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Nutraceutical potential of underutilized tuber crops: Pharmacological insights and applications

R. Gowshika*, J. Rajangam, R. Sundharaiya***, K. Venkatesan****◆ and K. Kalpana*****

** Department of Vegetable Science, Horticultural College and Research Institute, Periyakulam-625 604, Tamil Nadu, India*

*** Horticultural College and Research Institute, Periyakulam-625 604, Tamil Nadu, India*

**** Department of Fruit Science, Horticultural College and Research Institute, Periyakulam-625 604, Tamil Nadu, India*

***** Department of Floriculture and Landscape Architecture, Horticultural College and Research Institute, Periyakulam-625 604, Tamil Nadu, India*

****** Department of Plant Protection, Horticultural College and Research Institute, Periyakulam-625 604, Tamil Nadu, India*

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Abstract

Underutilized tuber crops represent a significant reservoir of nutraceutical potential, offering diverse phytochemicals with promising pharmacological properties. This review examines the nutritional profile, bioactive components, and health benefits of a number of underutilized tubers including West Indian arrowroot, Chinese yam, yam bean, *Dioscorea* and edible canna. We highlight their roles in addressing global health challenges, including obesity, diabetes, and cardiovascular diseases. Additionally, we also go over the mechanism of their bioactive components such as antioxidants, anti-inflammatory agents and antimicrobial properties. The findings underscore the need for increased awareness and integration of these crops into diets and agricultural practices, promoting sustainable food systems while unlocking their full therapeutic potential. Future research directions are proposed to investigate the pharmacological applications of these crops further, paving the way for novel health interventions.

1. Introduction

In 1979, Dr. Stephen coined the term "nutraceutical," which combines the words "nutrition" and "pharmaceutical" to refer to carefully prepared products meant to meet particular dietary requirements and provide preventative healthcare. These nutraceuticals include dietary supplements and nutritional compositions intended to help prevent and treat a range of illnesses (Puri *et al.,* 2022). The Indian Council of Medical Research (ICMR) recommends consuming 300 g of vegetables each day, which should include 50 g of green leafy vegetables, 200 g of other vegetables, 50 g of roots and tubers, and 100 g of seasonal fruits. This guideline aims to ensure a balanced intake of essential nutrients for optimal health (Padayachee and Baijnath, 2020).

In India, a significant concern is chronic undernutrition affecting 43.5% of children under five years old (Yadav and Pathak, 2016). This issue could be alleviated through the inclusion of healthy food supplements, with tuber crops playing a crucial role. Cultivable tubers are regarded as the third most significant crop category, after cereals and legumes. They have historically played a vital role in food security, nutrition and climate change adaptation during famines and other times of food scarcity. They supply a sizable portion of the diet's carbohydrates and are the main source of edible starches (Edison *et al.,* 2009). Tuber crops exhibit high photosynthetic efficiency, converting solar energy into carbohydrates with a high rate of biomass production, making them a potential solution for addressing future food crises. Besides their carbohydrate content, minerals and vitamins are also abundant in several tuber crops, offering an affordable source of nutrition and energy for economically disadvantaged populations (Tiwari *et al.,* 2023). In addition to well-known staple tubers, there are underutilized crops that thrive in challenging growing conditions such as alkaline soils, arid regions, and hilly terrains. The lack of comprehensive information about these underutilized crops impedes their development and conservation. Nonetheless, as agricultural land becomes increasingly scarce, these small-scale tuber crops have the potential to play a critical role (Nanbol and Namo, 2019) in helping to feed the world's expanding population and reducing food insecurity.

