International Journal of Food, Agriculture and Veterinary Sciences ISSN: 2277-209X (Online)
An Online International Journal Available at http://www.cibtech.org/jfav.htm
2015 Vol.5 (1) January-April, pp. 94-105/Vazhacharickal et al.
Research Article

A STUDY ON THE VITAMIN C CONTENTS OF VARIOUS NEGLECTED AND UNDERUTILIZED FRUITS FROM WESTERN GHAT REGION IN KERALA

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ABSTRACT
Underutilized or neglected fruit trees were considered to be an important role in mitigating malnutrition and poverty in developing and under developed countries. These fruit trees may be neglected due to ignorance, lack of knowledge, availability, difficulty in harvesting and storage. Vitamin contents especially Vitamin C (ascorbic acid) could be considered as a key factor in the quality determination of fruits. Various underutilized fruits samples (Bilimbi, Gooseberry, Indian plum, Coffee and Pepper) were collected, processed and analyzed for vitamin C content using titration method. These values were compared with vitamin C content of pharmaceutical tablets. Highest vitamin C content found in Indian gooseberry (12.73 ± 3.60 mg/g) followed by wild orange (5.09 ± 1.44), then wild lemon (3.20 ± 1.12), Pepper, Coffee, Bilimbi and Indian plum (2.54 ± 0.72). Underutilized fruit trees can play a vital role in supplementing human diets. Importance should be given to the propagation, processing and storage of various underutilized and neglected fruits.

Keywords: *Vitamin C; Underutilized Fruits; Redox Titration Method; Western Ghats*

INTRODUCTION
Population explosion and migration of people towards urban area increased the demand for food, shelter, water and basic necessities (Cohen, 2006). Since 2010, for the first time in human history, more than 50% of the global population lives in urban areas. The Kerala State (reorganized on 1956) has evolved as unique state in India in terms of education, health and highest per capita income (Kannan, 2011). However, agriculture is facing long time stagnation (Table 2) due to very low land-man ratio, shortage of labor and labor migration in Gulf areas. The state undergoing structural transformation from an agrarian society to non agrarian society (Table 3) dominated by non agricultural activities in which the land reform act in 1971 might have played a critical role. The main criticism faced by Kannan (2011) is that he has completely sidelined the food security aspect which was criticized by Tharamangalam (2012).
Underutilized or neglected fruit trees were considered to be an important role in mitigating malnutrition and poverty in developing and under developed countries. These fruit trees may be neglected due to ignorance, lack of knowledge, availability, difficulty in harvesting and storage (Sundriyal and Sundriyal, 2003; Badola and Aitken, 2010; Gebauer *et al.*, 2007). Most of these fruits are rich in vitamins, antioxidents, organic acids and phenolic contents (Pande and Akoh, 2010; Kelebek and Selli, 2011; Kong *et al.*, 2011; Salmanian *et al.*, 2014; Kalt *et al.*, 1999).
Vitamin C is a highly water-soluble compound that has both acidic and strong reducing properties, an essential nutrient in humans as it functions as a cofactor in several vital enzymatic reactions (Kalt *et al.*, 1999; Padayatty *et al.*, 2003; Gardner *et al.*, 2000). The richest natural sources of Vitamin C includes blackcurrant (*Ribes nigrum* L.), blueberry (*Vaccinium corymbosum*), orange (*Citrus x sinensis*), lime (*Citrus aurantifolia*), lemon (*Citrus x limon*), strawberry (*Fragara x ananassa*) and cabbage (*Brassica oleracea*). In general, the recommendation for vitamin C intake in humans is around 60–95 milligrams per day and the maximum upper intake level is 2000 milligrams per day (Carr and Frei, 1999; Levine *et al.*, 1995; Levine *et al.*, 1999; Naidu, 2003). However, it is reported that a long-term overdose of this vitamin may cause diarrhea, iron overload disorders, kidney stone formation and deficiency condition cause scurvy, which is characterized by gum disease, pain in muscles and joints, skin lesions, fatigue, and bleeding (Naidu, 2003; Carr and Frei, 1999; Holick and Chen, 2008; Mayland *et al.*, 2005; Weber *et al.*,

1995; Jacob, 1990; Jacob *et al.*, 1987). Vitamin C plays a major role in the manufacture and defense of human connective tissue, immunity, Alzheimer's disease, stroke and coronary heart disease (Padayatty *et al.*, 2003; Morris *et al.*, 1998; Gale *et al.*, 1995).

The Western Ghats (WG) is considered as an important biodiversity hot spot among 34 biodiversity hot spots with abundant supply of medicinal plants, insects, fishes, amphibians, reptiles and wildlife, received the UNESCO world heritage tag during 2012. The WG stretches from North to South running around 1490 km covering an area of 180,000 km2. The estimated conversion of forest to plantation crops during 1920 to 1990 was about 40% of the total area. In addition to the biodiversity WG, with well nourished diverse religious, linguistic, ethnic and social groups (CEPF, 2008). The protection of forest and wildlife is of top priory due to the climate change, global warming and green house gaseous emission.

