Tropical Root and Tuber Crops in Human Nutrition

भाकृअनुप-केन्द्रीय कन्द फसल अनुसंधान संस्थान
(भारतीय कृषि अनुसंधान परिषद)
श्रीकार्यम, तिरूवनन्तपुरम 695 017, केरल,भारत

ICAR-Central Tuber Crops Research Institute
(Indian Council of Agricultural Research)
SREEKARIYAM, THIRUVANANTHAPURAM 695 017, KERALA, INDIA

TB-102/2024

Tropical Root and Tuber Crops in Human Nutrition

भाकृअनुप-केन्द्रीय कन्द फसल अनुसंधान संस्थान
(भारतीय कृषि अनुसंधान परिषद)
श्रीकार्यम, तिरूवनन्तपुरम 695 017, केरल,भारत
ICAR-Central Tuber Crops Research Institute
(Indian Council of Agricultural Research)
SREEKARIYAM, THIRUVANANTHAPURAM 695 017, KERALA, INDIA

Diamond Jubilee of ICAR-CTCRI

ICAR-Central Tuber Crops Research Institute
Sreekariyam, Thiruvananthapuram 695 017
Kerala, India
Tel.No. : (91) (471) 2598551 to 2598554
E-mail: director.ctcri@icar.gov.in
Website: https://www.ctcri.org

Published by
Dr. G. BYJU
Director

Compiled and edited by
Dr. A.N. Jyothi

July 2024

Correct Citation
Jyothi, A. N. 2024. *Tropical Root and Tuber Crops in Human Nutrition*, Technical Bulletin No.TB-102/2024, ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala, India, 34 p.

Design, Layout & Printing
Aden Digital Signage, Thiruvananthapuram,
Mob: 9605206323

ICAR-Central Tuber Crops Research Institute

(Indian Council of Agricultural Research)

Sreekariyam 695 017, Thiruvananthapuram, Kerala, India

From the Director

Tropical root and tuber crops hold significant potential to meet the growing global food demand, offering climate resilience, better performance in marginal and degraded soils, high biological efficiency, and rich dietary energy and micronutrient contents. These crops provide sustenance for the ever-expanding population and address malnutrition among resource-challenged communities.

The technical bulletin on ‘Tropical Root and Tuber Crops in Human Nutrition’ aims to shed light on the nutritional aspects of tropical tuber crops, emphasizing their significance beyond just their high carbohydrate content. The research and insights encapsulated in this book are the results that combine the expertise of the scientists and researchers of ICAR-CTCRI dedicated to unravelling the intricacies of tuber crops nutrition. The focus on micronutrients, vitamins, minerals, and bioactive phytonutrients such as phenolics, flavonoids, and mucilages suggests a broader perspective on their health benefits. By addressing antinutritional factors, the book aims to provide insights into potential challenges and considerations during the processing of these.

The book is intended to be a useful resource for readers, encouraging a deeper appreciation for the nutritional treasures within tropical tuber crops and calls for collective efforts to promote a healthier and more resilient world.

01 July 2024

G. Byju

Contents

Tropical Root and Tuber Crops in Human Nutrition

Introduction

Tropical root and tuber crops are considered as the third most important crops after cereals and grain legumes. These crops play an important role in food security, nutrition and climate change adaptation. The major tuber crops include cassava (*Manihot esculenta* Crantz), sweet potato (*Ipomoea batatas* (L.) Lam., different species of yams (*Dioscorea L.*), taro (*Colocasia esculenta* (L.) Schott), tannia (*Xanthosoma sagittifolium* (L.) Schott) and elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson). There are many species under *Dioscorea,* although the edible yams widely consumed are *D. alata* (greater yam), *D. esculenta* (lesser yam) and *D. rotundata* (white yam). There are several minor tuber crops *viz*., Chinese potato (*Plectranthus rotundifolius* Poir), yam bean (*Pachyrhizus erosus),* West Indian arrowroot (*Maranta arundinacea* L.), East Indian arrowroot (*Curcuma angustifolia*) and Queensland arrowroot (*Canna edulis*). Three species of yam bean, *P. erosus* (jicama or Mexican yam bean), *P. tuberosus* (jíquima, chuin or Amazonian yam bean) and *P. ahipa* (ahipa) are cultivated and among these, *P. erosus* is popular in India.

These crops are important to agriculture, food security and income for 2.2 billion people in the developing countries. Roots and tubers have many advantages as food crops for household food security as they have a higher biological efficiency and the highest rate of dry matter production per day per unit area among all the crops. These crops contain micronutrients such as vitamins and minerals, antioxidants and many bioactive compounds. Tuber crops provide a vast scope for diversification and value addition, offering a great opportunity for non-traditional uses within the country and for exports.

In the context of climate change, tropical root and tuber crops, rich in calories and nutrients, have immense scope to become the future crop for combating poverty, hunger and malnutrition. In view of the climate resilience, better performance in marginal and degraded soils, high biological efficiency, high dietary energy and micronutrient contents, tropical root and tuber crops have great potential to combat the future food requirements to feed the ever-growing population and to meet the malnutrition among the resource poor people. Besides being rich sources of carbohydrates, most of these crops are rich in minerals such as calcium and phosphorus as well as vitamins, especially vitamin C. Potassium is the major mineral in most root crops while sodium tends to be low. This makes them particularly valuable in the diet of patients with high blood pressure, who have to restrict their sodium intake. The protein content is very low and sulphur-containing amino-acids are the limiting amino acids in almost all root crop proteins. In general, the proteins are deficient in cystine and methionine and most of them in lysine and leucine as well. High amounts of arginine is present in proteins of most of the tuber crops with the exception of sweet potato. The protein content of roots and tubers varies widely and in yams it is the highest, being approximately 2.1% on a fresh weight basis. All these crops also have very low lipid contents. The orange and yellow fleshed tuber and green leaves are good sources of beta carotene, which can prevent night blindness and malnutrition. Some of the tuber crops like elephant foot yam, *Curcuma* sp. and Chinese potato have medicinal properties. In contrast to tubers, the leaves of tuber crops are very rich in protein. The leaves contain good amounts of micronutrients such as iron, calcium and vitamins. The leaves contain a substantial amount of β-carotene that could contribute significantly to the daily requirement of vitamin A, especially for children. Some of the tuber crops contain anti-nutritional factors, which can be effectively removed by resorting to proper processing techniques.

In this book, the proximate composition and nutritional properties of different major and minor tuber crops are discussed along with their nutrient value.

Proximate Composition and Nutritional Profile of Cassava

1. Cassava tubers

Cassava (tapioca) (Fig. 1)is a major root crop cultivated and utilized by around 102 countries of the tropical and sub-tropical regions of the world . Cassava bags the fifth position globally for its importance as a significant food crop after maize, rice, wheat, and potato and its starchy tuberous roots serve as staple for over 800 million people (FAO 2018). The major biochemical constituent in cassava is the storage carbohydrate, starch, which constitutes up to 65-70% of the dry matter . The tubers also contain sugars, minerals, vitamins, fat, fibre and protein in very low quantities (Table 1). The tubers contain very low amounts of protein (0.3 - 1.5%) and fat (< 1% on fresh wt. basis). Cassava roots are high in potassium and vitamin C. It also contains most of the B-vitamins (except B12), vitamin A, and minerals such as magnesium, calcium and iron.

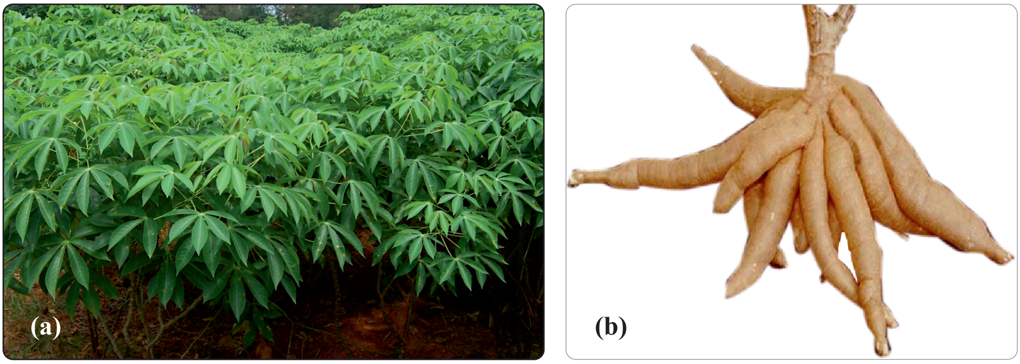


Fig. 1. (a) Cassava plant and (b) Tuber

Some cultivars of cassava have cream or yellow flesh colour and they contain appreciable amounts of beta carotene (Fig. 2). The varieties, Sree Vijaya and Sree Swarna released from ICAR-CTCRI are early bulking (6-7 months) and have yellow fleshed tubers.