Corresponding author: Dr. K. Venkatesan

Professor, Department of Floriculture and Landscape Architecture, Horticulture College and Research Institute, TNAU, Periyakulam-625604, Tamil Nadu, India

E-mail: venkatesan.k@tnau.ac.in

Tel.: +91-9894505478

2. Underutilized crops

In order to preserve biodiversity, ancient civilizations produced an astounding array of food varieties, meeting their daily needs and adapting to changing weather conditions (Padulosi *et al.,* 2019). Thousands of plant and animal species were tamed by humans at the beginning of civilization (Heywood, 2017). A vast diversity of plant germplasm with both nutritional and medicinal value, closely linked to their culture and environment, was produced prior to the Industrial Revolution as a result of people's efficient use of local resources to satisfy their daily requirements (Padulosi *et al.,* 2019). Modern farming methods; however, have decreased crop diversity, endangering food security and undervaluing crops that offer significant medicinal and nutritional benefits (Beddington *et al.,* 2012; Frison *et al.,* 2011). This showed the importance of biodiversity and neglecting crops with key nutritional and therapeutic benefits. However, underutilized plants, which thrive in marginal conditions, present opportunities to enhance nutritional stability for vulnerable communities (Vasanthkumar *et al.,* 2023).

3. Nutraceutical importance of underutilized tuber crops

In agricultural and forested areas of developing nations, 60-70% of people's daily diets consist of plant parts and foods sourced from forest species, including nuts, fruits, roots, and leaves (Pandiyaraj *et al.,* 2024). Out of 45,000 wild plant species, about 9,500 are relevant to ethnobotany, with 7,500 used in traditional medicine. More than 3,900 plant species are used by tribal communities, including 521 green vegetables and 145 edible roots and tubers. Small areas of the world are home to minor tuber crops. They have a wealth of useful food qualities, including the ability to be nutritious and provide therapeutic benefits (Figure 1) (Desai *et al.,* 2021). Chinese potatoes and arrowroot stand out among them, outperforming other minor tuber crops such as yam beans, Queensland arrowroot, *Curcuma*, *Typhonium*, *Costus*, *Tacca*, and *Vigna* species, among others. At CTCRI, studies are carried out to assess the crops' yield, starch content, and other important characteristics. These underutilized tuber crops contribute significantly to stable food availability through diversification (Table 1) and are rich in minerals, vitamins, antioxidants, and dietary fiber that can neutralize free radicals (Archana Mukherjee *et al.,* 2015).

Table 1: Nutraceutical properties of minor tuber crops

Crop	Important nutraceutical properties	Reference
Chinese potato *Plectranthus rotundifolius*	Hepatoprotection, anti-inflammatory effects, inhibition of tumor promotion, management of hyperlipidemia, anti-HIV properties, and treatment for dysentery, sore throat, eye conditions, and hematuria	Anbuselvi and Balamurugan (2013); Paramita *et al.* (2020)
Yam bean *Pachyrhizus erosus*	Hypoglycemic effects, antimicrobial properties, and antioxidant activities, along with the stimulation of gastric epithelial cell growth and the enhancement of digestive enzyme activity in the small intestine	Chan and Ng (2013)
West Indian Arrowroot *Maranta arundinacea*	Demulcent properties and addressing bowel complaints	Sastri (1962)
Konjac *Amorphophallus Konjac* syn. *A. rivieri*	Promotes the absorption and digestion of proteins and other nutrients, maintains intestinal cleanliness, and supports bowel movements. It helps balance the diet, alleviates fatigue, and contributes to overall fitness while potentially reducing cancer risk. Corms: Functions include detoxification, tumor suppression, reduction of blood stasis, relief of symptoms, and liquefaction of phlegm. Leaves: They are used as animal feed and as a natural insect repellent.	Chua *et al.* (2010)
Achira *Canna edulis*	Antioxidant property	Thitipraphunkul *et al.* (2003)
***Curcuma* spp.**		
Curcuma zedoaria	Carminative effects, antimicrobial activity, and inhibition of gastric cancer cell growth	Makabe *et al.* (2006)
Curcuma malabarica	Demulcent properties, pain-relieving effects, and anti-inflammatory benefits	Wilson *et al.* (2005)
Tikur *Curcuma angustilfolia*	Hypoglycemia, anticoagulant and antibacterial activities, wound-healing effects, antioxidant and anti-inflammatory qualities. Rhizomes: Relieve coughs and are used to treat bronchitis. Essential oil: Antifungal properties used as a nutritious supplement for babies soon after they are weaned, or as a breast milk substitute	Behera *et al.* (2012)
Curcuma caesia	Antioxidative and antimicrobial properties	Chaturvedi *et al.* (2021)
***Dioscorea* spp.** Chinese yam *D. polystachya*	Lower serum levels of low-density lipoprotein (LDL) cholesterol, possess anti-diabetic properties and exhibit anticancer effects	Li *et al.* (2023)
Wild yam *Dioscorea pentaphylla*	Demonstrate antibacterial and antifungal characteristics towards a range of Gram-positive and Gram-negative bacteria, such as *Pseudomonas aeruginosa, Vibrio cholerae, Salmonella enterica typhi, Klebsiella pneumoniae, Streptococcus mutans, and Streptococcus pyogenes*. Additionally, treats gastrointestinal discom-fort, boosts immunity, and treat joint pain	Kumar *et al.* (2017)