Given lacking qualitative and quantitative data on various underutilized fruits in WG of Kerala, objective of this study were: (1) to identify and characterize important underutilized and neglected fruits and (2) to determine Vitamin C content in them.

MATERIALS AND METHODS

Study Area

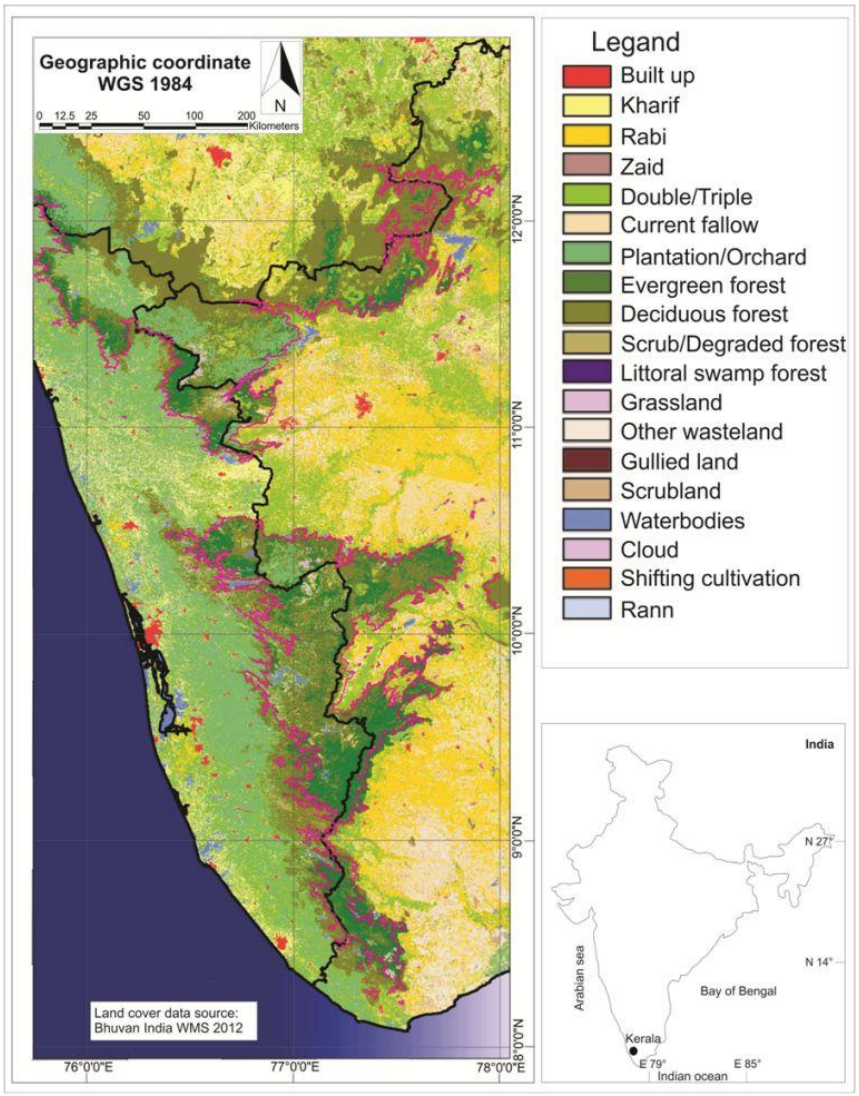

Figure 1: Map of Western Ghats (Kerala) showing the various land use management system during 2012 (after Lockwood, 2012)

Kerala state covers an area of 38,863 km^2 with a population density of 859 per km^2 and spread across 14 districts. The climate is characterized by tropical wet and dry with average annual rainfall amounts to 2,817 ± 406 mm and mean annual temperature is 26.8°C (averages from 1871-2005; Krishnakumar *et al.*, 2009). Maximum rainfall occurs from June to September mainly due to South West Monsoon and temperatures are highest in May and November (Figure 2).