Fig. 2. Flesh colour variation in cassava tubers

Table 1. Proximate composition, nutritional profile and nutrient value of cassava tubers (100g fresh tuber)

Principle	Unit	Content	Percentage of RDA from 100g*
Food energy	kcal kJ	150-200 627.6-836.8	8
Proximate composition			
Moisture	g	64.8-85.3	-
Dry matter	g	29.8-39.3	-
Carbohydrates	g	25.3-39.0	29
Protein	g	0.2-1.5	2.6(F**) 3.2 (M**)
Fat	g	0.15-0.5	1.0
Starch	g	24.0-38.0	-
Sugar	g	0.9-1.3	-
Fibre	g	0.08-0.50	1.3
Ash	g	0.4-1.7	-
Vitamins			
Thiamine	mg	0.03-0.28	7
Vitamin B6	mg	0.05-0.1	6
Riboflavin	mg	0.03-0.06	4
Niacin	mg	0.60-1.09	5
Vitamin C	mg	15-50	26 (M) 22 (F)
Minerals			
Phosphorus	mg	9-40	3.5
Calcium	mg	32-55	4.5 (M) 3.8 (F)
Magnesium	mg	18-27	7 (M) 5 (F)
Iron	mg	0.20-0.35	3.5 (M) 1.56 (F)
Manganese	mg	0.02-0.08	2.17 (M) 2.77 (F)
Zinc	mg	0.12-0.24	1.45 (M) 2 (F)
Potassium	mg	98-326	-
Sulphur	mg	30-38	-

*Based on data from U.S. Food and Drug Administration; Recommended Dietary Allowance (RDA); National Institutes of Health, U.S. Department of Health & Human Services; USDA National Nutrient database; ICMR-NIN, 2020 **M - Male; F- Female

The nutrient value of cassava tubers is presented in Table 1. Hundred grams of fresh raw cassava tubers contribute to about 8% of RDA in terms of energy requirement and 29% of RDA of carbohydrates in healthy adults. The RDA of protein and fat are very low with 2.6-3.2% and 1%, respectively, whereas the tubers meet the vitamin C requirement adequately with RDA of 22-26%.

2. Cassava leaves

Evern though cassava leaves (Fig. 3) are not used as human food in India, they are consumed as a vegetable in several countries in sub-Saharan Africa and Asian countris such as Malaysia, Indonesia and Philippines (Bokanga, 1994; Achidi et aal., 2005; Arnieyantie et al., 2012; Latif and Müller, 2015). In countries such as Zaire, Congo, Tanzania, Sierra Leone, Nigeria and Guinea, cassava leaves constitute a major component of the diet as a vegetable. The antinutrient cyanogenic glucosides present in cassava leaves in large quantities make them toxic and restrict their use as a human food.

The proximate and nutritional composition of cassava leaves is presented in Table 2. Cassava leaves contain good amounts of protein, minerals, and vitamins. The major minerals are phosphorus, potassium, calcium, and magnesium. Sulphur, iron, manganese, zinc, copper, and sodium are present in low quantities. The leaves contain the vitamins, B1, B2, C and carotenoids.

Fig. 3. Cassava leaves

Table 2. Proximate composition and nutritional profile of fresh cassava leaves (100g)

Principle	Unit	Content	Percentage of RDA from 100g
Food energy	kcal kJ	91.0-97.0 380.7-405.8	4.2
Proximate composition			
Moisture	g	75.0-82.0	-
Dry matter	g	19.0-28.3	-
Carbohydrates	g	5.0-8.0	5.8
Protein	g	4.6-8.3	13.4 (M) 16.3 (F)
Fat	g	0.6-1.25	3.3
Dietary fibre	g	1.0-3.0	6.6
Ash	g	2.5-3.0	-

Vitamins			
Thiamine	mg	0.02-0.31	16.7
Riboflavin	mg	0.10-0.74	38.5
Niacin	mg	1.3-2.8	12.5
Vitamin C	mg	34-70	55.6 (M) 66.7 (F)
Minerals			
Phosphorus	mg	31-95	8.5
Calcium	mg	225-455	30
Magnesium	mg	52-98	14.3 (M) 19.3 (F)
Iron	mg	4.5-7.0	75 (M) 33 (F)
Manganese	mg	1.6-6.1	69.6 (M) 88.9 (F)
Zinc	mg	1.4-3.3	18.1 (M) 25.0 (F)
Potassium	mg	142-405	-
Copper	mg	0.25-0.41	-
Sulphur	mg	4.4-9.5	-
Boron	mg	0.45-1.2	-

3. Antinutritional factor in cassava and processing to eliminate it

All parts of cassava leaves, stem, tuber and rind contain the compounds called cyanogenic glucosides viz., linamarin and lotaustralin (in the ratio of about 93:7), which are hydrolysed by the endogenous enzyme linamarase to acetone cyanohydrin which may break down spontaneously liberating free hydrogen cyanide. Both acetone cyanohydrin and free cyanide are toxic compounds. These glucosides impart a bitter taste to fresh cassava tuber. Cassava cultivars are categorized based on cyanide content: low (<50 $\mu g\ g^{-1}$), medium (50-100 $\mu g\ g^{-1}$), and high (>100 $\mu g\ g^{-1}$ HCN eq.). Non-bitter tubers contain less than 100 $\mu g\ g^{-1}$ HCN equivalent, while bitter fresh roots range from 100-450 $\mu g\ g^{-1}$, and very bitter roots exceed 450 $\mu g\ g^{-1}$ HCN equivalent.

Cassava leaves contain about 10 times higher amount of cyanoglucosides than roots and the content decreases with the increase in the age of the leaves. Young emerging leaves contain highest levels (>400 $\mu g\ g^{-1}$ HCN eq.), while the mature and old leaves have 50% and 70% lower concentrations, respectively. The rind/peel of cassava tubers contains several times higher cyanoglucoside content than the edible part. Irrespective of whether it is a low or high cyanide variety, the range of hydrogen cyanide equivalents in cassava rind is about 600-1000 $\mu g\ g^{-1}$ ($mg\ kg^{-1}$) fresh wt. The linamarase activity is also very high (30-100 times higher) in leaf and rind tissues compared to the tuber. This enables faster conversion of the cyanoglucoside to free HCN, which is highly temperature-sensitive and escapes into the atmosphere at 28°C.

Consumption of cassava and its products that contain large amounts of cyanogens may cause cyanide poisoning with symptoms of vomiting, nausea, dizziness, stomach pains, weakness, headache, exacerbates goitre and diarrhoea. The World Health Organisation (WHO) has set the safe level of cyanogens in cassava flour at 10 ppm or 10 mg HCN per kg. In India, according to FSSAI standards (2017), the maximum permitted level of cyanide is 10 ppm in cassava flour and sago. Plant materials containing $\geq 200\ \mu g\ g^{-1}$ of cyanogenic glucosides are dangerous.

Traditional methods of processing such as cooking in excess water in open vessels, chipping and sun drying, and parboiling and drying eliminate or reduce the glucoside content to safer levels. Peeling, cutting into thin slices and cooking in large excess of water (1:5 or 1:10) for about 30 min can remove about 80% of cyanoglucosides. However, care should be taken to see that the pieces are put in water at room temperature and the temperature is slowly raised. This allows the enzyme to act on the cyanoglucosides (linamarase gets inactivated at 72°C) and eliminate them to the maximum extent. If bitter varieties of cassava with high cyanide contents are used, grating/pounding of the peeled tubers and sun drying is the most effective method to remove cyanoglucosides. This treatment can eliminate up to 95-99% cyanoglucosides. Such a practice is followed in the preparation of High-Quality Cassava Flour (HQF) for human consumption purpose in African countries, where cassava is a staple food. Development of fermented products such as gari, fufu etc is a very common practice in African countries as an effective method for cyanoglucosides elimination. Sun drying of the peeled tuber chips (10 mm thick) for about 18 hours removes more than 80% of cyanoglucosides. The thickness of tuber slices is important especially for high cyanide varieties as slow drying helps retain the water content, which is necessary as a substrate for the linamarase enzyme. Although thin chips dry faster, retention of cyanide is more due to the faster elimination of water.

Proximate Composition and Nutritional Profile of Sweet Potato

1. Sweet potato tubers

Sweet potato has assumed great significance in recent years as a health food due to various bioactive principles in its tubers. Sweet potato tubers combine the properties of cereals, fruits and vegetables owing to its content respectively of starch, pectin and vitamins. The flesh colour of sweet potato tubers ranges from white to dark orange and purple (Fig. 4). The nutrient composition of sweet potato roots varies widely, depending on the cultivar, growing conditions, maturity, and storage. The tubers are rich in carbohydrates, which consist of starch, sugars, small amounts of pectins, hemicelluloses and cellulose. The dry matter varies from 25.1-38.2% and starch comprises 50-80% of the dry matter (Table 3). Raw tubers contain 2.19-5.0% sugars, mainly sucrose, glucose, fructose and maltose. The major sugar is sucrose. In boiled tubers, the sugar content may increase up to 6-10% due to the breakdown of starch into maltose and dextrin by the heat-stable -amylase enzyme, which is also present in the tubers. The crude protein content in the roots is in the range of 1.3-1.6% and sporamin, a storage protein constitutes about 60-80% of it.

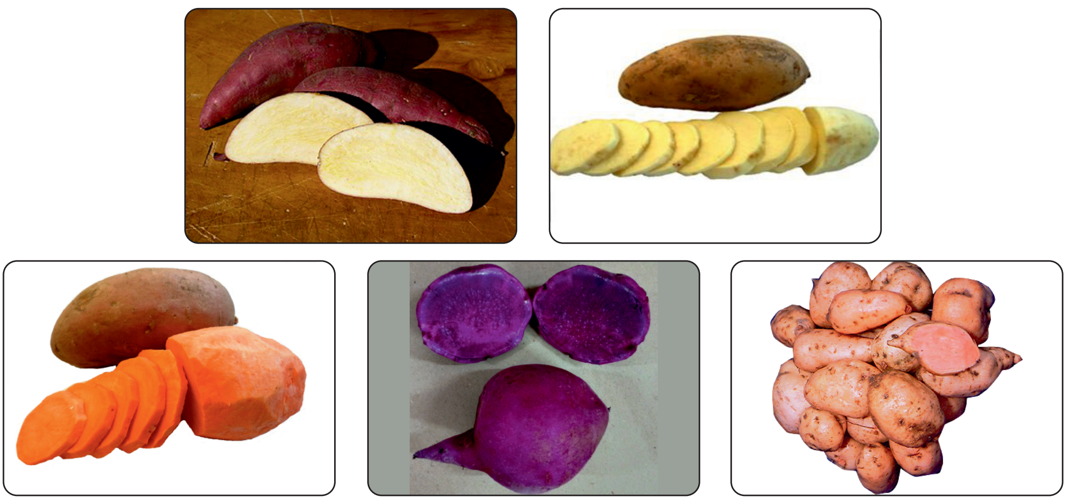


Fig. 4. Sweet potato tubers

Since sweet potato is a good source of non-starch polysaccharides, which play a significant role in the prophylaxis of various diseases such as colon cancer, diabetes mellitus, cardiovascular diseases, hypercholesterolaemia and obesity, its importance is increasingly recognized globally as a health promoting food. The major non-starch polysaccharides in sweet potatoes are cellulose, hemicellulose and pectins and these have the role of 'dietary fibre'. The raw sweet potato tubers contain on an average 1.8-3.0% dietary fibre and its 15-23% is the soluble fibre mostly pectin, and 77-85% is insoluble fibre consisting of cellulose, hemicellulose, and lignin. Dietary fibre plays an important role in the textural attributes such as firmness in the cooked sweet potatoes, while pectin has a role in the rheological properties of the tubers.

