species are used for the production of frozen puree [40]. *Elaeocarpus serratus* (Veralu) is an underutilized fruit in Sri Lanka which is very similar to *Olea europaea* (Olive fruit) [90] and can be successfully used to develop Ready to Serve (RTS) drinks [91,92]. *Prunus armeniaca* L. (Wild apricot) which is commonly known as chulli and grown in North-West Himalayan regions, has been used to develop a jam with combining apple pulp.

Heat process products are also prominent among available products in the local market. Canned products are one of the heat process products which uses sugar syrup or brine syrup to preserve species such as *Elaeocarpus serratus, Garcenia zeylanica, Emblica officinalis* etc. [40]

Nutraceutical production is another potential market strategy for UWEF. Asimina triloba (L.), Crataegus azarolus L., Lycium barbarum L., Morus nigra L., and Amelanchier canadensis (L.) are used for nutraceutical production since these species contain vitamin C and antioxidants, with the benefits of curing cardio-vascular diseases.

Most of the researchers nowadays have identified the need for developing novel products using UWEP with the objectives of adding value and enhancing the nutrient profile of the currently available products. Yadav *et al*., [93], conducted a study to develop noodles using sweet potato and *Colocasia* (*Colocasia esculenta*) flour, focusing the improvement of nutrient profile of the product in comparison to the commonly available conventional noodle products in the market. Pobar [94] also conducted a research study using *Diospyros blancoi* (Mabolo) UWEF species to develop confectionaries. Hence, these developed recipes were beneficial to improve the livelihood of local people in Philippine and create a potential market for entrepreneurs.

Therefore, promoting the untapped market section of UWEP can be a promising solution for a number of health effects including malnutrition. If it's possible to diversify the market with novel and value added products from UWEP species, the economy of local farmers will be improved up to a satisfactory level.

5. Future Strategies and Trends

Malnutrition, poor health, hunger and starvation are still remaining as burning issues for mankind around the world. According to the FAO, currently there are around 800 million people in underprivileged population groups, who are still suffering from food and nutrition insecurity. Moreover, there has been a dramatic increase of chronic diseases including cancer, cardiovascular diseases and diabetes in developing countries because of unbalanced dietary patterns. Therefore, agricultural and horticultural researches should develop strategies not only to produce more food, but also to improve access for more nutritious foods. One promising approach to gain that objective is to promote diversity in the dietary pattern of these people. Development of new products that are affordable to the local people is one way of enhancing the consumption of nutritious food.

With raising population, there is a surge of interest among researches and food experts around the world about exploring the potentials of UWEP. Research and development (R&D) scopes were expanded with association of diversification of UWEP and evaluating their suitability for different agro-ecosystems including severe agro climatic conditions. Specifically focusing on the requirements of rural farmers in marginal agro-habitats with limited livelihood alternatives and the policy implementation for securing the necessities of life in rural farmers has been emphasized through several global platforms [95,96].

As FAO claims, over a period of time many of these UWEP species are likely to face a dwindling state of 'vanishing crops/lost crops' [11]. Ignorance and lack of identification as a valuable food source, unacceptable taste, social value and lack of commercial cultivation can be listed as the causes which prevents UWEP from achieving its full potential. Due to these reasons they have either been poorly researched, less recognized for their nutritional value, had poor consumer preference and therefore continued with a tag of 'poor people's crops'. Therefore, this needs to be discussed in a global forum. Most of the countries have to start investing in UWEP, first to identify what are the available wild edibles and then to validate the species in respective regions. In terms of research conducting, almost all the studies have to start from basic ethno-botanical investigations and needs continuation until nutrition, health and other potential aspects are discovered [4]. Moreover, we need to involve communities and research scientists, do conservation and crop improvement, gather information, share knowledge and dissemination, create and maintain databases of UWEP species globally.

Bio fortification is a novel technology that can be used to enhance the nutritional values of a particular crop species through conventional breeding or genetic engineering [97]. This technology can be applied to the UWEP also which has the potential to overcome malnutrition in future generations. As previously discussed micronutrients and other nutritional compounds such as α carotene and β carotene are also found in UWEP species. Therefore, a number of modifications like, Fe fortification, Zn fortification and β carotenes fortification can be used to modify the nutrient profiles of commercial food crops using the related genes of UWEP.

UWEP have a huge prospective to address one of the severe global threats namely "global food security" or "food insecurity". Due to the high population growth it will be very difficult to cater the required amount of food by growing major or staple crops. Therefore, focus needs to be shifted to alternative food sources. Literature shows that micronutrients and bioactive compounds in UWEP have potential to address that requirement. Furthermore, studies have to be conducted to evaluate bioaccessibility of micronutrients and other related compounds in lying with anti-nutrients of UWEP [10]. Accordingly, UWEP can be described as a sustainable, economically viable solution to food shortage with minimal environmental damage.

Depending on how we address the previously discussed strategies and trends related to UWEP will allow us to combat micronutrients and related deficiencies (hidden hunger) by diversifying our dietary needs in developing countries like Sri Lanka.

6. Conclusions

Most of these ancient conventional knowledge about UWEP species are in the minds of our grandparents and most likely we will have to bury that knowledge along with them. Ongoing research studies and available data reveals that UWEP possess high nutritional values. These plants are a valuable source of protein, fat, fiber, vitamins, sugars, minerals and antioxidants. Beside the nutritional aspects, medicinal values and pharmacological importance also have been identified by a number of scientific studies done throughout the word. UWEP species ensure consistent yield despite adverse conditions and low input availability. Therefore, attention must be provided to promote cultivation, processing, and pharmaceutical production of UWEP. This paper strives to assemble and disseminate that knowledge in order to urge the researchers to study on UWEP. Application of modern processing methods along with incorporation of traditional knowledge will definitely provide a substantial base for the commercial exploitation of these plants to develop new food products (or for bio fortification), and also for the use in the pharmaceuticals industry. Still a wide gap in knowledge exists with regards to the exploration of actual gene pool in evaluating beneficial secondary metabolites, phytochemicals and other nutritional features in these UWEP resources.

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