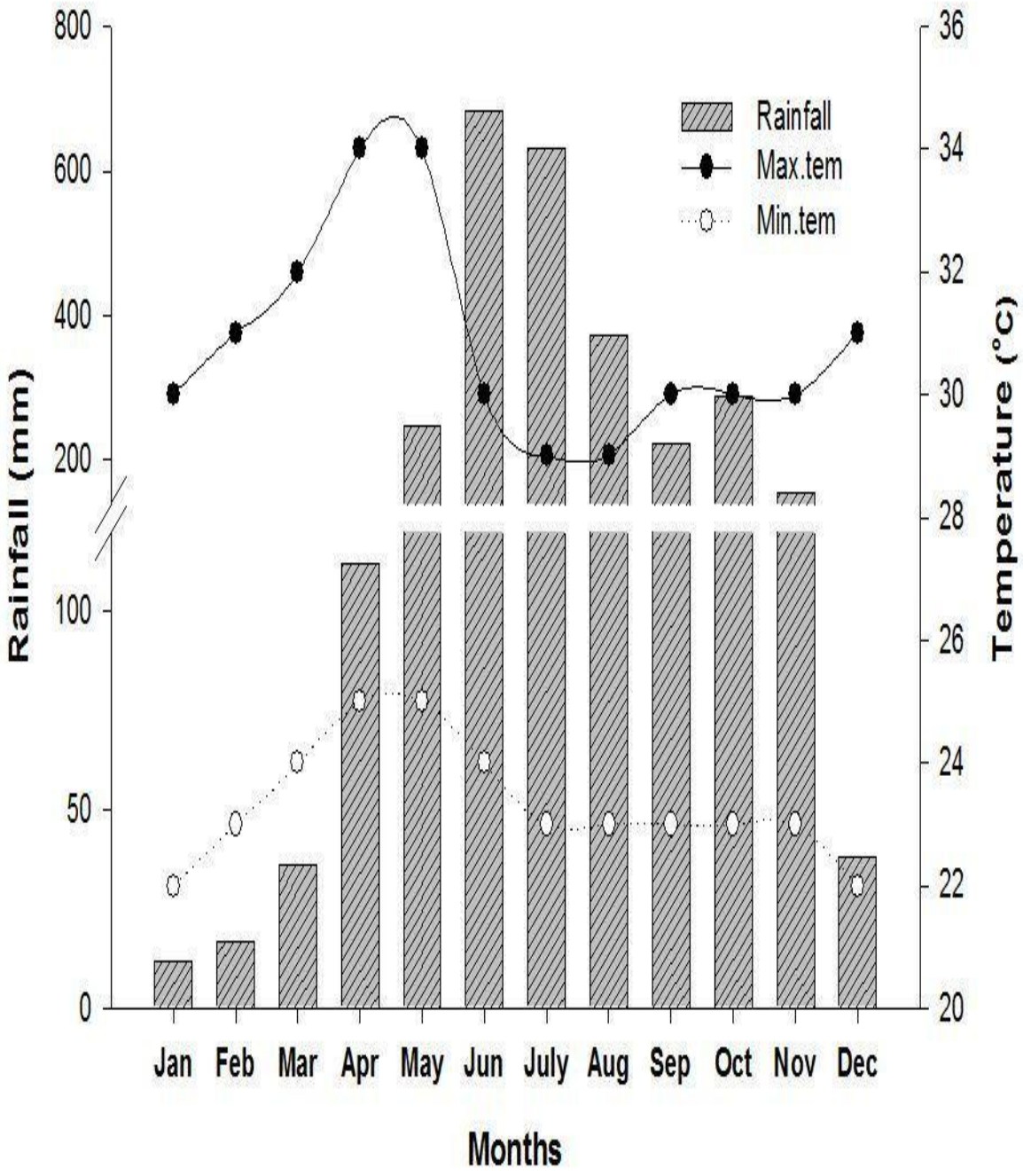

Figure 2: Mean monthly rainfall (mm), maximum and minimum temperatures (°C) in Kerala, India (1871-2005; Krishnakumar *et al.*, 2009)

Figure 3: Selected neglected and underutilized fruit trees from Western Ghats of Kerala: (Coffee); (top left), Bilimbi; (top right), wild orange; (middle left), wild lemon; (middle right), Indian gooseberry; (bottom left), Pepper; (bottom right) Photo courtesy; keralabiodiversity.org

History of Farming in Western Ghats of Kerala

After the famous voyages of Christopher Colombus and Vasco da Gama, the strategic and economic expansion of Europe was the driving force for domestication of non indigenous plants in colonial countries. Transformations happened in forest and grass lands leading to expansion of settled agriculture with an elaborate system of resource extraction and allocation of crops. Recent studies by Moench (1991) show that these expansions happened in early phase (1750-1860), plantation era (1860-1940) and settlement phase (1940-1965). It is estimated that during and after the colonial period (British East India Company) from 1890 to 1970, that 30 million hectares of forest and grassland were transformed to crop production and settlement areas (Richards et al., 1985; Tucker, 1988). The villages adjoining the forest bound regions struggle to maintain their existence, but successful in expanding their agriculture rather than maintaining the forest resources. By 1947 India's forest resources were completely depleted by

expanding crop production, commercial timber operations as well as plantation cropping targeted for European markets (Tucker, 1988).