Table 3. Proximate composition, nutritional profile and nutrient value of sweet potato (100g fresh tuber)

Principle	Unit	Content	Percentage of RDA from 100g
Energy	kcal kJ	86.0-90.0 359.8-376.6	4.3
Proximate composition			
Dry matter	g	25.1-38.2	
Moisture	g	62.0-75.0	
Carbohydrates	g	18.0-28.0	15
Protein	g	1.3-1.6	2.8 (M) 3.5 (F)
Fat	g	0.40-0.70	1.6
Starch	g	16.0-25.0	-
Sugar	g	2.19-5.0	-
Dietary fibre	g	1.8-3.0	6.5
Ash	g	1.5-2.7	-
Vitamins			
Thiamine	mg	0.078-0.083	6.5
Vitamin B6	mg	0.21-0.32	17.0
Riboflavin	mg	0.061-0.072	4.7
Niacin	mg	0.58-0.61	3.6
Vitamin C	mg	11-34	13.0 (M) 16.0 (F)
Vitamin A	µg RAE (Retinol Activity Equivalents)	675	75.0 (M) 96.4 (F)
Total carotenoids	mg	0.05-14.0	-
Minerals			
Phosphorus		24-60	6
Calcium	mg	9-16	1.2 (M) 1.0 (F)
Magnesium	mg	5.7-14.3	3.2 (M) 2.4 (F)

Iron	mg	0.09-0.25	2.5 (M) 1.1 (F)
Manganese	mg	0.03-0.084	3.2 (M) 2.5 (F)
Zinc	mg	0.035 - 0.15	1.1 (M) 1.5 (F)
Potassium	mg	55-112	-
Sulphur	mg	3.9-12.3	-
Copper	mg	0.03- 0.06	-

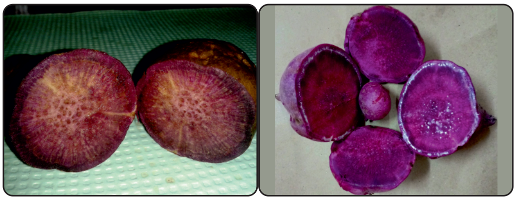
The nutrient value of 100g of sweet potato tubers is presented in Table 3. Hundred grams of sweet potato accounts for about 4.3% of RDA of energy, 15% of RDA of carbohydrates, 13-16% of RDA of vitamin C, and 17% of RDA of vitamin B6 in healthy adults. The orange fleshed sweet potato can meet about 75-96% of RDA of vitamin A depending on the carotene content.

2. Nutritional benefits of orange and purple fleshed sweet potatoes

The total carotenoids in cream, yellow and orange-fleshed tubers (Fig. 5a) range from 0.013-14 mg $100g^{-1}$ fresh wt. of tubers. It is low in sodium and a good source of fiber and other important vitamins and minerals. Since orange fleshed sweet potato (OFSP) is a good source of beta carotene, an essential antioxidant factor of food capable of reducing the risk from night blindness and certain types of cancer, its consumption is likely to help reduce the risk of certain cancers. Consumption of OFSPs, which is a cheap source of vitamin A could alleviate problems related to night blindness. Orange fleshed sweet potato can be recommended for nutritional security in tribal belts and noon meal programme for school children.

Purple fleshed sweet potatoes (Fig. 5b) are a good source of anthocyanins, the polyphenolic compounds known for their medicinal value as antioxidants and cancer preventing agents. The major anthocyanin pigments of purple variety are acetylated cyanidins and peonidins. Sweet potato anthocyanins have multiple physiological functions including radical-scavenging, anti-mutagenic, hepato-protective, anti-hypertensive, and antiproliferative activity against various human cancer cells. Traditional boiling enhances the phytochemical retention in sweet potato tubers.

(a)



(b)

Fig. 5. (a) Orange fleshed and (b) Purple fleshed sweet potato roots

3. Sweet potato leaves

Sweet potato leaves and tops are nutritious and are consumed in many parts of the world as a leafy vegetable. Sweet potato leaves are nutritionally similar to spinach and are a rich source of vitamins, minerals and protein (Fig. 6). Sweet potato leaves have high content of polyphenols also. The leaves contain 17.8-30.3% crude protein, 6.2-14.6 mg Ca, 0.15-0.16 mg iron, 750 mg carotene, and 11-27 mg vitamin C, per 100g fresh weight (Table 4). Sweet potato leaves are a good source of lutein, an eye-protectant xanthophyll. The lutein content is in the range of 38-58 mg per 100 g of fresh leaves, which varies depending on the variety. It is a yellow pigment which reduces the degeneration of the eye which leads to blindness in the elderly, and it also prevents cataract.

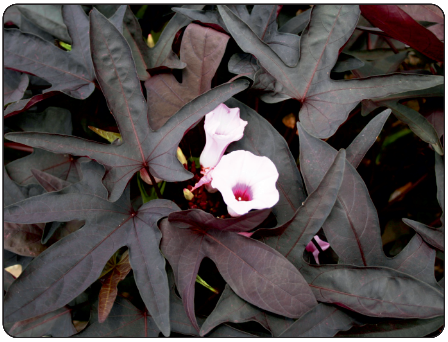


Fig. 6. Sweet potato leaves

Table 4. Proximate composition, nutritional profile and nutrient value of fresh sweet potato leaves (100g)

Principle	Unit	Content	Percentage of RDA from 100g
Energy	kcal kJ	19.4-60.0 81.2-251.0	2.0
Proximate composition			
Moisture	g	84.2-86.8	-
Dry matter	g	12.1-14.8	-
Carbohydrates	g	7.6-8.8	6.2
Protein	g	4.18-6.67	9.0 (M) 11.0 (F)
Fat	g	0.51-0.67	2.0
Dietary fibre	g	1.0-2.5	4.2
Total starch	g	0.35-0.43	-
Total sugars	g	0.20-0.27	-
Ash	g	1.71-2.05	-

Vitamins			
Thiamine	mg	0.156	13.3
Riboflavin	mg	0.345	26.0
Vitamin C	mg	11-27	26.6 (M) 22.2 (F)
Lutein	mg	38-58	-
Minerals			
Phosphorus	mg	6.4-17.6	1.7
Magnesium	mg	9.8-11.2	2.5 (M) 3.4 (F)
Calcium	mg	6.2-14.6	1.0 (M) 0.8 (F)
Iron	mg	0.18-0.68	5.6 (M) 2.5 (F)
Manganese	mg	0.13-0.23	7.8 (M) 10.0 (F)
Zinc	mg	0.06-0.13	0.8 (M) 1.1 (F)
Potassium	mg	70.4-158.4	-
Copper	mg	0.02-0.03	-
Sulphur	mg	20.3-35.4	-

4. Antinutritional factors in sweet potato

Sweet potatoes are generally considered a nutritious food, but they contain some antinutritional factors, which are substances that can interfere with the absorption of nutrients. The major ones are oxalates, phytates, tannins, α-amylase inhibitor and trypsin inhibitor. Sweet potato leaves, like many leafy greens, contain oxalates. Tannins and phytic acid are present in sweet potato leaves (9-13 mg 100 g^{-1} and 0.20-0.30 mg 100 g^{-1}, respectively) which can bind minerals such as iron, reducing their absorption. However, the impact can be minimized through cooking or other preparation methods such as pairing with vitamin C-rich foods. Cooking methods, such as boiling or steaming can reduce the levels of certain anti-nutritional factors while preserving the nutritional content of sweet potato leaves. Heating at 100°C can cause rapid inactivation of trypsin inhibitor in sweet potatoes. Microwave baking and flour preparation are very effective methods to eliminate enzyme inhibitors from sweet potatoes (Kiran and Padmaja, 2003). Compared to cooking by boiling in water, microwave baking is a more effective method for the inactivation of α-amylase inhibitor in sweet potatoes (Rekha and Padmaja, 2002).

Proximate Composition and Nutritional Profile of Edible Yams

Yams tuber

Yams are grown in many tropical regions throughout the world, but the main production centre is the Savannah region of West Africa, where more than 90 percent of the crop is grown mainly in Nigeria (FAO corporate document repository). Yams provide nutritional and food security to several millions of people, especially in Africa. Apart from starch, yam tubers are also rich in various minerals, dietary fibre and flavonoids. Besides, certain species of yams are also used as medicines in East Asian countries to prevent diarrhoea and diabetes. The major edible yams are greater yam, white yam and lesser yam (Fig. 7 a-f).

