Journal of Root Crops
Indian Society for Root Crops
ISSN 0378-2409, ISSN 2454-9053 (online)
Journal homepage: https://journal.isrc.in

Greater Yam: An overview of its phytochemical profile and potential for ensuring food security

Kalidas Pati*#, Biswajit Jena#, V.B.S. Chauhan, Hanume Gowda, R. Arutselvan, M. Nedunchezhiyan and K. Laxminarayana

ICAR-Central Tuber Crops Research Institute, Regional Station, Dumuduma, Bhubaneswar-751019, Odisha, India

Abstract

Millions of people in tropical nations rely on cultivated yams (*Dioscorea* spp.) as their main source of nutrition. Even though these underutilized crops are rich in nutrients, there is a dearth of information on them, which impedes their development and sustainability. Greater yam (*D. alata*) plant has medical, pharmacological, cosmetic, and industrial uses in addition to its nutritional value. Their bioactive components, which include anti-inflammatory, antibacterial, and antioxidant properties, have recently drawn more interest in scientific investigations. This analysis aims to highlight the undervalued benefits of yams for pharmacological applications and food security. These species differ greatly in their morphology with regard to the length of growing season, the types of tubers produced, the dry matter content of the tubers, and the nutritional and chemical components of the tubers. Nonetheless, there is a dearth of knowledge currently available about yams. As a result, we covered information regarding the botanical description, origin and distribution, genetic resource, agronomy, pharmacological properties, nutritional values, molecular and genomic research, and future prospects regarding yams in this review.

Keywords: Yams, Dioscorea, Food security, Phytochemicals, Bioactivity

Introduction

Some crops may not be consumed globally due to their adaptability to limited growing conditions but are staples for a particular region and contribute significantly to food supply with a nutritionally well balanced diet. Despite of having nutritionally rich content, very few information is available on these underutilized crops that hinders their sustainable development. One of such crops is Greater yam (*Dioscorea alata* L.). *Dioscorea alata* is one of the most important staple crops in Austronesian cultures. It is one of various species of yams that were domesticated and cultivated independently in Southeast Asia and New Guinea for their starchy tubers, including the round yam (*Dioscorea bulbifera*), ubi gadong (*Dioscorea hispida*), lesser yam (*Dioscorea esculenta*), Pacific yam (*Dioscorea nummularia*), fiveleaf yam (*Dioscorea pentaphylla*), and pencil yam (*Dioscorea transversa*). Among these, *D. alata* and *D. esculenta*are the only ones regularly cultivated and eaten, while the rest were usually considered as famine food due to their higher levels of the toxin, dioscorin which requires that they should be prepared properly before consumption. *D. alata* is cultivated more widely than *D. esculenta*, largely because of much larger tubers of the former.

D. *alata* and *D. esculenta* were the most suitable for long duration transport in Austronesian ships and were carried through all or most of the range of the Austronesian expansion. *D. alata* in particular, were introduced into the Pacific Islands and New Zealand (Crowther et al., 2016). They were also carried by Austronesian voyagers

* Corresponding author: # Equal contribution
E-mail: kalidas.pati@icar.gov.in; kalidas9555@gmail.com; Tel: +91 8249112793

into Madagascar and the Comoros. The tubers contain minerals such as potassium (30000 mg kg^{-1}), phosphorus (9680 mg kg^{-1}), sulphur (3600 mg kg^{-1}), calcium (2040 mg kg^{-1}), iron (395 mg kg^{-1}), manganese (129 mg kg^{-1}), nickel (28.2 mg kg^{-1}), tin 35.2 (mg kg^{-1}), copper (18.5 mg kg^{-1}), zinc (29.4 mg kg^{-1}), rubidium (63.1 mg kg^{-1}), strontium (9.74 mg kg^{-1})(Vincent Lebot *et al.*, 2022). Besides all these elements, several vitamins like Vitamin C (202 mg kg^{-1}), Thiamine (0.20 mg kg^{-1}), Riboflavin (0.29 mg kg^{-1}), Niacin (2.0 mg kg^{-1}), Pantothenic acid (1.135 mg kg^{-1}), Vitamin B6 (0.42 mg kg^{-1}), Vitamin E (4.6 mg kg^{-1}), Vitamin K (3.0 μg kg^{-1}) and several amino acids such as Threonine (0.18 gkg^{-1}), Isoleucine (0.16 gkg^{-1}), Leucine (0.25 gkg^{-1}), Lysine (0.26 gkg^{-1}), Methionine (0.07 g kg^{-1}), Cysteine (0.06 g kg^{-1}), Phenylalanine (0.017 g kg^{-1}), Tyrosine (0.12 g kg^{-1}), Valine (0.22 g kg^{-1}), Arginine (0.37 g kg^{-1}), Histidine (0.19 g kg^{-1}), Alanine (0.20 g kg^{-1}), Aspartic acid (2.0 g Kg), Glutamic acid (0.43 g kg^{-1}), Glycine (0.16 g/ kg^{-1}), Proline (0.25 g kg^{-1}), and Serine (0.25 g kg^{-1}) are also present in Greater yam tuber (*USDA ARS*, 2014; Lim, 2016).

This plant not only has nutritional values but also has medicinal and pharmaceutical as well as cosmetic and industrial values. Its seed has been used in traditional medicine for the treatment of insomnia, skin infection, herpes, and fever. Different parts of the plant possess a number of pharmacological activities like anticancer, antiviral, immune-modulatory, anti-tyrosinase or skin whitening, and photoprotective activities (Arinathan et al., 2009). An average yield of greater yam is reported to be 20-25 t ha^{-1}. These species have extensive morphological variation in plant structure, leaf structure, length of growing period, types of tubers produced, dry matter of content of tubers, and nutritional and chemical constituent of tubers. However, the existing information regarding yams is very limited. Therefore, in this review we described details about the botanical description, origin and distribution, genetic resource, agronomy, molecular and genomic studies, and future prospectusof yams.