The World War II brought major changes in the utilization of forest resources, with increase in timber production and fuel wood cutting. The war brought major changes in Assam, Himalaya region and WGs. After British annexation of Malabar in 1792 as a part of Madras Presidency, Travancore and Cochin (independent princely states in Kerala) still remained autonomous throughout British era. The European trade connection with Kerala cost started since 1500's, the international demand and market need more exotic plants to be introduced to Kerala. Massive forest clearance began during 1830 with appearance of plantation mono-crops especially coffee followed by tea. These biotic transformations were accompanied by social transformations including local farmer's as well as contract labourers (Moench 1991; Tinker, 1993).

With the issue of granting waste or uncultivated hill lands to planters by Travancore government during 1860's, British officers found as a good way of investment in virgin lands of Travancore hills. The typical example is John Daniel Munro (British resident) established estates in the Peermade hills in the 1860's (Moench, 1991; Tinker, 1993).

The increasing market for rubber products led to establishment of rubber (*Hevea brasiliensis*) plantations in Travancore in 1904 and continued spreading to other regions. The World War I rubber market even makes much faster expansion of the trees. Initially the rubber was to supply the demands of European market but later changed to a domestic market after independence. During the 1940's the extensive food shortage occurred throughout Travancore and the Government opened forest lands on an emergency basis for food cultivation (Moench, 1991) especially tapioca (*Manihot esculenta* Crantz) and other tuberous crops (Ninan, 1986). Mass migrations by Syrian Christians occurred during this period and many people died by Malaria (Shivaswamy, 1945; Varghese, 2006; Tauger, 2009). These cultivation rights given to them were known as 'Kuthakapattam' and up to five acres of land were distributed for food cultivation on short term lease where large forest area were opened (Moench, 1991).

The WG region of Kerala State covers 450 km (28.1%) of its total length and 31 out of 63 taluks in the State. This accounts for 72% of the total geographical area of the State and around 50% of the State population (DPEA, 2012). The population density in this region is 565 persons per km2 compared to the State average of 859 per km2 (Census, 2011).

Kerala has a vast group of ethnic tribes comprised of mixed races of Dravidian, Arayan, Mediterrranean, Polynesian and other origins. The forest WG were occupied by 38 tribal groups mainly Cholanaikkens, Pathinaikkens, Irular, Adiyan, Kuruman, Paniyan, Kurichan, with a total population of 0.2 million (Pushpangadan and Atal, 1984). The importance of agro-forestry practices by the farmers near to WG regions were already recognized and appreciated (Nair and Sreedharan, 1986; Kumar *et al.*, 1994).

From the beginning of 1970s, the area under rice production begin decline due to the shift of land from annual cultivation to perennial tree crops (Table 1). The major agricultural problems in Kerala includes, declining profitability of crops, market price fluctuations, uneconomic size of operational holding, shortage of farm laborer, high price of land and its conversion.

Bilimbi (Averrhoa bilimbi L.)

Bilimbi, is a fruit-bearing tree of the genus *Averrhoa*, family Oxalidaceae. It is a close relative of carambola tree. Tree reaches 5-10 m in height. Its trunk is short and quickly divides up into ramifications. Bilimbi leaves, 3-6 cm long, are alternate, imparipinnate and cluster at branch extremities. There are around 11 to 37 alternate or subopposite oblong leaflets.

Indian Plum (Flacourtia Rukam)

It is a small shrub or tree that grows to a height of 10m. It produces small white to green fragrant flowers. The fruit is eaten both raw and cooked as a jam, and the bark is sometimes used medicinally. Indian plum, is a lowland and mountain rain forest tree in the Salicaceae or Willow Family. It is widely cultivated in Southeast and East Asia, and has escaped cultivation in a number of places its wild origin is unknown but is speculated to be tropical Asia, perhaps India. It is sometimes harvested for its lumber. The plant is considered one of the primary host plants of the Queensland fruit fly *(Bactrocera tryoni)*.

Gooseberry (Emblica Officinalis)

A deciduous tree of the family Phyllanthaceae. The fruit is nearly spherical, light greenish yellow, quite smooth and hard on appearance, with six vertical stripes or furrows. The tree is small to medium in size, reaching 8 to 18 m in height, with a crooked trunk and spreading branches. The branchlets are glabrous or finely pubescent, 10-20 cm long, usually deciduous; the leaves are simple, subsessile and closely set along branchlets, light green, resembling pinnate leaves. The flowers are greenish-yellow. The taste of Indian gooseberry is sour, bitter and astringent, and it is quite fibrous.