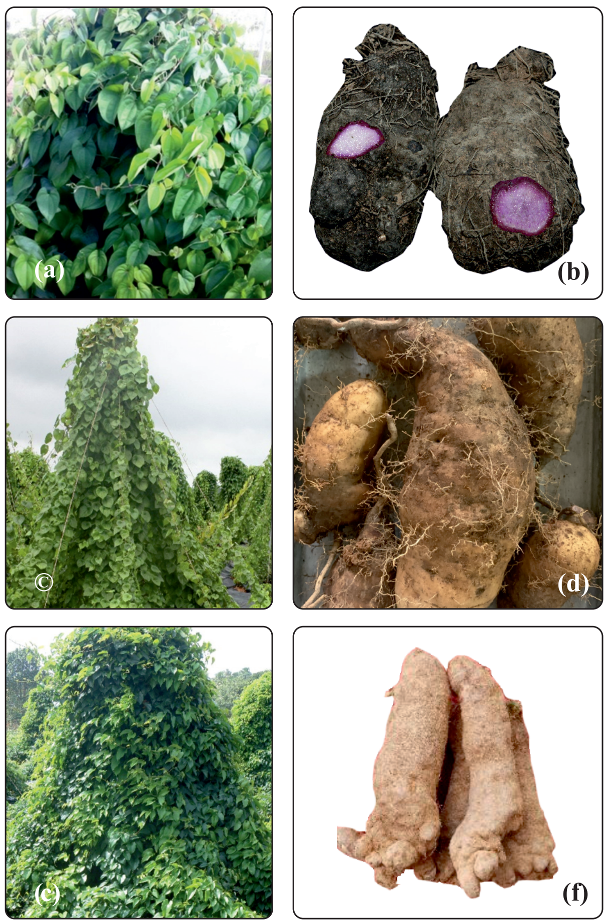


Fig. 7. (a) & (b) Greater yam plant and tuber, (c) & (d) Lesser yam plant and tuber (e) & (f) White yam plant and tuber

The proximate composition and nutritional profile of the tubers of these three edible yams are presented in Table 5. Starch constitutes the major carbohydrate in all the three species ranging from 17.5-23.8%. The main sugars in yams are glucose and sucrose, while maltose and fructose are formed during storage. The fat content is generally low in the tubers (0.04-0.6% fwb). Protein content shows slight variations among cultivars of the three species and most cultivars have approximately 0.7-1.8% crude protein and the major amino acid present is arginine. Yam tubers contain non-starch polysaccharides such as cellulose, hemicelluloses and pectin which contribute towards dietary fibre in the tubers.

Dioscorea sp. is an important source of the hydrocolloid in the form of mucilage, which are water-soluble polysaccharides. Mucilages are bioactive natural products which possess anti-tumour, anti-inflammatory, immune-modulatory and antioxidant activities. Yams are sources of essential micronutrients and phytochemical compounds such as iron, zinc, Vitamin C, carotenoids, polyphenols and flavonoids. Several physiological effects including lowering of lipid and sugar levels in blood, antioxidant activity, anti-mutagenic activity and anti-allergic activity have been reported in yam extracts due to the presence of phenolic phytochemicals. The tubers also contain a good quantity of other bioactive compounds such as alkaloids, tannins, saponins, glycoside steroids, and anthraquinones, which have various pharmacological activities.

Purple fleshed cultivars of greater yam (Fig. 8) contain anthocyanins, mostly acylated cyanidin derivatives which have antioxidant and antiproliferative activities. They also exhibit antihypertensive, bone protective, immune-stimulatory and antidiabetogenic effects.

Fig. 8. Purple yam

Table 5. Proximate composition, nutritional profile and nutrient value of yam tubers (100 g fresh tuber, edible portion)

Principle	Unit	Quantity			Percentage of RDA from 100g
		Greater yam	White yam	Lesser yam	
Energy	kcal kJ	82.3-118.0 344.3-493.7	108-116 451.9-485.3	112-118 468.6-493.7	6
Proximate composition					
Moisture	g	62.0-72.5	15-27	66.9-67.5	-
Carbohydrates	g	24.7-31.0	1.25-1.83	24.1-27.5	21
Protein	g	1.44-1.83	0.05-0.2	0.71-1.37	3 (M) 4 (F)

Fat	g	0.07-0.10	1.25-1.70	0.06-0.07	0.2
Dietary fibre	g	1.71-1.83	19.6-22.6	0.76-1.04	5.2
Starch	g	17.5-21.5	0.3-1.0	17.8-23.8	-
Sugar	g	0.5-1.4	1.7-2.6	0.83-1.0	-
Ash	g	1.2-2.1	1.5-2.0	1.6-1.8	-
Mucilage	g	1.3-2.0		1.7-2.5	-
Vitamins					
Thiamine (B1)	mg	0.036-0.21	0.034-0.11	0.025-0.18	8-9
Riboflavin (B2)	mg	0.08-0.13	0.01-0.05	0.032-0.06	2.5
Vitamin B6	mg	0.25-0.57	0.20-0.30	0.29-0.35	14
Niacin (B3)	mg	0.50-0.55	0.31-0.56	0.47-0.51	3.0
Vitamin C	mg	13.0-25.0	17.0-	12.1	19 (M) 22 (F)
Minerals					
Phosphorus	mg	54-117	60-75	102-125	11
Calcium	mg	11.3-14.0	10.8-11.5	10.2-13.3	1.3 (M) 1.0 (F)
Magnesium	mg	23.1-30.0	32.0-50.0	11.5-14.2	8 (M) 6 (F)
Iron	mg	0.13-0.22	0.15-0.20	1.87-2.00	2 (M) 1 (F)
Manganese	mg	0.11-0.30	0.06-0.08	0.20-0.32	5 (M) 6 (F)
Zinc	mg	0.52-0.86	0.60-0.75	0.58-0.75	6 (M) 8 (F)
Potassium	mg	72-141	180-270	128-144	-

Table 5 shows the nutrition value of yam tubers in the form of percentage of RDA. Hundred grams of yam provides about 21% of RDA of carbohydrates, 3-4% of RDA of protein, 19-22% of RDA of vitamin C and 14% of RDA of vitamin B6.

Antinutritional factors in yams

Anti-nutritional factors affect the bioavailability of dietary nutrients especially protein, minerals, and vitamins and reduce the nutritive value of the food. The tubers of yam species contain different anti-nutritional factors such as alkaloids (0.02-0.60 mg $100g^{-1}$), oxalate (0.12-0.75 mg $100g^{-1}$), phytate (0.11-0.52 mg $100g^{-1}$), tannins (0.28-1.38 mg $100g^{-1}$), and saponins (0.40-0.58 mg $100g^{-1}$). In some species of yam tubers, browning occurs when the tissues are injured and exposed to air due to the oxidation of phenolic compounds. Processes such as heat treatment, soaking, cooking, drying and flour preparation can significantly reduce the antinutrients factors in yams.

Proximate Composition and Nutritional Profile of Aroids

Aroids are important starchy tubers with high nutritive and medicinal values These are food security crops in tropical countries mainly West Africa, South East Asia, Pacific Islands, Papua New Guinea Islands and the Caribbean Islands. The major edible aroids are taro, tannia and elephant foot yam (Fig. 9). All parts of the plant are edible in the case of taro and tannia while in elephant foot yam, corms and petioles are used as food. Approximately 400 million people use taro in their diets, and it forms a staple food, mainly in humid tropics.

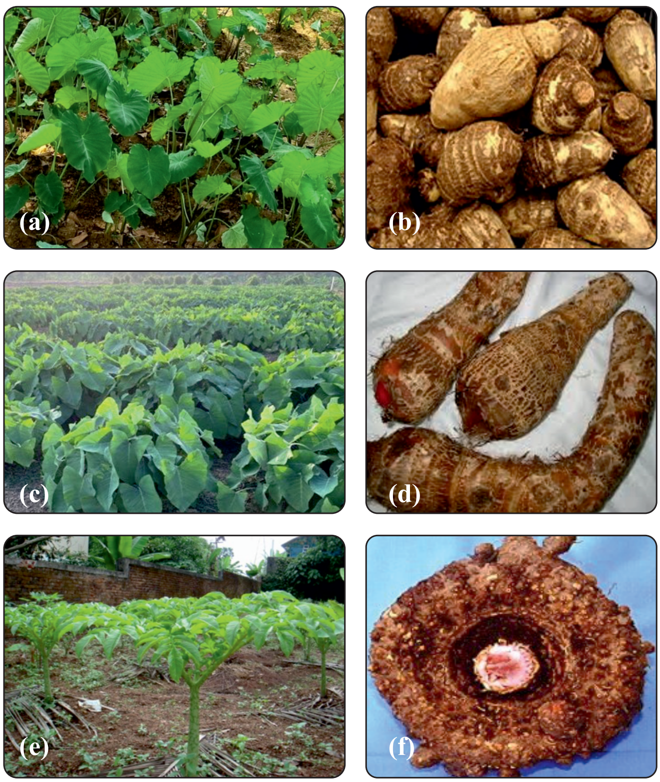


Fig. 9. Major edible aroids. (a) & (b) Taro plant and cormels, (c) & (d) Tannia plant and cormels, (e) & (f) Elephant foot yam plant and corm

1. Taro and tannia cormels

Taro has originated from the humid tropical rain forests of South-east Asia. Taro is mainly grown as a root crop or as a leafy vegetable. It is extensively cultivated and utilized in the Pacific Islands and the major producers in Asia are China, Japan, Philippines and Thailand. In India, taro is widely grown in West Bengal, Bihar, Odisha, Uttar Pradesh, Gujarat, Assam, Kerala and some parts of Tamil Nadu and Andhra Pradesh. Taro is a subsidiary food crop, and its tubers contain carbohydrates, calcium, protein and minerals like phosphorus and iron. The leaves, young shoots and corms of taro are also used for consumption.