D. membranacea	Breast cancer	Itharat *et al.* (2007)
D. collettii	Cervical/renal/urinary bladder carcinoma	Hu and Yao (2002)
D. cayenensis	Antifungal	Sautour *et al.* (2004)
D. dumetorum	Jaundice	Edison *et al.* (2006)
D. hirtiflora	Gonorrhoea	Sonibare and Abegunde (2012)
D. hispida	Vomiting, indigestion, purgatives	Miah *et al.* (2018)
D. hamiltonii	Show antibacterial and antifungal properties against fungi and bacteria that are Gram-positive	Kaladhar *et al.* (2010)

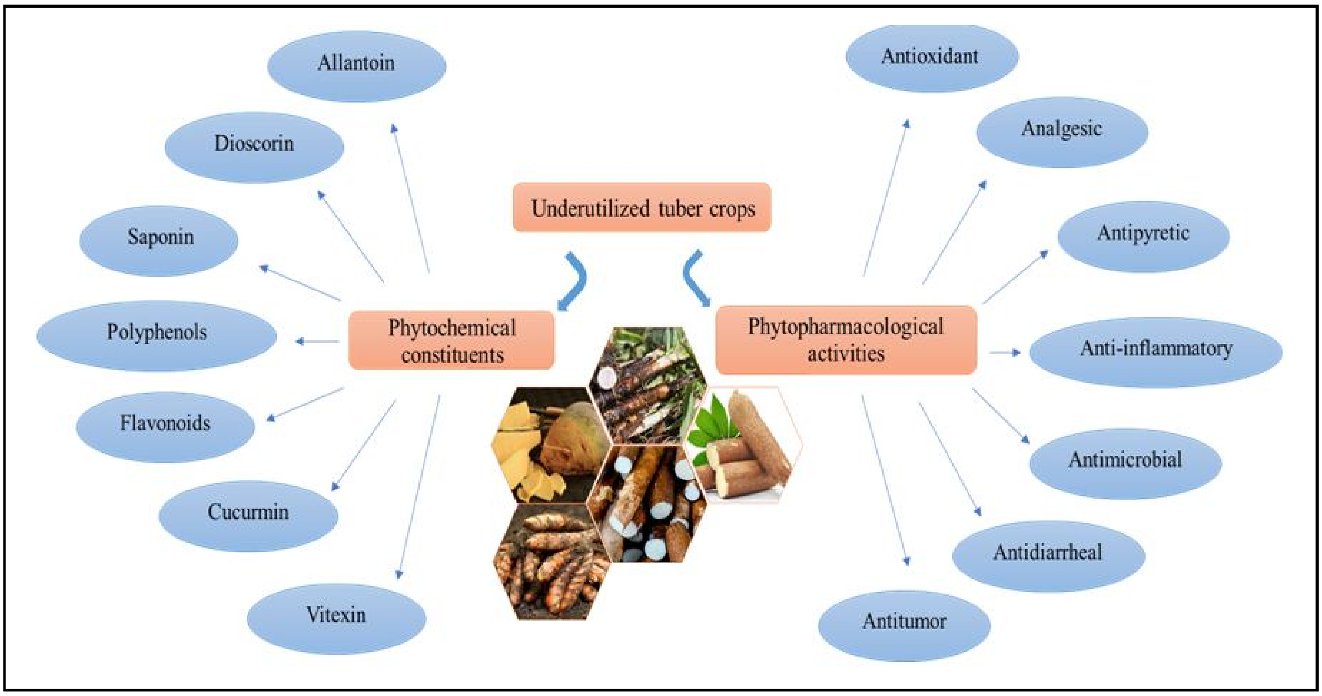

Figure 1: Pharmacological activities and phytochemical constituent of underutilized tuber crops.