Taxonomy

Greater yamis an underutilised tuber crop, and its common name varies across the world. Most commonly it is known as Guyana arrowroot, ten-months yam, water yam, white yam, winged yam, violet yam, or simply yam. In India, this crop is called in different common names such as Ratalu, Kand, Kachil or Indian Purple yam in different states or regions.

Taxonomical position

The taxonomy of the plant is as follows:

Kingdom	:	Plantae
Clade	:	Tracheophytes
Clade	:	Angiosperms
Clade	:	Monocots
Order	:	Dioscoreales
Family	:	Dioscoreaceae
Genus	:	*Dioscorea*
Species	:	alata

Botanical description

This is a large climber, which can reach 15 m in height, with quadrangular winged stems, twining is anticlockwise (to the right). The leaves are opposite, variable in size and shape, but essentially ovate to cordate with a deep basal sinus, acuminate. The male flowers are borne on panicles, up to 30 cm long; the female flowers are on small axillary spikes. Few cultivars produce fertile seeds, and most are completely sterile. Bulbils are sometimes formed in leaf axils, but not so freely as with certain other species. The tubers are usually single and show a great deal of variation in size, shape and colour: they are generally cylindrical but may be long and serpentine to almost globular, and are often branched or lobed, or even flattened and fan shaped. Their weight is usually 5-10 kg though special cultivation practices can produce giant tubers of 60 kg or more. The flesh of some cultivars can be pink or even deep reddish-purple and these forms have been classified as *D. purpurea* Roxb. and *D. afropurpurea* Roxb. but this is not generally accepted.

Origin and distribution

D. alata is not known in the wild state but appears to have been developed from native species originating in the Assam-Burma region, by selection from deeper-rooting forms. Subsequently, it was spread through Thailand and Vietnam into the Pacific region, westwards and southwards to India and Malaysia and thence apparently to Madagascar and East Africa, later to be taken by the Portuguese and Spaniards to West Africa, northern South America and the Caribbean; in the eastern Caribbean and in the Pacific it is the most popular species of yam. It is cultivated throughout the tropical world. In India, greater yam reported to be found in the states like Assam, Tamil Nadu, Kerala, Bihar, Odisha, West Bengal, Rajasthan, Gujarat and Maharashtra.

Genetic diversity in greater yam

The exact location of greater yam origin is unknown. It is assumed to have been domesticated about 6000 years ago and is native to Asia-Pacific, however it has never been seen in its natural condition. In *D. alata*, the highest phenotypic heterogeneity was seen in the southern region of Southeast Asia and Melanesia, the species' likely site of origin. *Ex situ* collections of *D. alata* may be found in the South Pacific islands of Papua New Guinea, Fiji, New Caledonia, Solomon Islands, and Vanuatu, with over 1000 varieties. *Ex situ* germplasm collections have been developed in India, including the most significant collection at ICAR-Central Tuber Crops Research Institute (CTCRI), Kerala, India, which has 431 accessions. Several international collections, notably the CRB-PT (Centre de Ressources Biologiques Plantes Tropicales INRA-CIRAD, Guadeloupe, France) and the IITA (International Institute of Tropical Agriculture, Ibadan, Nigeria), have been assembled, comprising 181 and 772 *D. alata* accessions, respectively.

Using enzymatic markers, Lebot et al., (1998) assessed the diversity of 269 *D. alata* accessions from diverse locations (South Pacific, Asia, Africa, and the Caribbean). The modest polymorphism of the four enzymatic systems, on the other hand, revealed no relationships between zymotype groups and geographic origins, ploidy levels, and/or phenotypic traits of the accessions.Various molecular markers including RAPD, AFLP and SSR have been used to characterize the genetic diversity of *D. alata* collections. Asemota *et al*. have used random amplified polymorphic DNA (RAPD) analysis to characterize eleven cultivars of the five economically most important yam species grown in Jamaica (*Dioscorea alata, D. cayenensis, D. rotundata, D. trifida and D. esculenta*) (Asemota et al., 1995). Arnau et al. used Amplified fragment length polymorphism markers to assess the genetic relatedness between *D. alata* and nine other edible *Dioscorea* (Arnau et al., 2017). These species include *D. abyssinica* Hoch., *D. bulbifera* L., *D. cayenensis*-rotundata Lamk. et Poir., *D. esculenta* Burk., *D. nummularia* Lam., *D. pentaphylla* L., *D. persimilis* Prain. et Burk., *D. transversa* Br. and *D. trifida* L. Four successive studies were conducted with emphasis on the genetic relationship within *D. alata* and among species of the *Enantiophyllum* section from Vanuatu (Malapa et al., 2005). Cardona et al., used seven intersimple sequence repeat (ISSR) markers to describe the genetic diversity of *Dioscorea alata* L. and associated species from Colombia (42 *D. alata* L., 6 *D. bulbifera* L., 3 *D. rotundata* Poir., and 3 *D. trifida* L. f.)(Cardona et al., 2020).