Starch is the major component of dry matter and it ranges from 9.6-18.8% of fresh weight in taro (Table 6). The important sugars are sucrose, fructose, maltose, glucose and raffinose. The lipid content is very low in the cormels. Taro corms are good sources of minerals such as calcium, phosphorus, potassium, manganese and iron. The protein fraction is rich in threonine, leucine, arginine, valine and phenyl alanine. The small granule size (1-4 µm in diameter) makes taro starch a highly digestible food. Besides, the fine nature of starch granules imparts hypoallergenic property to taro starch and it also helps increase the bioavailability of its nutrients due to efficiency of digestion and absorption. The mucilage component of taro is a complex mixture of neutral polysaccharides, along with some fibre and protein. The mucilage is important from the health point of view, imparting properties such as slow transit of food through upper gastrointestinal tract, hold moisture to prevent constipation and lower blood cholesterol by binding bile.

Table 6. Proximate composition, nutritional profile and nutrient value of taro (100g fresh cormels)

Principle	Unit	Quantity	Percentage of RDA from 100g
Energy	kcal kJ	112-135 468.6-564.8	5
Proximate composition			
Moisture	g	72.5-80.5	-
Carbohydrates	g	13.0-29.0	20
Protein	g	1.13-1.75	2.6 (M) 3.3 (F)
Fat	g	0.10-0.14	0.5
Dietary fibre	g	1.03-1.27	10.8
Starch	g	9.6-19.0	-
Ash	g	1.95-2.27	-
Total phenols	mg	42-60	-
Vitamins			
Thiamine	mg	0.085-0.095	8
Vitamin B6	mg	0.088-0.283	16
Riboflavin	mg	0.025-0.035	2
Niacin	mg	0.60	3.8
Vitamin C	mg	3.5-7.0	10.6 (M) 12.6 (F)

Minerals			
Phosphorus	mg	53-92	10
Calcium	mg	67-90	8 (M) 6.7 (F)
Magnesium	mg	10-17	3 (M) 4.5 (F)
Iron	mg	0.86-1.5	15 (M) 8 (F)
Manganese	mg	0.7-1.3	43 (M) 55 (F)
Zinc	mg	0.7-2.3	14 (M) 19 (F)
Potassium	mg	253-460	-

Tannia, also known as cocoyam, is originated in northeastern South America. It is nutritionally very similar to taro. In parts of Africa, both taro and tannia are known as cocoyam, and in some other places, both are listed as taro. The corm, cormels, and leaves are used for edible purpose. The cormels are mostly starch, possessing the highest starch concentrations among the edible aroids that ranges between 14.6 to 21% (Table 7). The corms are low in protein, fat and fibre contents.

The percentage of recommended daily allowance of various nutrients obtained from 100g of the taro and tannia cormels is presented in Tables 6 and 7 respectively . Taro cormels (100g) provides 20% RDS of carbohydrates, 10.8% RDA of dietary fibre, 16% RDA of vitamin B6 and 10.6-12.6% RDA of vitamin C. It also provides 8-15% of the daily requirement of iron in healthy individuals. Tannia cormels provide 18% of RDA of carbohydrates, 3-4% RDA of protein, 14% RDA of vitamin B6, and 10-12% RDA of vitamin C.

Table 7. Proximate composition, nutritional profile and nutrient value of tannia (100g fresh cormels)

Principle	Unit	Quantity	Percentage of RDA from 100g
Energy	kcal kJ	98-105 410-439.3	4.5
Proximate composition			
Moisture	g	64.0-75.9	-
Carbohydrates	g	22-32	18
Protein	g	1.26-2.20	3 (M) 3.7 (F)
Fat	g	0.11-0.20	0.6
Dietary fibre	g	0.98-1.00	6.5

Starch	g	14.6-21.0	-
Ash	g	1.20-1.89	-
Total phenols	mg	15-32	-
Vitamins			
Thiamine	mg	0.024-0.097	8
Vitamin B6	mg	0.120-0.237	14
Riboflavin	mg	0.032-0.040	3
Niacin	mg	0.67	4
Vitamin C	mg	8.0-10.0	10 (M) 12 (F)
Minerals			
Phosphorus	mg	143-150	20
Calcium	mg	8.5-9.6	1 (M) 0.8 (F)
Magnesium	mg	8.5-10.1	2 (M) 3 (F)
Iron	mg	0.23-0.52	5 (M) 2 (F)
Manganese	mg	0.10-0.52	13 (M) 16 (F)
Zinc	mg	0.40-1.20	7 (M) 10 (F)
Potassium	mg	192-220	-

2. Taro and tannia leaves

In many states of India, tannia leaves are used as a leafy vegetable. In Gujarat, tannia crop is grown throughout the year mainly for leaf purpose. In Gujarat and some parts of Maharashtra it is used for making a value added product called 'Paatra' and the subji of 'Turiya-patra' in marriage season. The leaves can be used as vegetable after boiling just like spinach. A variety of tannia called, Navsari Pari has been recently released in Gujarat exclusively for leaf purpose. It has an average green leaves yield of 7.96 t ha^{-1} after 270 days of planting.

The leaves of taro and tannia are a rich source of protein, beta-carotene and minerals. The proximate composition and nutritional profile of the leaves are presented in Table 8. The young tender leaves have significant levels of antioxidants such as β-carotenes and cryptoxanthin along with vitamin A. These compounds are required for maintaining healthy mucus membranes, skin and vision. It also contains some of the valuable B-complex group of vitamins such as pyridoxine (vitamin B6), folates, riboflavin, pantothenic acid and thiamine. Table 8 shows the percentage of RDA of various nutrients from 100g of the fresh leaves.

Table 8. Proximate composition, nutritional profile and nutrient value of fresh taro and tannia leaves (100g)

Principle	Unit	Quantity		Percentage of RDA from 100g
		Taro	Tannia	
Energy	kcal kJ	42-50 175.7-209.2	40-48 167.4-200.8	2.0
Proximate composition				
Moisture	g	70.0-74.0	72.5-85.7	-
Carbohydrates	g	5.3-6.7	5.7	4.2
Protein	g	3.8-5.9	4.57	8.0 (M) 9.8 (F)
Fat	g	0.05-0.07	0.08	0.23
Dietary fibre	g	0.8-1.1	0.92	2.4
Ash	g	1.65-1.85	1.3-1.75	-
Vitamins				
Thiamine	g	0.209	-	16.6
Riboflavin	g	0.456	-	30.0
Niacin	mg	1.51	-	9.3
Vitamin B6	mg	0.146	-	8.2
Vitamin C	mg	37-52	11-60	50.0 (M) 60.0 (F)
Vitamin A, RAE	µg	241	-	26.7 (M) 34.3 (F)
Total carotenoids	µg	2900	-	-
Minerals				
Phosphorus	mg	70-90	57-66	10
Calcium	mg	55-118	141.5-155.7	11.0-15.0 (M) 9.2-12.5 (F)
Magnesium	mg	5.8-12.3	18.7-20.8	2.1-4.5 (M) 4.5-6.1 (F)
Iron	mg	0.4-0.86	0.74-0.85	8.8 (M) 3.9 (F)
Manganese	mg	0.37-0.5	-	17.4 (M) 22.2 (F)
Zinc	mg	0.75-1.25	1.2-1.4	7.2 (M) 10 (F)
Potassium	mg	143-608	346-406	-

3. Elephant foot yam corm

Elephant foot yams have a unique and rich nutritional profile and offer a number of significant health benefits. The edible corm finds use as a nutritionally rich vegetable and is also an ingredient of several Ayurvedic preparations due to its medicinal and health benefits. The proximate composition of elephant foot yam corm is presented in Table 9. Apart from carbohydrates, the corm is a good source of phytochemical compounds such as flavonoids and polyphenols, vitamins and minerals. The aqueous extract of elephant foot yam contains flavonoids and tannins contributing to health effects, especially antioxidant activity. Quercetin is the major flavonoid isolated and characterized from elephant foot yam.

Hundred grams of elephant foot yam tuber can provide 13% of daily requirement of carbohydrates, 2.5-3% of RDA of protein, 10% of RDA of dietary fibre, 16% of RDA of vitamin B6 and 7-9% RDA of vitamin C (Table 9).

Table 9. Proximate composition, nutritional profile and nutrient value of elephant foot yam (100g fresh corm)

Principle	Unit	Quantity	Percentage of RDA from 100g
Energy	kcal kJ	90-116 376.6-485.3	4
Proximate composition			
Moisture	g	71.1-79.0	-
Carbohydrates	g	10-24	13
Protein	g	1.2-1.5	2.5 (M) 3 (F)
Fat	g	0.05-0.40	0.5
Dietary fibre	g	0.80-1.41	10
Starch	g	11.0-20.5	-
Ash	g	0.80-1.85	-
Total phenols	mg	66-86	-
Vitamins			
Thiamine	mg	0.05-0.10	5.0
Riboflavin	mg	0.02-0.07	3.8
Niacin	mg	-	9 (F) 7 (M)
Vitamin B6	mg	0.250-0.272	16
Vitamin C	mg	3.5-8.0	9 (F) 7 (M)
Minerals			
Phosphorus	mg	50-68	8.5
Calcium	mg	46-84	2.4 (M) 2 (F)
Magnesium	mg	21-23	5 (M) 7 (F)
Iron	mg	1.4-1.7	16 (M) 7 (F)

Manganese	mg	0.46-0.84	28 (M) 36 (F)
Zinc	mg	1.0-1.3	15 (F) 11 (M)
Potassium	mg	237-288	-

4. Antinutritional factor in aroids

The edible parts of taro plant contain different antinutritional compounds which include oxalates, trypsin inhibitor, alpha amylase inhibitor, phytates, tannins, and alkaloids. Oxalates are the major limiting factor in the utilization of aroids which impart acrid taste or cause irritation when raw or unprocessed foods from them are eaten. This acridity is caused by needle-like calcium oxalate crystals called raphides that can penetrate soft skin. High oxalate concentrations in the leaves and corms of plants consumed daily are of concern because of the harmful health effects associated with the intake of high amounts of oxalates.