4. Nutritional composition of underutilized tuber crops

Tubers are underground storage organs of plants that serve as reservoirs of nutrients essential for both the plant's growth and human consumption. Tubers are rich in starch, which serves as their primary energy reserve. Starch content varies among different tuber species but typically ranges from 60% to 80% of dry weight (Bhavsar *et al.,* 2023). Tubers also contain dietary fiber, which aids in digestion and contributes to feelings of fullness. The majority of tuber species have high dietary fiber content. Though not as much as other plant-based protein sources like legumes, tubers do contain some proteins. On a fresh weight basis, the tubers' protein content ranges from 1% to 2%. Tubers have a very low-fat content, usually less than 1% of their dry weight. The fat present is predominantly in the form of healthy unsaturated fats (Table 2) (Rani *et al.,* 2023).

Table 2: Nutritional composition of underutilized tuber crops

Crop	Carbohydrate	Protein	Fat	Fibre	Energy	Reference
Chinese potato	21.9%	1.3%	0.2%	1.1%	394 kJ	Behera *et al.*, (2012)
West Indian Arrowroot	20%	1-3%	0.2%	22%	271 kJ	Nanbol *et al.*, (2019)
Yam tubers	10.6-14.9%	1.5-2.4%	0.09-1.3%	0.6-0.7%	186-264 kJ	Anantharaman and Nambiar (1993)
Canna	25%	1-3%	0.15%	22%	32.57 kJ	Xie *et al.* (2019)

4.1 Starch content

Starchy roots are a major dietary source of carbohydrates (Table 3). Being easily absorbed, starch is preferred as food, particularly for young children, the sick, and those recovering from illness. It is utilized in the baking of cakes, puddings, cookies, and jams. It is used to treat digestive issues and has demulcent qualities. It is used as a suspending ingredient while preparing barium meals, and because it dissolves quickly, starch is commonly used when making tablets. Arrowroot starch is used to make specialty glues and as a foundation for face powders and the roots contain about 25% starch (Sastri, 1962).

Table 3: Total carbohydrate content of underutilized tuber crops

Crop	Dry matter	Starch content	Sugar content	Reference
Yam bean	9.17-21.82%	3.63-15.78%	3.07-5.43%	Anantharaman and Nambiar (1993)
Chinese yam	~ 67%	85%	0.2-1.5%	Zhang *et al.* (2018)
West Indian Arrowroot	30.69-31.25%	17.20-18.86%	0.1-0.5%	Augustus *et al.* (2003)
Canna	75 - 80%	25%	6 - 14%	Behera *et al.* (2012)

Yam beans contain starch, which makes up about 65% of the carbohydrates. Older roots can occasionally be utilized as a source of starch or for feeding animals, as their starch concentration rises with maturity. According to reports, Chinese patients with fevers are treated with the dried roots as a cooling supper. Chinese yam starch is more resistant to digestive enzymes and promotes the development of good bacteria in the human microbiome. Thus, resistant starch can prevent hyperglycemic cycles, reduce the risk of diabetes, and improve colon health as well as lessen the risk of colon cancer (Rinaldo, 2020). Animals' blood levels of triglycerides and LDL cholesterol can be lowered by Chinese yam starch (Nishimura *et al.*, 2012). According to Epping and Laibach (2020), starch has health benefits that also include enhancing the microbiome of the fish gut and serving as an immunostimulatory feed ingredient. In the paper production business, yam starch can also be utilized in oxidized form to build biofilms along with antimicrobial substances to protect food, like hog meat and mayonnaise. Infants and individuals with disabilities can easily digest the starch granules found in canna (Kilaru *et al.,* 2022).

Arrowroot tubers which have 10% to 25% extractable starch are the world's richest (unenriched) natural starch, valued for their therapeutic qualities and excellent digestion (Speinneman, 1992). The starch is often used as a thickener and due to its lack of gluten starch, it is a perfect substitute for wheat flour in baking. Demulcent properties of the tuber help with bowel complaints and protect the body's interior tissues that are irritated or inflamed (Peter, 2008).