A total of ten microsatellite loci were chosen by Siqueria *et al.*, and nine polymorphic loci were used to analyse 80 *D. alata* accessions from various parts of Brazil (Siqueira et al., 2014). The power discrimination (PD) ranged from 0.15 to 0.91, while the polymorphism information content (PIC) ranged from 0.39 to 0.78. Six of the markers were shown to be transferable between the *D. bulbifera, D. cayenensis, D. rotundata, and D. trifida* species. For phenotypic and genetic diversity, a working collection of yam (*Dioscorea* spp.) was analysed by Adjei et al., which included 53 landraces and seven improved cultivars from four species (*Dioscorea alata* L., *D. cayenensis* Lam., *D. dumetorum* (Kunth), and *D. rotundata* Poir.) (Adjei et al., 2022). The examination included a field assessment of 24 physical features as well as DNA analysis using 32 SSR polymorphism markers. Between-species diversity was higher than within-species diversity, with *D. rotundata* having the most diversity and *D. alata* and *D. cayenensis* having the lowest. *D. rotundata* and *D. cayenensis* were shown to have a close connection based on combined phenotypic and SSR marker data sets, whereas *D. alata* and *D. dumetorum* remained separate species. Genetically, *D. alata* was connected to *D. rotundata* and *D. cayenensis*, while phenotypically, it was similar to *D. dumetorum*. According to the research, cultivars grown from various farmers may have the same name yet vary genetically.

Collection and conservation

Greater yam gives optimum yields at rainfall of 150 cm evenly distributed over 6-7 months though it will perform moderately well on 100 cm. *D. alata* can tolerate poorer soils than most other species of yam, but it responds well to fertilising. In India, FYM at the rate of 25 t ha^{-1} has been recommended. In Barbados, where the crop is frequently grown as a rotation crop with sugar cane which has been fertilised with a 22:0:22 NPK mixture, yields of about 10 t ha^{-1} are normal, but additional fertilising with NPK at the rate of nitrogen 22 kg, phosphorus 25 kg and potassium 57 kg per hectare gave significant and economic increases in yield. Smaller increases were given when phosphorus was omitted. Application should be about 10 weeks after planting, when the plant is completing its dependence upon the parent sets. It is usually cultivated at low or medium elevations but is grown as high as 2700 m in India. Maturity takes 9-10 months on an average, while certain 'early' types may be harvested as early as 6 months. Harvesting is usually done by forking, however due to the size and irregular form of many cultivars' tubers, damage is common, with 20-25 percent of tubers being damaged. Recent improvements in the Caribbean have resulted in the creation of a mechanised harvester and an 8 percent decrease in damaged tubers. Under typical tropical circumstances, storage lasts 4-6 months. Storage is terminated by the breaking of dormancy if the tubers are sound; if sprouts are removed as they emerge, storage may be prolonged to nearly 8 months.

Pests and diseases

In addition to yam beetles and scale insects, the greater yam is attacked by the larvae of three Lepidoptera species: *Loxuraatymnus, Theretranessus*, and *Tagiadesgana*. The first is the most harmful, since the larvae attack the stems after first eating on the leaves, forcing them to snap off. *Scutellonemabradys*, a yam nematode, is also capable of attacking *D. alata*. One of the most troublesome diseases affecting this species is anthracnose caused by *Colletotrichum gloeosporioides*, sometimes in association with other fungi, notably *Botryodiplodia and Fusarium* spp.; crop losses can sometimes amount to 70-80 per cent. Spraying of zineb or ferbam at 10 day intervals is stated to be effective (Winch et al., 1984). Leaf spot, due to *Cercospora* spp., is reported to be serious in Sri Lanka (Hong et al., 2010). In Guadeloupe, crown-gall, a bacterial condition caused by *Agrobacterium tumefaciens* has been observed. An internal brown spot has caused serious losses in yams exported from Barbados; this has been traced to a virus infection which also leads to considerable reduction in yield (Okon et al., 2022).

Ethno-botanical uses

The word 'ethno-botany' refers to the studies on how people from a specific culture and region use plants. Different *Dioscorea* species plays a remarkable position in the traditional medicines for the treatment of various diseases (Kumar et al., 2017). There are numerous reports available on ethno-medicinal uses worldwide (Sharma and Bastakoti, 2010; Sheikh et al., 2017). In South Asia, the tuber syrup is used to reduce labour pain and to treat various diseases such as colic pain, asthma, cough, rheumatism, and gastric problem (Foster and Duke, 2000). The native people of Southern Thailand use tubers to cure warts (Maneenoon et al., 2008). The tuber is an important component in limiting water loss during pregnancy, and it also helps to alleviate nausea and vomiting. In Bangladesh, the tubers of *D. bulbifera* are used to treat leprosy and tumours, and to heal sore throats in Chinese medicine (Mbiantcha et al., 2011). In Zimbabwe, the tuber is used to cure wounds and sores, and in Cameroon and Madagascar, the bulbils paste is externally applied to boils and wound (Mbiantcha et al., 2011). *D. alata* was utilised by the native tribal populations of Enugu, Nigeria to treat fever (Aiyeloja and Bello, 2006).

Pharmacological uses

Dioscorea species have been reported to have anti-microbial, anti-fungal, antimutagenic, hypoglycaemic, and immunomodulatory effects (Kumar et al., 2017). The extracts of *D. alata* is identified to have antifungal activities on *Botryodiploidia theobromae* (Eleazu et al., 2013). Antimicrobial activities of yams against gram-positive and gram-negative bacteria such as *Staphylococcus aureus, Pseudomonas aeruginosa, Streptococcus mutans, Streptococcus pyogenes, Vibrio cholerae, Salmonella enteric-typhi, Shigella flexneri,* and *Klebsiella pneumoniae* have been reported by several researchers (Kumar et al., 2013). The existence of anticancer components has been demonstrated by the cytotoxicity of *D. alata* extract on human cancer cell lines (Das et al., 2014). *D. alata* (Maithili et al., 2011) has been shown to have anti-diabetic properties and can be used in the treatment of type 2 diabetes. Diosgenin, a chemical component found in *D. alata*, is used to create steroids like dehydroepiandrosterone (Jesus et al., 2016).