Depending up on the variety, the total oxalate content in the taro cormels varies from 19.5 mg 100 g^{-1} to 166.2 mg 100 g^{-1} on fresh weigh basis. The acrid taro cultivars synthesize more oxalic acid and store mainly as calcium oxalate. However, the non-acrid cultivars have lower total oxalate content and the major portion of the stored oxalate is in the soluble form. The total oxalate content in the fresh taro corm/cormels of acrid varieties ranges from 165 to 232.5 mg 100g^{-1}, whereas it is in the range of 47.5-82.5 mg 100g^{-1} for the non-acrid varieties. The tryspsin inhibitor content is in the range of 241.1-1907.1 TIU g^{-1} in the cormels. The total oxalate content in tannia cormels range from 150 to 321 mg 100g^{-1}, whereas it is in the range of 10.5-31.5 mg 100g^{-1} in elephant foot yam corm. Oxalates are also present in the leaves which is about 10 times higher than that in the cormels. In taro leaves, the total oxalate content is in the range of 220-856 mg 100 g^{-1} fresh wt., and the soluble oxalate forms 27.8-40.7% of the total oxalate content.

Processing methods such as peeling, washing, dicing, soaking, blanching, drying and fermentation help to reduce the anti-nutritional factors in aroids (Alcantara et al., 2013; Kumoroa et al., 2014). Calcium oxalate is destroyed by soaking, prolonged boiling, or cooking operations. Boiling the corm or steeping in water for 24 h can reduce the oxalate content by 35-40%. Soaking the raw leaves in water for 18 h results in about 25% reduction in the soluble oxalate content. Boiling and sun-drying of the leaves are effective ways of reducing the oxalate content of the tissue. Boiling in water for about 10 min can cause about 35% reduction in soluble oxalates and 45% in total oxalates. Trypsin inhibitors in taro are more rapidly inactivated than those in sweet potato (Kiran and Padmaja, 2003). Cooking, baking in microwave and preparation of flour are very effective methods to eliminate trypsin inhibitors from taro. In comparison to cooking by boiling in water, microwave baking is a much better method for the inactivation of the α-amylase inhibitor in taro (Rekha and Padmaja, 2002).

Proximate composition and nutritional profile of minor tuber crops

Apart from the major tropical tuber crops, there are some minor tuber crops which are cultivated in small pockets in many parts of the world. Some of these which have nutritional potential are Chinese potato, yam bean , arrowroot and *Curcuma* sp.

1. Chinese potato

Chinese potato (Fig. 10) is native to tropical Africa and is called in different names such as Native Potato, Country Potato, Hausa Potato or Sudan Potato in different parts of the world. In India, this is known as Chinese Potato. These plants are cultivated in Tropical Southern Africa, Sree Lanka, India, and Malaysia and the aromatic tubers are used for edible purpose. The tubers are round or slightly elongated in shape with thin skin. Besides carbohydrates, the tubers contain protein, fat and fibre (Table 10). There are several secondary metabolites in the tubers which include terpenoids, steroids, glycosides, saponins, flavonoids, phenolic compounds, alkaloids and tannins with therapeutic and pharmaceutical potential.

Fig. 10. (a) Chinese potato plant and (b) tubers

The high contents of phenolic and flavonoid compounds impart good antioxidant property to the tubers, which significantly enhances on cooking. The proximate composition and micronutrients contents of the tubers is presented in Table 10. The total phenolic content and flavonoids in the tubers are 71.8±2.27 mg and 52.9±1.87 mg per 100g fresh weight, respectively. The tubers also contain unsaturated fatty acids (102.3±3.32 mg in 100g fresh weight). Among the lipids, linoleic acid, ascorbic acid 2,6-dihexadecanoate and oleic acid constitute about 40%, 25% and 24%, respectively of the major lipids. Linoleic acid is a doubly unsaturated fatty acid, also known as an omega-6 fatty acid, which has anti-inflammatory, acne reductive, skin-lightening and moisture retentive properties. Oleic acid is a monounsaturated omega-9 fatty acid and it has hypotensive effects. Ascorbic acid 2,6-dihexadecanoate has antimicrobial properties. Unsaturated triterpenoid derivatives with acid groups are present in the tubers (94.9±1.87 mg 100 g^{-1} fresh wt.), which are reported to have bioactivities such as hepatoprotection, anti-inflammation, antitumor-promotion and anti-hyperlipidemia. The characteristic flavour of Chinese potato tubers is due to the presence of terpenoids in them.

The nutrient value of 100g of Chinese potato tubers is presented in Table 10. Apart from carbohydrates, it is a good source of minerals and vitamin C. Hundred grams of the tubers provide 16% of RDA of carbohydrates, 2.3-2.8% of RDA of protein, 11-13% of vitamin C and 8.7-19.5% of iron.

Table 10. Proximate composition, nutritional profile and nutrient value of Chinese potato tubers (100 g fresh tuber)

Principle	Unit	Quantity	Percentage of RDA from 100g
Energy	kcal kJ	83-94 347.3-393.3	4
Proximate composition			
Moisture	g	72.0-78.0	-
Carbohydrates	g	19.0-23.3	16
Protein	g	0.84-1.7	2.3 (M) 2.8 (F)
Fat	g	0.05-0.48	1.0
Dietary fibre	g	0.30-0.50	2.6
Starch	g	17.3-19.0	-
Ash	g	1.63-2.36	-
Micronutrients			
Vitamin C	mg	10-12	11 (M) 13 (F)
Total phenolics	mg Gallic acid equivalent	45.6-71.8	-
Total flavonoids	mg	52.9-56.1	-
Total terpenoids	mg	93.0-96.8	-
Phosphorus	mg	91.5-102.8	14
Calcium	mg	76.1-86.7	8 (M) 6.8 (F)
Magnesium	mg	56-62	14 (M) 19 (F)
Iron	mg	1.43-1.69	19.5 (M) 8.7 (F)
Manganese	mg	0.52-0.60	24 (M) 31 (F)

Zinc	mg	0.98-1.1	9.5 (M) 13 (F)
Potassium	mg	109-110	-
Copper	mg	0.08-0.09	-

2. Yam bean

Yam bean (Fig. 11) believs to have originated in Mexico and northern South America, in the head-water region of the River Amazon, and was cultivated there in pre-Columbian days. The Spaniards took it to the Philippines, and it is now cultivated and naturalised in the Philippines, Cambodia, China, Indonesia, northern India as well as in western and northern South America and the Caribbean.

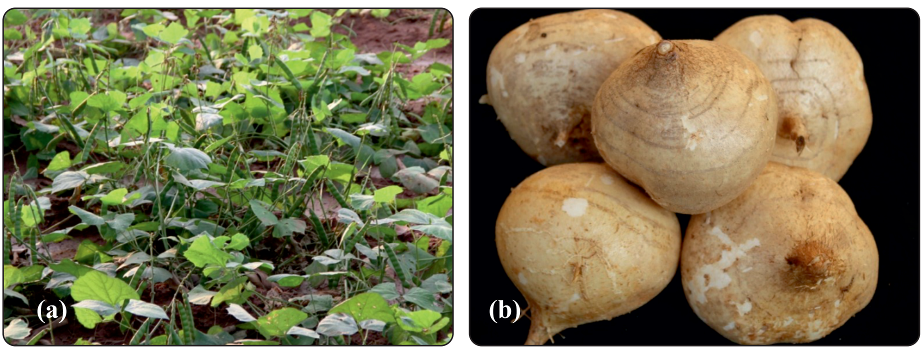


Fig. 11. (a) Yam bean plant and (b) tuber

The average yield of tuberous roots is about 7.5-20 t ha^{-1}. The tuberous roots contain both starch and sugar and are a moderately good source of Vitamin C. Average composition of the tuber is presented in Table 11. Mature tubers yield a grayish-white starch, consisting of polyhedral or semi-polyhedral grains. The young tubers are eaten raw in salads, or cooked as a vegetable, or in pickles and chutney. They are popular among the lower income groups in parts of Latin America and the Caribbean. In the USA, they are sometimes used as a substitute for Chinese water chestnut. The starch content of the roots increases with maturity. The older roots are sometimes used as a source of starch or for animal feeding. In China, the dried roots are used as a cooling food for people with fever.

Hundred grams of yam bean tuber accounts for 10% of RDA of carbohydrates, 1.5% of protein, 19-23% of vitamin C and 7.8-17.5% of iron apart from providing significant amounts of another minerals (Table 11).

Table 11. Proximate composition, nutrient profile and nutritive value of yam bean tuber (100g fresh tuber)

Principle	Unit	Quantity	Percentage of RDA from 100g
Energy	kcal kJ	44-63 184-263.6	3
Proximate composition			
Moisture	g	82-88	-
Carbohydrates	g	10.6-14.9	10
Protein	g	0.78-1.4	1.4 (M) 1.7 (F)
Fat	g	0.09-0.20	<1
Dietary fibre	g	0.6-0.7	5
Total starch	g	10.5-11.7	-
Ash	g	0.3-0.5	-
Vitamins			
Thiamine	mg	0.04-0.10	6.3
Niacin	mg	0.2-0.3	1.5
Riboflavin	mg	0.02-0.10	2
Vitamin C	mg	14-21	19 (M) 23 (F)
Minerals			
Phosphorus	mg	20-24	3
Calcium	mg	49-51	5 (M) 4 (F)
Magnesium	mg	21-24	5 (M) 7 (F)
Iron	mg	0.6-1.3	10 (M) 4.4 (F)
Manganese	mg	0.32-0.37	15 (M) 19 (F)
Zinc	mg	0.30-0.35	3 (M) 4 (F)
Potassium	mg	86-244	-
Copper	mg	0.10-0.95	-

Antinutritional factor in yam bean

The seed pods of yam bean are toxic when mature but can be used as a vegetable when young and can be eaten as a cooked vegetable, similarly to French beans. Yam bean seeds cannot be used directly as food due to rotenone and its derivatives, but true seed propagation is an important attribute, which makes disseminating and maintaining yam bean much easier compared to traditional root crops. The powdered seeds are sometimes used as an insecticide or fish poison. In Indonesia, the pulverised seeds mixed with sulphur are applied to certain types of skin eruption. Mature seeds also contain good amounts of oil (20-25%) and protein (23-34%), but high content of rotenone also (Broadbent and Shone 1963; Grüneberg et al., 1999). If the insecticidal/anti-nutritional compounds are removed, the oil then has a composition comparable to that of groundnut and cottonseed oil (Broadbent and Shone 1963).