Konjac glucomannan (KGM) is a neutral heteropolysaccharide that is water soluble, comprising more than 45% of β-d-glucose and β-d-mannose produced by finely grinding tiny pieces of dried tubers into a powder, and is often separated by wind sifting. Glucomannan may relieve constipation in the stomach and intestines by absorbing water and forming a bulky protein. Additionally, it might lessen cholesterol levels and assist slow the intestinal absorption of sugar and cholesterol to lower blood sugar levels in diabetics. Additionally, it has been shown to lower serum insulin, prevent constipation, control blood sugar and lipid metabolism, aid in weight loss, strengthen the body's immunological system, and act as a mycotoxin adsorbent (Nishinari *et al.,* 2007).

4.2 Protein

On a fresh weight basis, the tubers' protein content ranges from 1% to 2%. According to (Liu *et al.,* 2010), containing sulfur amino acids like methionine, cystine, and lysine are the tubers' limiting amino acids. With more than 45% glucomannan, 9.7% crude protein, 16 various types of amino acids up to 7.8%, and 7 essential amino acids up to 2.5%, konjac is a very nutrient-dense food. Yam bean tuber contains more than 14 different essential amino acids (Table 4) (Duke, 1994). The tubers of Chinese potato are reported to include several different amino acids, such as aspartic acid, glutamic acid, and arginine (Pichop *et al.,* 2014).

Table 4: Amino acid content of underutilized tuber crops

Crop	Essential amino acid	Quantity (mg kg^{-1})
Yam bean	Alanine	380-3500
	Arginine	720-6635
	Aspartic acid	3870-35670
	Cystine	110-1015
	Glutamic acid	820-2855
	Glycine	310-2855
	Histidine	370-3410
	Isoleucine	310-2855
	Leucine	410-4425
	Lysine	510-4700
	Methionine	130-1200
	Phenylalanine	320-2950
	Proline	430-4330
	Serine	470-4330

4.3 Lipids

A GC/MS analysis of the Chinese potato tubers' chloroform extract showed that the tubers contained a sizable number of fatty acids. The extract contained 40.12% linoleic acid, 24.97% ascorbic acid 2,6 -dihexadecanoate and 24.07% oleic acid as major lipids (Manikandan *et al.,* 2016). Omega-6 fatty acid, or doubly unsaturated fatty acid, is linoleic acid that has anti-inflammatory, acne-reductive, skin-lightening and moisture-retentive properties. Oleic acid is a monounsaturated omega-9 fatty acid and has hypotensive effects. Ascorbic acid 2,6 – dihexadecanoate has antimicrobial properties (Yang *et al.,* 2015). The tuber extract also has significant antioxidant activity (Zhang *et al.,* 2016).

4.4 Vitamins

Underutilized tuber crops are valuable for their rich vitamin content, providing essential nutrients that support various physiological functions (Table 5). These crops are especially well-known for having a lot of vitamin C, a vital nutrient that plays a crucial role in several bodily processes. Vitamin C plays a major role in functioning of immune system, offering antioxidant protection to combat free radicals, and supporting collagen synthesis, which is important for skin health and tissue repair. Among these underutilized tubers, yam tubers stand out for their exceptionally high vitamin content compared to other tuber varieties. They are especially rich in vitamin C, which is often found to be valuable dietary, contributing significantly to nutritional intake and overall health benefits (Udensi *et al.,* 2008). The vitamin content of underutilized tuber crops is listed in (Table 5) (Behera *et al.*, 2012; USDA, 2019).

4.5 Major minerals

Major minerals in plants, such as calcium, potassium, and magnesium, are crucial for their growth and development. Calcium supports cell wall strength, potassium regulates water balance and enzyme functions, and magnesium aids in photosynthesis and energy transfer. These minerals not only enhance plant health but also offer pharmacological benefits for humans, such as supporting bone health, cardiovascular function, and muscle relaxation. Underutilized tuber crops often have a diverse mineral composition, including significant amounts of potassium, magnesium, calcium, iron, and zinc (Table 6). They also provide phosphorus and trace elements. Specific concentrations of these types of minerals can vary among different types of tubers. Overall, contributes a rich array of essential minerals (Olango *et al.,* 2013).