Sample Collection

Samples were collected based on an elaborative literature survey as well as traditional knowledge. A total of 10 samples were collected in different regions of the Kerala from January 2015 to February 2015. Locations of the sample collection areas were recorded using a Trimble Geoexplorer II (Trimble Navigation Ltd, Sunnyvale, California) and data were transferred using GPS Pathfinder Office software (Trimble Navigation Ltd, Sunnyvale, California). Following samples were selected for Vitamin C content analysis.

Table 1: Area under major crops in Kerala from 1960-2004. Values are presented in '000 hectare. Adapted from (Planning commission, 2008)

Crop	Scientific name	1960-61	1975-76	1995-96	2003-04
Rice	*Oryza sativa* L	779	876	471	287
Coconut	*Cocos nucifera* L	501	693	914	906
Tapioca	*Manihot esculenta* Crantz	242	327	114	111
Rubber	*Hevea brasiliensis*	136	212	449	476
Pepper	*Piper nigrum* L	100	108	192	207
Cashewnut	*Anacardium occidentale* L	54	109	103	88
Arecanut	*Areca catechu* L	54	77	71	93
Banana	*Musa acuminata* L	44	52	73	107
Tea	*Camellia sinensis* (L.) Kuntze	38	38	37	37
Cardamom	*Elettaria cardamomum*	29	54	44	32
Coffee	*Coffea arabica* L, *Coffea canephora*	17	42	82	85
Ginger	*Zingiber officinale*	12	12	13	9
Total cropped area		2319	2981	3067	2976

Table 2: Sectoral growth rate of Kerala economy (1970-71 to 2007-08). Adapted from (Kannan, 2011)

Sector	1970-71 to 1983-84	1984-85 to 1996-97	1997-98 to 2007-08	Overall (1970 to 2008
Primary: agriculture	-0.24	4.64	0.21	1.67
Primary: non-agriculture	-1.88	3.52	1.75	0.48
Secondary sector	3.49	7.25	9.08	5.20
Tertiary sector	3.35	6.15	9.78	6.07

Pepper (Pepper Nigrum)

Pepper is often described as the "king of spices," and it shares a place on most dinner tables with salt. The word pepper originated from the Sanskrit word pippali, meaning berry. The various species of Piper are grown mostly as woody shrubs, small trees, and vines in the tropical and subtropical regions of the world.

The hot taste sensation in pepper comes from a resin called chavicine in the peppercorns. Peppercorns also are the source of other heat-generating substances, including an alkaloid called piperine, which is used to add the pungent effect to brandy, and an oil that is distilled from the peppercorns for use in meat sauces. As a natural medicinal agent, black pepper in tea form has been credited for relieving arthritis, nausea, fever, migraine headaches, poor digestion, strep throat, and even coma. It has also been used for non-medical applications as an insecticide. Of course, black pepper is a favorite spice of cooks because of its dark color and pungent aroma and flavor.

Coffee (Coffea Canephora)

Coffee, beverage brewed from the roasted and ground seeds of the tropical evergreen coffee plant of African origin. It is consumed either hot or cold by about one-third of the people in the world, in amounts larger than those of any other drink Its popularity can be attributed to its invigorating effect, which is produced by caffeine, an alkaloid present in green coffee in amounts between 0.8 and 1.5 percent for the Arabica varieties and 1.6 to 2.5 percent for Robusta.

Wild Orange (Citrus × Sinensis)

Orange is a small trees or shrubs of the genus *citrus* of the family Rutaceae and their nearly round fruits, which have leathery and oily rinds and edible, juicy inner flesh. The species of orange most important commercially are the China orange, also called the sweet, or common, orange; the mandarin orange, some varieties of which are called tangerines; and the sour, or Seville, orange, which is less extensively grown. The tree of the sweet orange often reaches 6 m (20 feet) and sometimes 10 m. The broad, glossy, evergreen leaves are medium-sized and ovate; the petioles (leafstalks) have narrow wings. Its flowers are very fragrant. The usual shape of the sweet-orange fruit is round and the color of its pulp orange, but there are variations. The mandarin, for example, is distinctly flattened, and the blood orange has red pulp. The pulp of the sweet orange is agreeably acidulous and sweet, the peel comparatively smooth, and the oil glands convex.

Wild Lemon (Citrus limon)

Lemon is a small tree or spreading bush of the rue family (Rutaceae) and its edible fruit. Its young leaves have a decidedly reddish tint; later they turn green. In some varieties, the young branches of the lemon are angular; some have sharp thorns at the axils of the leaves. The flowers have a sweet odor and are rather large, solitary or in small clusters in the axils of the leaves. Reddish-tinted in the bud, the petals are white above and reddish purple. The fruit is oval with a broad, low, apical nipple and 8 to 10 segments. The outer rind, or peel, yellow when ripe and rather thick in some varieties, is prominently glandular-dotted. The seeds are small, ovoid, and pointed; occasionally, fruits are seedless. The pulp is decidedly acid. The predominant acid present is citric acid, which may amount to 5 percent or more by weight of the lemon's juice. Lemon juice is rich in vitamin C and contains smaller amounts of the B vitamins, particularly B1, B2, and niacin.