3. West Indian Arrowroot

Arrowroot (West Indian Arrowroot) (Fig. 12) has tremendous potential in food and pharmaceutical industries. The tubers are mostly used for starch extraction. The tubers contain about 17-20% starch (Table 12) and the amylose content in the starch ranges between 16 to 27% . Arrowroot starch is popular for its high digestibility and medicinal properties. It possesses demulcent properties that soothes and protects irritated or inflammed internal tissues of the body and hence is given in bowel complaints. Arrowroot starch is used for stomach and intestinal disorders, including diarrhoea. The starch is often used as a thickener in all kinds of foods. Arrowroot is used as an article of diet in the form of biscuits, puddings, jellies, cakes, hot sauces etc. and an easily digestible food for children and people with dietary restrictions. The lack of gluten in arrowroot starch makes it ideal as a replacement for wheat flour in baking.

Hundred grams of the tuber provides 11% of RDA of carbohydrates, 4-4.5% of protein, 10% RDA of thiamine, 15% RDA of vitamin B6 and 7-16% of RDA of iron in healthy adults (Table 12). It also provides other minerals such as manganese, zinc and magnesium in appreciable amounts.

Fig. 12. (a) Arrowroot plant and (b) tuber
(Photo courtesy: Dr. P. Murugesan)

Table 12. Proximate composition, nutritional profile and nutrient value of arrowroot (100g fresh rhizome)

Principle	Unit	Quantity	Percentage of RDA from 100g
Energy	kcal kJ	80-85 334.7-355.6	4
Proximate composition			
Moisture	g	70.0-72.0	-
Carbohydrates	g	16-22	11
Protein	g	1.7-2.5	3.8 (M) 4.5 (F)
Fat	g	0.04-0.60	0.3
Dietary fibre	g	1.0-1.9	8
Starch	g	17-20	-
Sugar	g	0.6-1.0	-
Ash	g	0.5-1.0	-
Vitamins			
Thiamine	mg	0.10-0.14	10
Niacin	mg	1.40-1.69	9
Riboflavin	mg	0.055-0.059	4.5
Vitamin C	mg	1.5-1.9	1.8 (M) 2.0 (F)
Vitamin B6	mg	0.25-0.27	15
Minerals			
Phosphorus	mg	106-120	15
Calcium	mg	86-89	8 (M) 7 (F)
Magnesium	mg	68-73	17 (M) 22 (F)
Iron	mg	1.2-1.4	16 (M) 7 (F)
Manganese	mg	0.86-0.98	40 (M) 51 (F)
Zinc	mg	1.0-1.2	10 (M) 14 (F)
Potassium	mg	332-338	-
Copper	mg	0.46-0.52	-

4. East Indian Arrowroot (Tikhur)

East Indian arrowroot or tikhur (Fig. 13) is native to the Indian subcontinent. The moisture content of the rhizhomes is 66-73% and starch and sugar contents are in the range of 10.5-

14.1% and 0.25-0.35%, respectively (Table 13). The major chemical constituents of the plants are methyl eugenol, camphor, cineol etc. Rhizomes of tikhur contain secondary metabolites such as alkaloids, flavonoids, terpenoids, phenols, tannins, saponins, and glycosides. The rhizomes contain a significant amount of sesquiterpenoids and mono terpenoids as the major bioactive components. Thes bioactive components are responsible for antioxidative, anti-inflammatory properties, wound-healing, hypoglycemia, anticoagulant, and antimicro bial activities. The tikhur starch can be used in the diet of children as it is easily digestible like arrowroot starch. The rhizomes are ground into a flour which can then be mixed together with milk or water to form a nutritious meal. It is an excellent diet in case of dysentery, dysuria, gonorrhea etc.

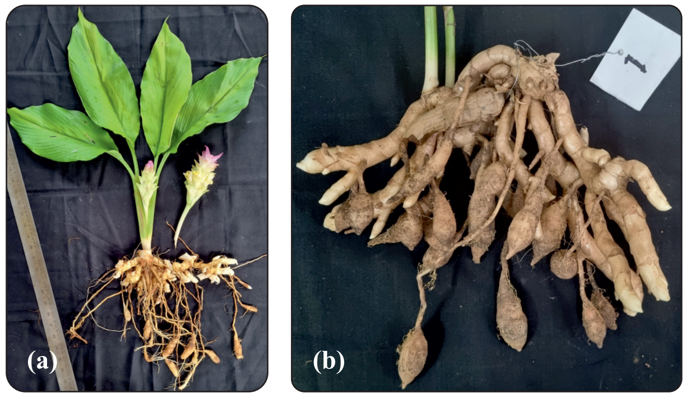


Fig. 13. (a) East Indian Arrowroot plant and (b) Rhizome (Photo courtesy: Dr. P. Murugesan)

Table 13. Proximate composition of East Indian arrowroot (100g fresh rhizome)

Principle	Unit	Quantity
Moisture	g	66.0-73.0
Carbohydrates	g	13-20
Crude Protein	g	1.3-1.7
Fat	g	0.10-0.20
Crude fibre	g	0.30-0.52
Starch	g	10.5-14.1
Sugar	g	0.25-0.35
Ash	g	0.30-0.50

5. Queensland Arrowroot (Canna/Achira)

Queensland arrowroot, also known as Canna or Achira (Fig. 14) is two main types - one with white corms and green foliage, and the second with violet-skinned corms. Production of this crop is found throughout the low- to midaltitude tropics, with most concentrated in South America, especially in Peru, where it is a valued crop. Its commercial importance is limited to starch production in a few regions and as a staple food in parts of Peru, Ecuador and South-east Asia. The moisture content in the rhizomes varies from 70 to 80%. The starch, sugar and crude fibre contents are in the range of 9.5-13.5%, 0.45- 0.71% and 0.40-0.80%, respectively

(Table 14). The very young tubers can also be eaten cooked. They are sweet but fibrous. Young shoots are cooked and eaten as a green vegetable. The roots are high in potassium, but low in calcium and phosphorus. Edible canna is one of the few root and tuber crops that can be eaten raw.

The rhizomes are used mainly for starch extraction. The starch is obtained by rasping the rhizomes to a pulp, then washing and straining to get rid of the fibres. The percentage of starch varies with the age of the rhizomes and is usually at a maximum between 6 and 15 months. Queensland arrowroot starch is easily digestible and often used in the food of infants and invalids.

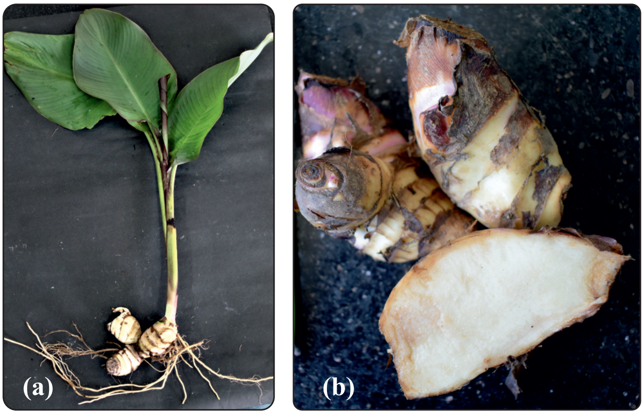


Fig. 14. (a) Canna plant and (b) Rhizome
(Photo courtesy: Dr. P. Murugesan)

Table 14. Proximate composition of canna (100g fresh rhizome)

Principle	Unit	Quantity
Moisture	g	70 - 80
Carbohydrates	g	10-16
Crude Protein	g	1.0-1.5
Fat	g	012-0.20
Crude fibre	g	0.40-0.80
Starch	g	9.5-13.5
Sugar	g	0.45- 0.71
Ash	g	0.9-1.4

6. Curcuma (*Zingiberaceae* sp.)

The curcuma species, *viz*., *C. zedoaria* (White turmeric or Kochura) and *C. malabarica* are good source of terpenoid compounds which possess antimicrobial, anti-inflammatory, antitumor, hepatoprotective and neuroprotective properties. These rhizomes are used for the preparation of starch, a substitute for arrowroot and barley starches. White turmeric closely resembles turmeric in appearance (Fig. 15). It is a native of northeast India and is widely cultivated in many parts of China, Sri Lanka, and India. Dried rhizomes have a bitter and strong camphoraceous taste. It is used in traditional medicines (Ayurveda and Chinese medicine) to treat various cancers, inflammation, wounds, skin ailments and pain. It is very effective in treating respiratory disorders and works as an aphrodisiac agent. Steam distillation of the rhizomes yields a light yellow oil. The rhizome oil contains several sesquiterpenoids, apart from the pigment, curcumin. The tuber extracts of white turmeric exhibits antimicrobial, anti-inflammatory, antitumor, hepatoprotective and neuroprotective properties.