Table 5: Vitamin content of underutilized tuber crops

Vitamins	Quantity (mg/ 100 g)			Medicinal benefits
	Chinese potato	Yam bean	West Indian arrowroot	
Vitamin B1 - thiamine	0.05	0.02	0.413	Energy metabolism and nerve function, essential for overall brain and cardiovascular health
Vitamin B2 - riboflavin	0.02	0.029	0.059	Antioxidant, aiding in energy production and maintaining healthy skin and eyes
Vitamin B3 - niacin	1.0	0.2	1.69	Regulate cholesterol levels, supports energy production, and promotes skin health
Vitamin C -ascorbic acid	1.0	20.2	1.9	Features that promote wound healing, collagen production, iron absorption, anti-inflammatory and antioxidant effects, and radical scavenging

Table 6: Major mineral composition of underutilized tuber crops

Major minerals	Crop	Medicinal benefits	Reference
Potassium	Yam tubers, canna	Maintaining fluid balance, nerve function, and muscle contractions	Chen *et al.* (2023)
Phosphorous	Konjac	Supports bone strength, enhances energy metabolism, and aids in cell function	Xie *et al.* (2007)
Calcium	Chinese potato Yam tubers, Konjac	Regulating blood flow and preserving the structural integrity of intra cellular cementing substances	Enyiukwu *et al.* (2014)
Sodium	Yam bean, Konjac	Blood pressure regulation, maintenance of muscle and nerve activity	Folkow (1982)

Table 7: Major mineral composition of underutilized tuber crops

Minor minerals	Crop	Medicinal benefits	Reference
Iron	Chinese potato, taro, yam tubers and Konjac	Oxygen transport in the blood and energy metabolism. Production of blood haemoglobin, which aids in the body's oxygen transfer	Enyiukwu *et al.* (2014)
Zinc	Yam tubers, Konjac	Supports immune function, wound healing, and cell blood coagulation and preservation of intracellular cementing materials' integrity	Padhan and Panda (2020)
Manganese	Konjac	Involved in antioxidant defenses and bone formation	Wang *et al.* (2008)
Copper	Konjac	Necessary for iron metabolism, connective tissue formation, and enzyme function	Liu *et al.* (2016)

4.6 Minor minerals

Minor minerals in plants, such as iron, zinc, copper, and manganese, are needed in trace amounts but are crucial for optimal growth and development. They support key processes like enzyme function, photosynthesis, and antioxidant defense. In human health, these essential trace minerals offer pharmacological benefits including enhanced immune function, improved antioxidant protection, and support for metabolic processes (Gomes and Rautureau, 2021) (Table 7). Adequate intake of these minerals from diverse plant sources is vital for maintaining overall health and preventing deficiencies.

4.7 Ash content

The ash content refers to the inorganic mineral residue remaining after the combustion of the organic matter. This residue includes essential minerals such as potassium, calcium, magnesium, phosphorus, sodium, and trace elements, which are important for both plant nutrition and human health (Bakker and Elbersen, 2005). In underutilized tuber crops, the ash content varies significantly: yam bean has 20.5%, Chinese yam 65%, West Indian arrowroot 30.5%, and canna 78%. This variation reflects the differing mineral concentrations, nutritional profiles, and potential health benefits among these crops (Chiranthika *et al.*, 2022). Such diversity underscores the importance of incorporating a variety of these crops into diets to harness a broader spectrum of essential nutrients.

4.8 Moisture content

Moisture content, defined as the proportion of water relative to the total weight, is crucial for determining texture, shelf-life, and nutritional quality (Ergun *et al.*, 2010). High moisture content, common in ullucus (75-80%), indicates freshness but can lead to quicker spoilage, while lower moisture content, as seen in sweet potatoes, yam beans, and ahipa (60-70%), enhances shelf stability but may affect the texture and nutritional value (Behera *et al.*, 2012). Precise assessment of moisture content is crucial for optimizing storage conditions and processing techniques, ensuring that the tubers retain their desired quality and nutritional benefits over time.