Usage as Food

Greater yam is used mainly as a vegetable, similar to potato, and some cultivars can be used to make French fries and chips, claimed to be superior to similar potato products. Although it is the preferred yam in many parts of the tropics, especially by those accustomed to European dietary habits, it is less highly regarded in West Africa, because it is not suitable for the preparation of 'fufu'. In some countries, such as Philippines, Barbados and Puerto Rico, attempts are being made to develop processed products such as yam flakes or powder from surplus supplies of *D. alata* (Anyaogu, 2013). Coloured cultivars have been utilised as a colouring and flavouring agent for ice cream. Secondary and waste products like severely damaged tubers are often fed to pigs. A typical analysis of the edible portion of the tubers is: water 65-73 per cent; protein 1.12-2.78 per cent; fat 0.03-0.27 per cent; carbohydrate 22-29 per cent; fibre 0.65-1.4 per cent; ash 0.67-2.06 per cent. The starch contains a high proportion of large granules with size ranging from 5 to 50 microns have been reported. The starch gelatinization temperature ranges from 69°C to 88°C and the viscosity from 100 to 200 Brabender units. Unlike most other yam species, starch from *D. alata* has a high gel strength. Starch from white-fleshed and purple-fleshed cultivars have similar typical composition averaging: moisture 13.6 per cent; protein 0.14 per cent; ash 0.22 per cent; amylose 21.1 per cent; reducing sugars 0.18 per cent; pH 7.1; iodine value 5.5. Ascorbic acid contents ranging from 4.9 to 8.2 mg100 g^{-1} of edible portion have been reported, while certain cultivars in the South Pacific have been found to contain 6 $mg100^{-1}$ g of carotene. Three anthocyanins have been isolated from *D. alata* var. atropurpurea and rubella and found to be cyanidin glycosides (Anyaogu, 2013).

Nutritional parameters

In comparison to other tropical tuber crops, greater yams are thought to provide a significant quantity of different nutritional components. The yam tuber is said to be an excellent source of key nutritional components such carbohydrates, proteins, fats, vitamins, and minerals, among others (Arinathan et al., 2009; Mohan and Kalidas, 2010).

Proximate composition

Moisture, ash, crude fat, crude protein, crude fibre, and carbohydrate make up the proximate composition, which is very essential in highlighting the food quality (Polycarp et al., 2012). Ghanaian greater yams had a moisture level of 58 to 79 percent (Polycarp et al., 2012), Indian greater yams had a moisture content of 71 to 92 percent (Shanthakumari et al., 2008), and Nepalese yams had a moisture content of 19 to 30 percent (Bhandari et al., 2003). The ash content of the food determines the presence of important dietary minerals and useful for the development of the body (Otegbayo et al., 2018). Greater yam has a lower ash content than other tuber crops like potato and cassava (Bhandari et al., 2003; Otegbayo et al., 2018). Dietary fats aid in the absorption and preservation of tastes during cooking, resulting in improved food palatability (Otegbayo et al., 2018). Yam has been observed to have a greater dietary fat or lipid content than potato and sweet potato (Otegbayo et al., 2018). According to researchers, yam species have higher dietary fibre than other tuber crops including potatoes, cassava, and sweet potatoes (Baah et al., 2009; Shanthakumari et al., 2008) as high fibre in the diet aids in the digestion and absorption of nutrients in the large intestine, preventing constipation (Baah et al., 2009). The texture quality of yam is also influenced by non-starchy carbohydrates such as lignin, cellulose, and hemicelluloses (Otegbayo et al., 2018).

In all living species, protein aids in the structural and functional activities of cells, as well as the regulation of metabolic processes. The protein content of yam species is said to be greater than that of other major tuber crops such as cassava (Charles et al., 2005) and sweet potato (Moongngarm, 2013). The crude protein content is reported in Ethiopian yam (*D. bulbifera*) (9.7% dry wt. basis) (Tamiru et al., 2008); Sri Lankan yams (*D. alata and D. esculenta*) (10.16%) (Senanayake et al., 2012); and several Indian varieties (*D. alata, D. bulbifera, D. esculenta, D. oppositifolia, D. pentaphylla*(Aprianita et al., 2014). Carbohydrate is a component of the proximate composition of food that gives energy to the body and is crucial to the construction and operation of cellular mechanisms (Baah et al., 2009). The sugar and starch contentsin yams are said to be lower than that of potatoes and cassava (Baah et al., 2009; Ohene Afoakwa and Simpson Budu, 2012; Otegbayo et al., 2018). Greater yams, followed by cassava (20%), taro (4%) and sweet potato (2%) are said to offer 12 % of the energy diet for humans in tropical nations (Otegbayo et al., 2018).

Vitamins

Different dietary vitamins assist the body in converting protein, fat, and carbohydrate into energy and making it accessible to the body. Vitamins C and E are antioxidants that also serve as cofactors for enzymes. Vitamin C has a variety of functions, including radical scavenging, collagen production, iron absorption, wound healing, and anti-inflammatory effects. Greater yam tubers have a greater concentration of vitamins than other tuber crops (USDA ARS, 2015). The most abundant nutrient in yam tubers is Vitamin C (Udensi et al., 2008).