Vitamin C Standard

Vitamin C standard were prepared using two pharmaceutical samples procured from a local drug store. The tablets were finely grounded using a pestle and mortar stored in plastic vials till analysis. Standard stock solutions were prepared by dissolving the finely powered samples to give a concentration of 1 mg per ml. The titration values from the standard solution were used for the further calculations.

Sample Preparation

Freshly collected fruit samples were washed with distilled water with skin and seeds removed. The samples were chopped to small pieces and later made into pulp with 20 ml distilled water using a tissue homogenizer.

Determination of Vitamin C

The Vitamin C contents were measured using the redox titration method of potassium dichromate with starch as indicator (Roe and Kuether, 1943; Bessey and King, 1933). When iodine solution is a titrant, vitamin C is oxidized to form dehydroascorbic acid while the iodine is reduced to iodide ions. When all vitamin C has finished, the excess iodine solution will react will starch solution to form blue-black color as endpoint of titration. The formation of a pale blue color was considered as the end point of titration.

Statistical Analysis

The survey results were analyzed and descriptive statistics were done using SPSS 12.0 (SPSS Inc., an IBM Company, Chicago, USA) and graphs were generated using Sigma Plot 7 (Systat Software Inc., Chicago, USA).

RESULTS AND DISCUSSION

Vitamin C Concentration using Redox Titration

The vitamin C content among various fruits ranged from 2.54 ± 0.72 to 12.73 ± 3.60 mg/g of fresh fruit weight. Highest vitamin C were reported in sample 6 (Indian gooseberry) while least sample 5 and 6.