5. Secondary metabolites

Bioactive chemicals found in plants can affect both humans and animals in pharmacological or toxicological ways. As opposed to the basic metabolites needed for growth, secondary metabolites are produced to serve specific functions such as protection, attracting pollinators, and signaling. Roots and tubers, including yams, are rich in these non-nutritive phytochemicals (Table 8). Yam tubers, in particular, contain substances such as dioscorin, mucin, polyphenols, diosgenin, allantoin, choline, and saponins (Bhandari *et al.,* 2003)

Table 8: Secondary metabolites of underutilized tuber crops

Underutilized tuber crops	Secondary metabolites	Reference
Chinese potato	Flavonoids and polyphenols, including quercetin, rutin, gallic acid, caffeic acid, rosmarinic acid, and p-coumaric acid	Jayapal *et al.* (2015)
Yam tubers	Rotenone, diosgenin, polyphenols, dioscin, dioscorin, allantoin, and choline	Iwu *et al.* (1990)
C. zedoaria	Curcumenol and curcuzedoalide	Wilson *et al.* (2005)
C. malabarica	Germacrane, guaiane, and carabrane, along with curcumenol and dehydrocurdione	Yoshioka *et al.* (1998)
D. villosa	Cholestane steroid glycosides	Ali *et al.* (2013)
D. zingiberensis	Saponin I, deltonin, gracillin, dioscin, asperin, and pro-genin III of zingiberensis	Zhu *et al.* (2010)
D. pseudojaponica	Allantoin and allantoic acid	Fu *et al.* (2006)
D. opposite	Soluble proteins and mannan-rich mucilage	Myoda *et al.* (2006)
D. dumetorum	β-carotene epoxides and mutatochrome	Ferede *et al.* (2010)

5.1 Phenolic compounds

Phenolic chemicals are synthesized by the pentose phosphate, shikimate, and phenylpropanoid pathways from precursors such as pyruvate, acetate, phenylalanine, tyrosine, acetyl CoA, and malonyl CoA. The characteristic aromatic ring of phenolic substances is its hydroxyl group. Numerous phenolic groups, including tannins, lignans, lignins, flavonoids, coumarins, stilbenes, and simple phenolics and phenolic acids, are found in plants and have a variety of health advantages (Naczk and Shahidi, 2006).

Among their many health advantages, the phenolics present in tubers contain antibacterial, anti-inflammatory, and antimutagenic qualities. Chinese potato tubers offer various medicinal benefits (Shahidi and Naczk, 2003). The Chinese potato tubers contain 52.9 mg of flavonoids, per 100 g fresh weight which can lower blood cholesterol (Mareen Abraham and Radhakrishnan, 2005) and exhibit high antioxidant activity (Sandhya and Vijayalakshmi, 2000). Although, not scientifically validated, traditional uses in Africa and Asia include treating dysentery, sore throat, eye disorders, and hematuria.

Yam varieties, particularly those from the *Dioscorea* genus, are emerging as potential antimicrobial agents due to their phenolic compounds. According to Sonibare and Abegunde (2012), methanolic extracts of *D. dumetorum* and *D. hirtiflora* have significant antioxidant and antibacterial qualities. The pour plate method for fungi and the agar diffusion method for bacteria were used to assess the antibacterial efficacy. In particular, *D. dumetorum* showed notable in vitro antibacterial activity against *Proteus mirabilis* while not being edible. In the meantime, *D. hirtiflora* showed broad-spectrum antibacterial action, being effective against *Salmonella typhi*, *Candida albicans*, *Aspergillus niger, E. coli, Bacillus subtilis, Proteus mirabilis, and Penicillium chrysogenum*. Furthermore, these yams' saponins which function as organic antibiotics to help the body fight illnesses and microbial threats contribute to their antibacterial properties (Sodipo *et al.,* 2000).

5.2 Terpenoids

Off all the secondary metabolites found in plants, terpenoids are the most prevalent and varied group of organic substances. produced by the MEP and MVA pathways (Maffei *et al.,* 2011). Terpenoids are essential to plants because they enable them to fix carbon through photosynthetic reactions with the help of pigments that are photosensitizing. Additionally, plants heavily depend on a variety of phytochemical protectants to prevent oxidative reactions (Dillard and German, 2000).