Minerals

Dietary minerals are necessary for human nutrition and play an important part in the body's metabolic processes (Polycarp et al., 2012). Calcium is a necessary mineral that aids in blood coagulation and the integrity of intracellular cementing elements (Polycarp et al., 2012). Iron is required for the synthesis of blood haemoglobin and aids in the transfer of oxygen throughout the body. Myocardial illness, gastrointestinal infection, nasal bleeding, and other conditions are caused by a lack of iron in the body (Polycarp et al., 2012). Zinc is an important mineral that aids in the growth of the brain and bone, as well as wound healing (Padhan et al., 2018). It also aids in glucose, protein, vitamin A, and nucleic acid biosynthesis metabolic processes (Padhan et al., 2018). Potassium deficiency in the body enhances iron usage, which is excellent for hypertension management (Padhan and Panda, 2020). Potassium is good for diuretics who are trying to lower their blood pressure (Padhan and Panda, 2020)The greater yam tubers are high in minerals, with potassium being the most prevalent mineral found in the tubers (Baah et al., 2009; Polycarp et al., 2012).

Physico-functional properties

For bioprospecting of food ingredients, physico-functional properties such as water absorption capacity (WAC), foam capacity (FC), paste clarity (PC), water solubility index (WSI), and iodine affinity to starch (IAS), bulk density, and gelatinization temperature are important parameters in the food industry (Ohene Afoakwa and Simpson Budu, 2012). Starch and the ratio of amylose to amylopectin are two elements that determine the physico-functional characteristics (Sanful et al., 2013). Many researchers have researched many physico-functional properties in the yam tuber and have concluded that its flour may be used to make food products (Ojinnaka et al., 2017; Sanful et al., 2013). The quantity of water absorbed by flour to make dough of the desired consistency is known as water absorption capacity (WAC) (Chandra et al., 2015). The consequences of the flour's interactions with water and oil are reflected in the taste and texture of dishes. The flour with a high WAC is acceptable for use in the formulation of several culinary and bakery items that need viscosity (Chandra et al., 2015). The amylose leaching from starch granules is linked to the water solubility index (WSI) (Padhan & Panda, 2020). The texture, consistency, and look of food products are all improved by foam (Chandra et al., 2015). The foam capacity (FC) reveals how much interfacial area the protein in the flour creates (Chandra et al., 2015). The foam capacity and foam stability are inversely proportional (Chandra et al., 2015). Paste clarity (PC) is a desired quality that affects the food's brightness and turbidity (Mweta et al., 2008). Greater yam tuber flours, they said, have a lot of promise as a food component in the food sector. But, wild species such as *D. hamiltonii, D. pubera, and D. oppositifolia* showed greater WAC, FC, PC, WSI, and IAS values than farmed species *D. alata*, according to some researchers (Padhan and Panda, 2020). Hence, enhancement of these factors is to be done to this species to make it more usable in the commercialized food sector.

Anti-nutritional factors

Anti-nutritional factors are chemical compounds produced naturally by regular metabolism that impair the body's nutrient consumption (Bhandari and Kawabata, 2004). Anti-nutritional factors lower the nutritive value of food by reducing the bioavailability of dietary components such as protein, minerals, and vitamins (Padhan et al., 2018). The acrid tubers of yam species contain anti-nutritional substances that cause skin irritation and inflammation of the buccal cavity and throat after ingestion (Kumar et al., 2017). Anti-nutritional elements in yams include phenols, alkaloid, oxalate, phytate, tannin, saponin, amylase inhibitors, and trypsin inhibitors, which are responsible for toxicity and bitterness (Poornima and Ravishankar, 2009).

Yam tubers have a higher concentration of alpha amylase inhibitor than other commercial tuber crops (Padhan et al., 2020; Polycarp et al., 2012). The amylase inhibitor creates a compound with pancreatic amylase enzyme in a 1:1 ratio and attaches to a place other than the active site, inactivating the enzyme's catalytic power via conformational changes (Jamil et al., 2000). Protease inhibitors are a group of proteins that suppress proteolytic enzymes. Trypsin inhibitor is one of them. The concentration of trypsin inhibitors in wild yam tubers has been observed to be higher than in farmed species (Bhandari and Kawabata, 2006; Padhan et al., 2020). Alkaloids and their derivatives exhibit a variety of pharmacological effects, including analgesic, antispasmodic, and antibacterial activities (Polycarp et al., 2012). The alkaloid content of wild yam species is said to be higher than that of farmed yam species (Polycarp et al., 2012). The antioxidant activity of flavonoids found in yam species has been proven to scavenge free radicals (Bhandari and Kawabata, 2004). Tannins are the compounds that give foods and beverages their astringent flavour. Plants with high tannin content have been used to cure disorders including leucorrhoea, rhinorrhoea, wound healing, and diarrhoea (Eleazu et al., 2013). The presence of tannins in yam species causes them to be bitter (Padhan et al., 2020).

The principal physiologically active elements of yams have been found to be steroidal saponins (Avula et al., 2012). There are 20 distinct forms of steroidal saponins in *Dioscorea* species, each with different pharmacological effects (Avula et al., 2012). Saponins from yam species have been utilised to make steroid medicines in the past (Kumar et al., 2017). Phenolic chemicals act as a growth inhibitor in plants. They are generally found in conjunction with glucosyl residues in plant tissue. Phenols are classified as anti-nutrients because they reduce protein, carbohydrate, and mineral digestibility and hence render them insoluble (Padhan et al., 2018). They also stop digestive enzymes like amylase, trypsin, and chymotrypsin from working, causing injury to the mucosa of the digestive system (Bhandari and Kawabata, 2004). When the tuber flesh is exposed to the air, the phenols from the larger yam tubers are the main source of browning (Bhandari and Kawabata, 2004). The presence of phenol in higher yam helps to the antioxidant capacity, according to researchers (Cornago et al., 2011; Niu et al., 2010). Oxalate is found in plants in the form of calcium oxalate and is extensively spread. Oxalic acid forms oxalate salts when it reacts strongly with dietary elements such calcium, magnesium, sodium, and potassium (Padhan et al., 2018). Calcium oxalate crystals occur when insoluble calcium oxalate salts precipitate in the kidney and urinary system, causing kidney stones (Padhan et al., 2018). Increased oxalate levels in diet induce nutritional deficiencies as well as severe throat discomfort. The presence of calcium oxalate crystals (raphides) in increased yam mucilage promotes skin and mucous membrane irritation (Otegbayo et al., 2018). Wild yam species have been shown to have a higher concentration of oxalates, which cause skin irritation and throat discomfort (Bhandari and Kawabata, 2004; Polycarp et al., 2012).