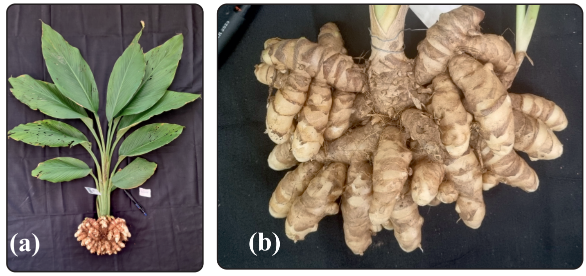


Fig. 15. (a) *Curcuma zeodaria* plant and (b) rhizomes
(Photo courtesy: Dr. P. Murugesan)

Curcuma malabarica, Vel. has bluish white fleshed rhizomes with camphoraceous odour (Velayudhan et al., 1990). It is grown widely in South India for its starch, which is reported to have medicinal properties. In South India, the starch is used in the diet of infants and convalescents due to its cooling and demulcent properties. The rhizomes contain different types of sesquiterpenes and diterpene with potent anti-inflammatory and analgesic effects (Sheeja and Nair, 2010). The extract of tubers exhibits antimicrobial properties (Wilson et al., 2005).

Summary and Conclusion

Root crops are essential components of the diet of people in many countries, especially in the tropical countries. Root crops have the potential to provide more dietary energy per hectare than cereals. Apart from being rich source of carbohydrates, many root and tuber crops such as sweet potato, aroids etc are also potential sources of many other nutritional components such as protein, dietary fibre, carotenes, vitamins, flavonoids and minerals.

Root and tuber crops provide adequate amounts of carbohydrates, vitamins and minerals. One serve (100 g) of tuber crops provides approximately 4-6% of RDA of energy and 15-30% of carbohydrates for an adult. Most of the major tuber crops are good sources of vitamin C, which accounts for about 10-26% of RDA with the highest being in cassava tubers. The orange fleshed varieties of sweet potato are excellent sources of vitamin A accounting for about 75-90% of RDA in adults. Other major nutrients in these crops are vitamin B6 (6-16% of RDA), phosphorus (3.5-20% of RDA), calcium (1-8% of RDA), manganese (2-50% of RDA) and zinc (1.5-20% of RDA). Aroids are very good sources of the micronutrients, Mn and Zn. These crops offer immense potential not only for meeting nutrient requirements but also as health protectants and therapeutics. By exploring these possibilities, India can revitalize tuber crop cultivation, improve the livelihoods of farmers, and add significant value to these crops.

References

Achidi, U.A., Ajayi, O.A., Bokanga, M., Maziya-Dixon, B. 2005. The use of cassava leaves as food in Africa. *Ecology of Food and Nutrition*, **44**: 423-435.

Alan Sheeja, D.B. and Mangalam S. Nair. 2010. Chemical constituents of *Curcuma malabarica*, *Biochemical Systematics and Ecology*, **38**(2): 229-231.

Alcantara, R. M., Hurtada, W. A. &Dizon, E I. 2013. The nutritional value and phytochemical components of taro [Colocasia esculenta (L.) Schott] powder and its selected processed foods. *Journal of Nutrition and Food Sciences*, **3**:1-7.

Arnieyantie, A.H., Rafidah Aida, R., Fadhlina, M., Norfezah, M.N., Nurul Huda, H., and Anderson, N. 2012. Cassava (*Mahinot esculanta* Crantz) leave floss a potential protein source. UMT 11th International Annual Symposium on Sustainability Science and Management. Terengganu, Malaysia.

Blazek, E. (2006-2023). Root Crops/Queensland arrowroot (*Canna indica*). Appropedia. Retrieved February 16, 2024.

Bokanga, M. 1994. Processing of cassava leaves for human consumption. *Acta Horticulturae*, **375**: 203-207.

Bradbury, J. H. and Holloway, W. D. 1988. Chemistry or Tropical Root Crop: significance for nutrition and agriculture in the Pacific. ACIAR Monograph No. 6, 201 p. Bradbury, J. H., Beatty, R. E., Bradshaw, K., Hammer, B., Holloway, W. D., Jealous, W., Lau, J., Nguyen, T. and Singh, U. 1985. Chemistry and nutritive value of tropical root crops in the South Pacific. *Proc. Nutr. Soc. Austr*., **10**: 185- 188.

Broadbent, J.H. and G. Shone. 1963. The composition of *Pachyrrhizus erosus* (yam bean) seed oil. *J. Sci. Food Agric.,* **14**(7): 524-527.

Byju, G., Sheela, M.N., Geethu Mohan, Revathi, A., Thanusha Thajudeen, Rejin, D.T. and Abhilash, P.V. 2022. Data book on biochemical, mineral and proximate composition of tropical tuber crop varieties, ICAR-CTCRI, Thiruvananthapuram, Kerala, India, pp.60.

Eka, O. U. 1985. The chemical composition of yam tubers. In: Advances in yam research. G. Osuji (ed.). Enugu, Nigeria: Anambra State University Press. pp. 51-74.

FAO (Food and Agriculture Organization of the United Nations) (2018) Food Outlook–Biannual Report on Global Food Markets–November 2018. Available from: https://reliefweb.int/report/world/food-outlook-biannual-report-global-food-markets-november-2018.

FAO. 1999. Taro cultivation in Asia and the Pacific. Food and Agricultural Organization of the United Nations (FAO), Rome. Italy.

FAO/WHO. 2001. FAO/WHO expert consultation on human vitamin and mineral requirements. Report of a joint FAO/WHO expert consultation Bangkok, Thailand. pp. 286. FAOSTAT. 2014. Sweet potato production statistics. http://faostat.fao.org. Accessed on 12 January 2015.

Grüneberg, W. J., Goffman, F., Velasco, L. 1999. Characterization of yam bean (*Pachyrhizus spp*.) seeds as potential sources of high palmitic acid oil. *Journal of the American Oil Chemists' Society*. 76. 1309-1312. 10.1007/s11746-999-0144-x.

ICMR-NIN. 2020. A Brief Note on Nutrient Requirements for Indians, the Recommended Dietary Allowances (RDA) and the Estimated Average Requirements (EAR). Kiran, K.S. and Padmaja, G. 2003. Inactivation of trypsin inhibitors in sweet potato and taro tubers during processing. *Plant Foods Hum Nutr.*, **58**(2):153-63.

Kumoroa, A.C., Putrib, A. R., Budiyatia, S. C. and Retnowatia, S. D. 2014. Kinetics of Calcium Oxalate Reduction in Taro (*Colocasia esculenta*) Corm Chips during Treatments Using Baking Soda Solution. *Procedia Chemistry*, **9**: 102-112.

Latif, S. and Müller, J. 2015. Potential of cassava leaves in human nutrition: A review. *Trends in Food Science & Technology*, **44**(2): 147-158.

Rekha, M.R. and Padmaja, G. 2002. Alpha-amylase inhibitor changes during processing of sweet potato and taro tubers. *Plant Foods Hum. Nutr.,* **57**: 285-294.

Velayudhan, K.C., Amalraj, V.A. and Muralidharan, V.K. *Curcuma malabarica* Velay. 1990. *J. Econ. Tax. Bot*., **14**: 189.

Wilson, B., Abraham, G., Manju, V.S., Mathew, M., Vimala, B., Sundaresan, S. and Nambisan, B. 2005. Antimicrobial activity of *Curcuma zedoaria* and *Curcuma malabarica* tubers. *J. Ethnopharm*., **99**: 147.

Appendix I

Definitions of Technical terms

Term	Definition
Antioxidants	Compounds that inhibit oxidation, a chemical reaction that can produce free radicals.
Anti-nutrient factors	Biological components present in foods that can reduce nutrient utilization or food uptake. They can interfere with the absorption of biomolecules and hamper their bioavailability to the human beings and monogastric animals.
Recommended Dietary Allowance (RDA)	The levels of intake of essential nutrients that, on the basis of scientific knowledge, are judged by the Food and Nutrition Board to be adequate to meet the known nutrient needs of practically all healthy persons.
Dietary fibre	Portion of plant-derived food that cannot be completely broken down by human digestive enzymes.
Free radical-scavenging	Removal of reactive oxygen species in living organisms before they can damage vital components of the cell.
Hepato-protective	A bility of a chemical substance to prevent damage to the liver.
Anti-hypertensive	Ability to lower high blood pressure.
Antiproliferative activity	Tending to suppress or inhibit cell growth, especially the growth of malignant cells.
Anti-inflammatory	Ability of a substance to reduce inflammation or swelling.
Immune-modulatory	Treatments that change the body's immune response.
Secondary metabolites	Organic compounds produced by any lifeform, which are not directly involved in the normal growth, development, or reproduction of the organism.
Acne reductive	Ability to control acne, a long-term skin condition that occurs when dead skin cells and oil from the skin clog hair follicles.
Anti-hyperlipidemia	Action to prevent or counteract the accumulation of lipids in the blood.
Anticoagulant	Blood thinners, that prevent or reduce coagulation of blood, prolonging the clotting time.
Antimicrobial activities	Activity against microbes
Demulcent properties	The soothing nature of a substance, that is capable of soothing inflamed or abraded mucous membranes and protecting them from further irritation.

Appendix II

List of Abbreviations	Expansion
RDA	Recommended Daily Allowance
FSSAI	Food Safety and Standards Authority of India
OFSP	Orange Fleshed Sweet Potato
HCN	Hydrogen cyanide

Tuber Crops for ……………….
Food, Health, Wealth and Prosperity

हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद
Agrisearch with a human touch

भा कृ अनु प
ICAR

ICAR-Central Tuber Crops Research Institute

Sreekariyam, Thiruvananthapuram 695 017, Kerala, India
Phone: (91) (471) 2598551 to 2598554
E-mail: director.ctcri@icar.gov.in
Website: https://www.ctcri.org
Social Media
Facebook Twitter Whatsapp Instagram You Tube

केकफअसं
CTCRI