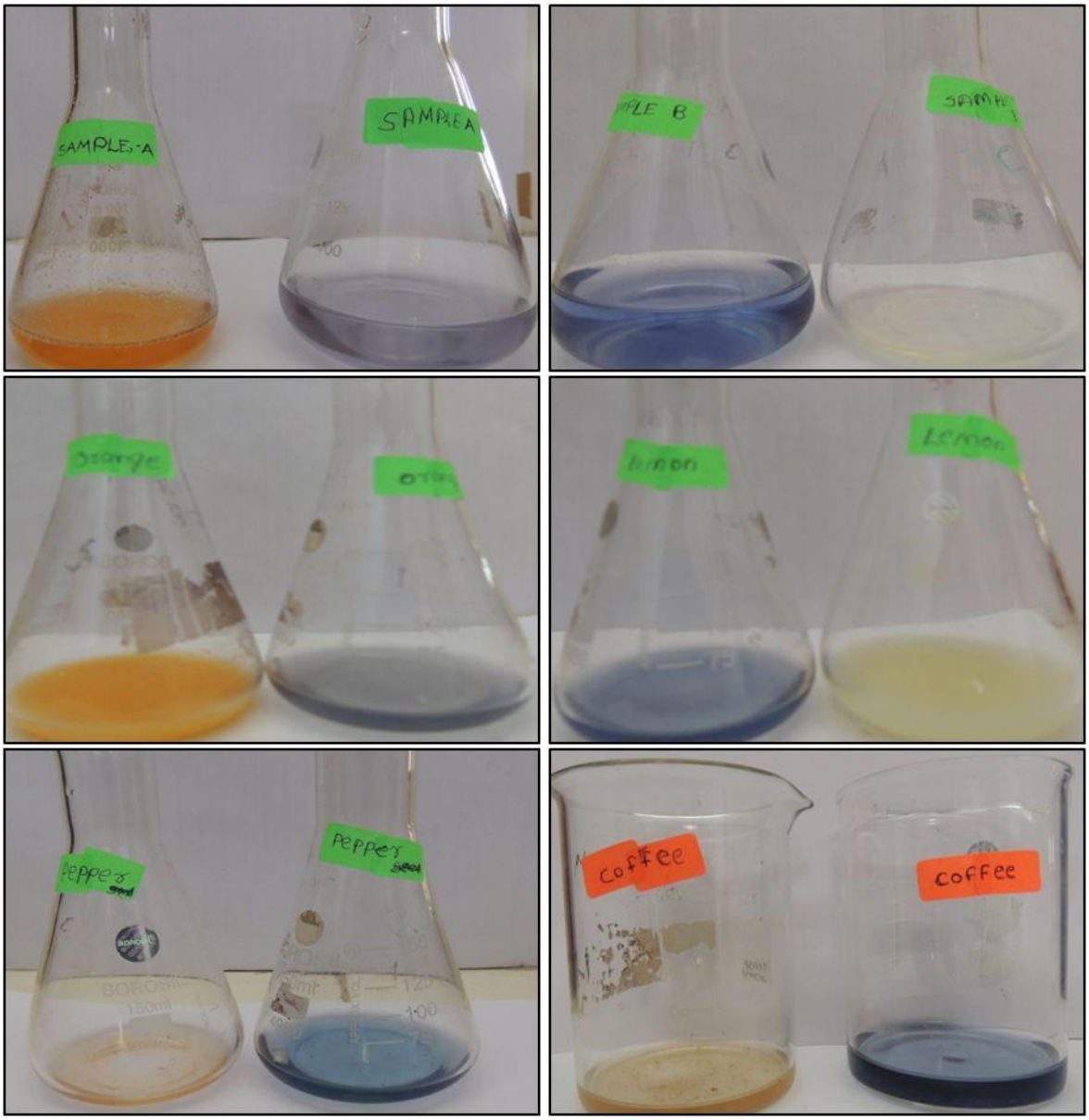

Figure 4: Redox titration of neglected and underutilized fruit trees from Western Ghats of Kerala: sample 1-vitamin tablet 1; (top left), sample 2-vitamin tablet 2; (top right), sample 3-wild orange; (middle left), sample 4-wild lemon; (middle right), sample 5-pepper; (bottom left), sample 6-coffee; (bottom right)

Table 3: Redox titration values and concentration of vitamin C (n=3, mean ± one standard deviation) in various underutilized and neglected fruits in Western Ghat region of Kerala

Samples	Burette volume (ml)	Concentration (mg/g)
Sample 1 (tablet 1)	22.46 ± 0.46	1.14 ± 0.07
Sample 2 (tablet 2)	35.46 ± 0.46	1.13 ± 0.12
Sample 3 (wild orange)	1.40 ± 0.69	5.09 ± 1.44
Sample 4 (wild lemon)	0.63 ± 0.05	3.20 ± 1.12
Sample 5 (pepper)	0.53 ± 0.05	2.54 ± 0.72
Sample 6 (coffee)	0.53 ± 0.05	2.54 ± 0.72
Sample 7 (Indian gooseberry)	2.66 ± 0.28	12.73 ± 3.60
Sample 8 (Indian plum)	0.53 ± 0.05	2.54 ± 0.72
Sample 9 (bilmbi)	0.53 ± 0.05	2.54 ± 0.72