Bioactive components

The bioactive components are secondary metabolites derived from plants that are employed in insect and pest defence mechanisms. Phenols, polyphenols, alkaloids, polypeptides, steroids, terpenoids, and essential oils are bioactive components with a variety of pharmacological actions (Alamu et al., 2014). Bioactive substances such as phenols, alkaloids, tannins, flavonoids, saponins, glycoside steroids, anthraquinones, and others are known to be abundant in *Dioscorea* species (Price et al., 2017).

Conclusion

Greater yam *(D. alata)* is the world's most popular yam after the *D. rotundata/cayenensis* complex and appears to have held its place. Although traditional methods of production (especially in Africa) are more costly in manpower than for other yams, the introduction of complete field mechanisation, which is now a reality, should reduce production costs and make this crop more competitive as a tropical carbohydrate food and also enable it to maintain or improve its position on the export market. No figures are available for the production of *D. alata* separately from other yams. There has been a small export trade in *D. alata* from some of the Caribbean islands to the UK since the early 1960s. In 1968, approximately 1000 t of tubers of *D. alata* were exported from Barbados, but the occurrence of chilling injury at the receiving point, and the incidence of internal black spot (virus), reduced the trade almost to zero. However, the recent production of virus-free yams has allowed the trade to re-start bringing on the new era for yam.

Acknowledgements

The authors are thankful to the Director, ICAR-CTCRI, Thiruvananthapuram, Kerala, India for kind support.

References

Adjei, E. A., Esuma, W., Alicai, T., Bhattacharjee, R., Dramadri, I. O., Agaba, R., Chamba, E. B., et al. 2022. Phenotypic Diversity within Ugandan Yam (*Dioscorea* species) Germplasm Collection. *Int. J. Agron.,* **2022**:5826012.

Aiyeloja, A. A. and Bello, O. A. 2006. Ethnobotanical potentials of common herbs in Nigeria: A case study of Enugu state. *Educ. Res. Rev.,* **1**:16–22.

Alamu, E. O., Maziya-Dixon, B., Okonkwo, C. C. and Asiedu, R. 2014. Physicochemical and bioactive properties of selected white yam (Dioscorea rotundata) varieties adapted to riverine areas of Nigeria. *African J. Food Sci.,* **8**:402–409.

Anyaogu Daniel Chinedu. 2013. The Production of Yam Flour. Submitted To the Department of Chemical Engineering Faculty of Engineering Caritas Universsity Amorji-Nike.

Aprianita, A., Vasiljevic, T., Bannikova, A. and Kasapis, S. 2014. Physicochemical properties of flours and starches derived from traditional Indonesian tubers and roots. *J. Food Sci. Technol.,* **51**:3669–3679.

Arinathan, V., Mohan, V. R. and Maruthupandian, A. 2009. Nutritional and anti-nutritional attributes of some underutilized tubers. *Trop. Subtrop Agroecosystems,* **10**:273–278.

Arnau, G., Bhattacharjee, R., Sheela, M. N., Chair, H., Malapa, R., Lebot, V., Abraham, K., et al. 2017. Understanding the genetic diversity and population structure of yam (*Dioscorea alata* L.) using microsatellite markers. *PLoS One,* **12**:1–17.

Asemota, H. N., Ramser, J., Lopez-Peralta, C., Weising, K. and Kahl, G. 1995. Genetic variation and cultivar identification of Jamaican yam germplasm by random amplified polymorphic DNA analysis. *Euphytica,* **92**:341–351.

Avula, B., Wang, Y. H., Wang, M., Ali, Z., Smillie, T. J., Zweigenbaum, J. and Khan, I. A. 2012. Structural characterization of steroidal saponins from *Dioscorea* species using UHPLC-QTOF-MS. *Planta Med.,* **78**:PI385.

Baah, F. D., Maziya-Dixon, B., Asiedu, R., Oduro, I. and Ellis, W. O. 2009. Nutritional and biochemical composition of *D. alata* (*Dioscorea* spp.) tubers. *J. Food Agric. Env.,* **7**:373–378.

Bhandari, M. R., Kasai, T. and Kawabata, J. 2003. Nutritional evaluation of wild yam (*Dioscorea* spp.) tubers of Nepal. *Food Chem.,* **82**:619–623.

Bhandari, M. R. and Kawabata, J. 2004. Organic acid, phenolic content and antioxidant activity of wild yam (Dioscorea spp.) tubers of Nepal. *Food Chem.,* **88**:163–168.

Castañeda-Cardona, C. C., Morillo-Coronado, Y. and Morillo, A. C. 2020. Assessing the genetic diversity of dioscorea alata and related species from colombia through inter-simple sequence repeat (ISSR) markers. *Chil. J. Agric. Res.,* **80**:608–616.

Chandra, S., Singh, S. and Kumari, D. 2015. Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. *J. Food Sci. Technol.,* **52**:3681–3688.