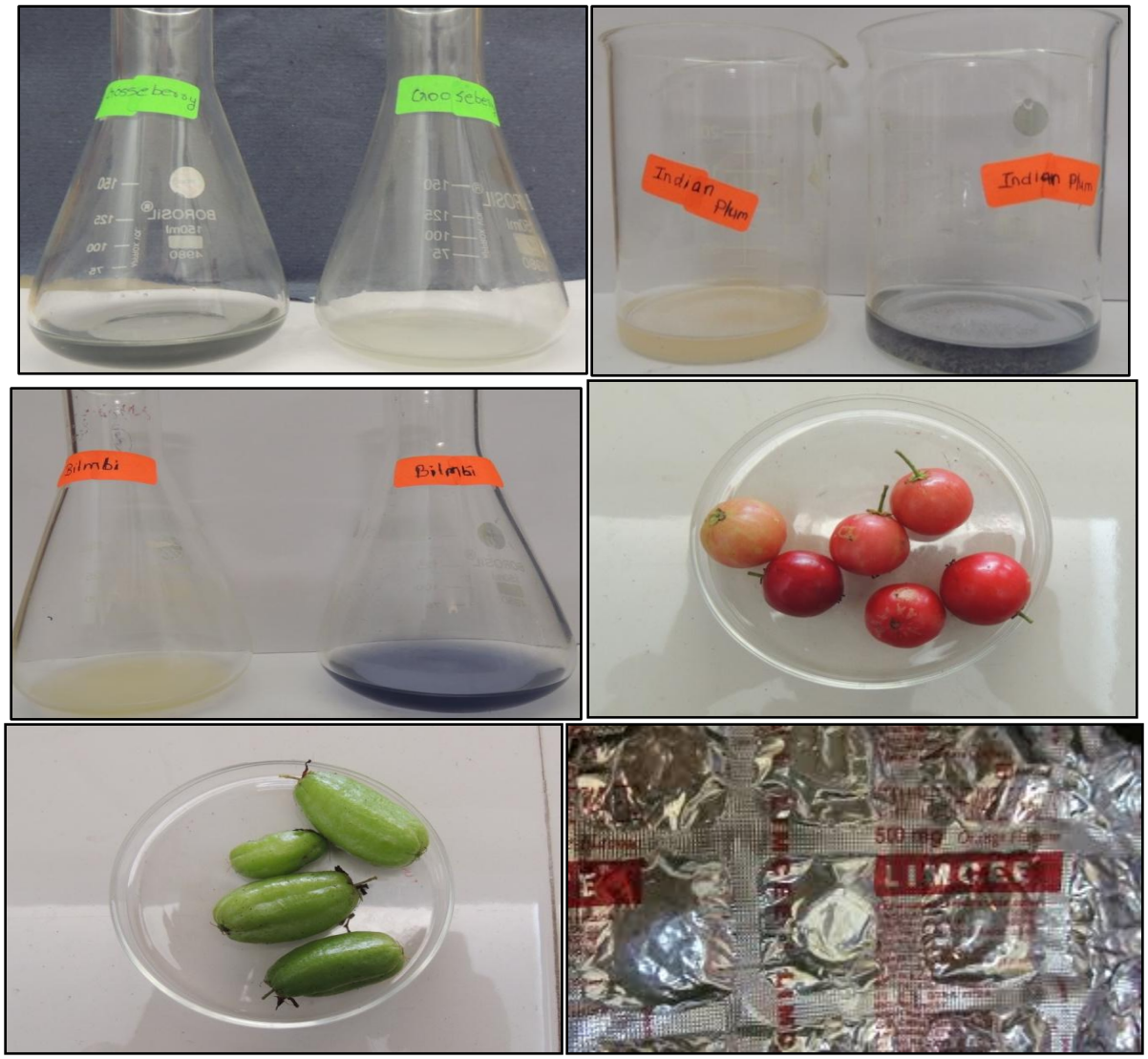

Figure 5: Redox titration of neglected and underutilized fruit trees from Western Ghats of Kerala: sample 7-Indian gooseberry; (top left), sample 8-Indian plum; (top right), sample 9-bilimbi; (middle left), ripe and unripe Indian plum; (middle right), Bilimbi; (bottom left), vitamin C tablets; (bottom right) Photo courtesy; fitnessvsweightloss.com

Table 4: Details of the underutilized and neglected fruits produced in different production systems across the Kerala State (UG: Urban Garden; F: Farm; HG: Home Garden)

Serial No	Common name (English)	Local name (Malayalam)	Botanical name	Production system
1	Bilimbi	Ilumpanpuli	*Averrhoa bilimbi L.*	UG, HG
2	Indian Plum	Shemmanellika	*Flacourtia rukam*	UG, HG
3	Goose berry	Neelika	*Emblica officinalis*	UG, HG
4	Pepper	Kurumulaku	*Pepper nigrum*	F, HG
5	Coffee	Kappi	*Coffea canephora*	F, HG
6	Wild orange	Madhuranaranga	*Citrus × sinensis*	HG
7	Wild lemon	Vadukapullinaranga	*Citrus limon*	HG

Vitamin C is a highly water-soluble compound that has both acidic and strong reducing properties. It naturally occurs in many plants and animals except in humans. Vitamin C is an essential nutrient in humans as it functions as a cofactor in several vital enzymatic reactions. The richest natural sources of Vitamin C are fruits and vegetables, for example, blackcurrant, blueberry, orange, lime, lemon, strawberry, cabbage and malt. Underutilized or neglected fruit trees were considered to be an important role in mitigating malnutrition and poverty in developing and under developed countries. These fruit trees may be neglected due to ignorance, lack of knowledge, availability, difficulty in harvesting and storage.

Most of these fruits are rich in vitamins, antioxidants, organic acids, carotenoids and phenolic contents (Ikram *et al.,* 2009; Khoo *et al.,* 2008; Loganayaki and Manian, 2010; Pande and Akoh, 2010; Kubola *et al.,* 2011; Gordon *et al.,* 2011; Vuong, 2000). The Western Ghats in Kerala provide a diversity of fruit trees where majority of them remains neglected or underutilized (Kumar, 2008; Nazarudeen, 2010; Sasi *et al.,* 2011). Even though pepper and coffee were commercial cash crops, but they remain neglected in their use as fresh fruits. In my current research work, the presence of vitamin C contents in studies various underutilized fruits samples (Bilimbi, Gooseberry, Indian plum, Coffee and Pepper) seems a promising result for them as a food supplement which reduce malnutrition in marginalized poor community.

Conclusion

The research work highlights the importance Vitamin C contents of various neglected and underutilized fruits from Western Ghat region in Kerala. These underutilized fruit trees can be further explored to reduce malnutrition. However elaborate research should be conducted to reveal the other nutritional parameters (protein, carbohydrates, fats, fibers, minerals and other vitamins) for the effective utilization and biodiversity preservation these species.

ACKNOWLEDGEMENT

The author is grateful for the cooperation of the management of Mar Augusthinose college for necessary support. Technical assistance from Binoy A Mulanthra is also acknowledged. We also thank an anonymous farmer for proving the majority of samples used in the study.

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