Charles, A. L., Sriroth, K. and Huang, T. 2005. Proximate composition, mineral contents, hydrogen cyanide and phytic acid of 5 cassava genotypes. *Food Chem.,* **92**:615–620.

Cornago, D. F., Rumbaoa, R. G. O. and Geronimo, I. M. 2011. Philippine Yam (*Dioscorea* spp.) tubers phenolic content and antioxidant capacity. *Philipp. J. Sci.,* **140**:145–152.

Crowther, A., Lucas, L., Helm, R., Horton, M., Shipton, C., Wright, H. T., Walshaw, S., et al. 2016. Ancient crops provide first archaeological signature of the westward Austronesian expansion. *Proc. Natl. Acad. Sci. U. S. A.,* **113**: 6635–6640.

Das, A., Chaudhuri, D., Ghate, N. B., Chatterjee, A. and Mandal, N. 2014. Phytochemical analysis, antioxidant and anticancer potential of leaf extracts from edible greater yam, *Dioscorea alata* L., from north-east India. *Int. J. Phytopharm.,* **5**:109–119.

Eleazu, C. O., Kolawole, S. and Awa, E. 2013. Phytochemical composition and antifungal actions of aqueous and ethanolic extracts of the peels of two yam varieties. *Med. Aromat. Plants,* **2**: 1–4.

Foster, S. and Duke, J. A. 2000. *A Field Guide to Medicinal Plants and Herbs of Eastern and Central North America*. Peterson field guide series. Houghton Mifflin Company. Retrieved from https://books.google.co.in/books?id=f4qql6V8a38C

Hong, S. K., Kim, W. G., Lee, Y. K., Choi, H. W., Choi, K. J. and Lee, S. Y. 2010. Leaf Spot of Yam Caused by Pseudophloeosporella dioscoreae in Korea. *Mycobiology,* **38**:78–80.

Jamil, A., Khan, K. M., Hamid, Y. and Sial, M. B. 2000. Effect of different cooking procedures on in vitro amylolytic activity, inherently present amylase and amylase inhibitors in black gram. *Pak. J. Agr. Sci.,* **37**:1–2.

Jesus, M., Martins, A. P. J., Gallardo, E. and Silvestre, S. 2016. Diosgenin: Recent Highlights on Pharmacology and Analytical Methodology. *J. Anal. Methods Chem.,* **2016**:4156293.

Kumar, S., Behera, S. P. and Jena, P. K. 2013. Validation of tribal claims on *Dioscorea pentaphylla* L. through phytochemical screening and evaluation of antibacterial activity. *Plant Sci. Res.,* **35**:55–61.

Kumar, S., Das, G., Shin, H.-S. and Patra, J. K. 2017. *Dioscorea* spp. (A Wild Edible Tuber): A study on its ethnopharmacological potential and traditional use by the local people of similipal biosphere reserve, India. *Front. Pharmacol..* **8**:52.

Lebot, V., Trilles, B., Noyer, J. L. and Modesto, J. 1998. Genetic relationships between *Dioscorea alata* L. cultivars. *Genet. Resour. Crop Evol.,* **45**:499–509.

Lebot, Vincent, Lawac, F. and Legendre, L. 2022. The greater yam (*Dioscorea alata* L.): A review of its phytochemical content and potential for processed products and biofortification. *J. Food Compos. Anal.,* **15**:104987.

Lim, T. K. 2016. Dioscorea esculenta - Edible Medicinal and Non-Medicinal Plants: Volume 10, Modified Stems, Roots, Bulbs. In: *Edible Medicinal and Non-Medicinal Plants* (T. K. Lim, ed.), 253–260.

Maithili, V., Dhanabal, S. P., Mahendran, S. and Vadivelan, R. 2011. Antidiabetic activity of ethanolic extract of tubers of *Dioscorea alata* in alloxan induced diabetic rats. *Indian J. Pharmacol.,* **43**:455–459.

Malapa, R., Arnau, G., Noyer, J.-L. and Lebot, V. 2005. Genetic diversity of the greater yam (*Dioscorea alata* L.)

and relatedness to *D. nummularia* Lam. and *D. transversa* Br. as revealed with AFLP markers. *Genet. Resour. Crop Evol.,* **52**:919–929.

Maneenoon, K., Sirirugsa, P. and Sridith, K. 2008. Ethnobotany of *Dioscorea* L.(Dioscoreaceae), a major food plant of the Sakai tribe at Banthad Range, Peninsular Thailand. *Ethnobot. Res. Appl.,* **6**:385–394.

Mbiantcha, M., Kamanyi, A., Teponno, R. B., Tapondjou, A. L., Watcho, P. and Nguelefack, T. B. 2011. Analgesic and Anti-Inflammatory Properties of Extracts from the Bulbils of *Dioscorea bulbifera* L. var sativa (Dioscoreaceae) in Mice and Rats. *Evid. Based. Complement. Alternat. Med.,* **2011**:912935.

Mohan, V. R. and Kalidass, C. 2010. Nutritional and antinutritional evaluation of some unconventional wild edible plants. *Trop. Subtrop. Agroecosystems,* **12**:495–506.

Moongngarm, A. 2013. Chemical compositions and resistant starch content in starchy foods. *Am. J. Agric. Biol. Sci.,* **8**:107.

Mweta, D. E., Labuschagne, M. T., Koen, E., Benesi, I. R. M. and Saka, J. D. K. 2008. Some properties of starches from cocoyam (*Colocasia esculenta*) and cassava (*Manihot esculenta* Crantz.) grown in Malawi. *African J. Food Sci.,* **2**:102–111.

Niu, C.-S., Chen, W., Wu, H.-T., Cheng, K.-C., Wen, Y.-J., Lin, K.-C. and Cheng, J.-T. 2010. Decrease of plasma glucose by allantoin, an active principle of yam (*Dioscorea* spp.), in streptozotocin-induced diabetic rats. *J. Agric. Food Chem.,* **58**:12031–12035.

Ohene Afoakwa, E. and Simpson Budu, A. 2012. Viscoelastic Properties and Physico-Functional Characterization of Six High Yielding Cassava Mosaic Disease-Resistant Cassava (*Manihot Esculenta* Crantz) Genotypes. *J. Nutr. Food Sci.,* **02**:1000129.

Ojinnaka, M. C., Okudu, H. and Uzosike, F. 2017. Nutrient composition and functional properties of major cultivars of aerial yam (*Dioscorea bulbifera*) in Nigeria. *Food Sci. Qual. Manag.,* **62**:1–2.

Okon, N. I., Markson, A.-A. A., Okon, E. I., Ita, E. E., Uyoh, E. A., Ene-Obong, E.-O. E. and Ntui, V. O. 2022. Characterization of some fungal pathogens causing anthracnose disease on yam in Cross River State, Nigeria. *PLoS One,* **17**:e0270601.

Otegbayo, B. O., Oguniyan, D. J., Olunlade, B. A., Oroniran, O. O. and Atobatele, O. E. 2018. Characterizing genotypic variation in biochemical composition, anti-nutritional and mineral bioavailability of some Nigerian yam (*Dioscorea* spp.) land races. *J. Food Sci. Technol.,* **55**:205–216.

Padhan, B., Biswas, M., Dhal, N. K. and Panda, D. 2018. Evaluation of mineral bioavailability and heavy metal content in indigenous food plant wild yams (*Dioscorea* spp.) from Koraput, India. *J. Food Sci. Technol.,* **55**:4681–4686.

Padhan, B., Nayak, J. K. and Panda, D. 2020. Natural antioxidant potential of selected underutilized wild yams (*Dioscorea* spp.) for health benefit. *J. Food Sci. Technol.,* **57**:2370–2376.

Padhan, B. and Panda, D. 2020. Potential of Neglected and Underutilized Yams (*Dioscorea* spp.) for Improving Nutritional Security and Health Benefits. *Front. Pharmacol.,* **11**:496.

Polycarp, D., Afoakwa, E. O., Budu, A. S. and Otoo, E. 2012. Characterization of chemical composition and anti-nutritional factors in seven species within the Ghanaian yam (*Dioscorea*) germplasm. *Int. Food Res. J.,* **19**:985-992.

Poornima, G. N. and Ravishankar, R. V. 2009. Evaluation of phytonutrients and vitamin contents in a wild yam, *Dioscorea belophylla* (Prain) Haines. *African J. Biotechnol.,* **8**:971-973.

Price, E. J., Bhattacharjee, R., Lopez-Montes, A. and Fraser, P. D. 2017. Metabolite profiling of yam (*Dioscorea* spp.) accessions for use in crop improvement programmes. *Metabolomics,* **13**:1–12.

Sanful, R. E., Oduro, I. and Ellis, W. O. 2013. Proximate and functional properties of five local varieties of aerial yam (D*ioscorea bulbifera*) in Ghana. *Middle East J. Sci. Res.,* **14**:947–951.

Senanayake, S. A., Ranaweera, K., Bamunuarachchi, A. and Gunaratne, A. 2012. Proximate analysis and phytochemical and mineral constituents in four cultivars of yams and tuber crops in Sri Lanka. Faculty of Agriculture, University of Ruhuna: Kamburupitiya.

Shanthakumari, S., Mohan, V. R. and Britto, J. de. 2008. Nutritional evaluation and elimination of toxic principles in wild yam (*Dioscorea* spp.). *Trop. Subtrop. Agroecosystems,* **8**:319–325.

Sharma, L. N. and Bastakoti, R. 2010. Ethnobotany of *Dioscorea* L. with emphasis on food value in Chepang communities in Dhading district, central Nepal. *Bot. Orient. J. Plant Sci.,* **6**:12–17.

Sheikh, N., Kumar, Y., Jeri, L. and Bhat, N. A. 2017. Ethnobotanical Uses and Survey of *Dioscorea* Species of North East India: Its Conservation and Sustainable Utilization. *Int. J. Curr. Res. Biosci. Plant Biol.,* **4**:117–124.

Siqueira, M. V. B. M., Bonatelli, M. L., Günther, T., Gawenda, I., Schmid, K. J., Pavinato, V. A. C. and Veasey, E. A. 2014. Water yam (*Dioscorea alata* L.) diversity pattern in Brazil: an analysis with SSR and morphological markers. *Genet. Resour. Crop Evol.,* **61**:611–624.

Tamiru, M., Maass, B. L. and Pawelzik, E. 2008. Characterizing diversity in composition and pasting properties of tuber flour in yam germplasm (*Dioscorea* spp.) from Southern Ethiopia. *J. Sci. Food Agric.,* **88**:1675–1685.

Udensi, E. A., Oselebe, H. O. and Iweala, O. O. 2008. The investigation of chemical composition and functional properties of water yam (*Dioscorea alata*): Effect of varietal differences. *Pakistan J. Nutr.,* **7**:342–344.

USDA ARS. 2014.

USDA ARS. 2015.

Winch, J. E., Newhook, F. J., Jackson, G. V. H. and Cole, J. S. 1984. Studies of Colletotrichum gloeosporioides disease on yam, *Dioscorea alata*, in Solomon Islands. *Plant Pathol.,* **33**:467–477.