Chinese potato has 94.9 mg of terpenoids per 100 g of fresh weight reported to have potent anti-HIV activity, along with hepatoprotection, anti-inflammatory, antitumor, and anti-hyperlipidemic properties. *C. zedoaria* contains curcumenol, a sesquiterpene alcohol with effects that are neuroprotective, hepatoprotective, anticancer and anti-inflammatory. Additionally, its tuber extracts possess antibacterial qualities (Wilson *et al.,* 2005).

Curcuzedoalide from the rhizomes shows antiproliferative effects by triggering apoptosis in human stomach cancer cells (Jung *et al.,* 2018). *C. malabarica* features various sesquiterpenes and diterpenes, including germacrane, guaiane, and carabrane types. Dehydrocurdione can reduce acute inflammation in animals (Alonso-Amelot, 2016), while furanodiene and furanodienone exhibit similar to indomethacin in terms of its anti-inflammatory properties (Makabe *et al.,* 2006). Curcumenol's traditional therapeutic benefits are supported by its powerful analgesic effects in animal models (De Fátima Navarro *et al.,* 2002). Furthermore, curzerene and epicurzerene, two antioxidants, are present in *C. zedoaria* rhizome oil (Mau *et al.,* 2003).

5.3 Catechin

Catechin is a plant-derived secondary metabolite found widely in nature, classified within the flavonoid family. Chemically, catechin is composed of two benzene rings (A and B rings) and a dihydropyran ring (the C ring), with a hydroxyl group attached to carbon 3 on the C ring. The presence of chiral centers at carbons 2 and 3 leads to the formation of diastereoisomers. The isomers with a trans configuration are called catechins, while those with a cis configuration are referred to as epicatechins. These diastereoisomers can be separated using chiral chromatography. The ability of these polyphenols to be absorbed by biological systems highlights their significance for potential therapeutic and pharmacological applications (Ganeshpurkar and Saluja, 2020).

Catechin, a notable flavonoid with strong antioxidant properties, is present in several species of *Dioscorea including D. villosa* (wild yam), *D. alata* (water yam) and cocoyam (*Xanthosomamaffa scoth*) (Ukom *et al.,* 2014) contribute to the plant's health benefits and are part of its diverse array of secondary metabolites. Catechin in Dioscorea provides significant pharmacological benefits due to its antioxidant, anti-inflammatory, cardiovascular, anticancer, neuroprotective, and metabolic effects (Lebot *et al.,* 2019).

5.4 Carotenoids

Carotenoids are pigments that can be isolated naturally or synthesized chemically. They are characterized by their unsaturated tetraterpene structure and are soluble in nonpolar solvents such as petroleum ether and hexane. Numerous biological actions of carotenoids are essential to human nutrition and health. These activities include inducing cell-to-cell communication, regulating gene expression, and having an antioxidant effect (Paiva and Russell, 1999). Carotenoids are abundant in yellow to orange yam cultivars. It is reported that D. cayennensis, the most commonly farmed species, has a greater carotenoid concentration (Table 9) (USDA, 2019) (Bhattacharjee *et al.,* 2011).

Table 9: Carotenoid content of underutilized tuber crops

Crop	Carotenoids	Medicinal benefits
Yam bean	Beta carotene	13 µg
West Indian arrowroot	Beta carotene	11 µg

5.5 Anthocyanin

Anthocyanins are naturally occurring water-soluble pigments subgroup of large secondary plant metabolites called flavonoid, class of phytochemicals (Delgado-Vargas *et al.,* 2000). Anthocyanins are responsible for the vibrant colors found in various plant organs, including stems, leaves, flowers, fruits, roots, and tubers, producing shades of orange, red, purple, and blue and are known for their antioxidant benefits. Additionally, these pigments are important for human health, suggesting they aid in the treatment of conditions such as cancer and cardiovascular diseases (Cao *et al.,* 2001). In underutilized tuber crops, these pigments add both nutritional and visual value. Examples include Oca (*Oxalis tuberosa*), Ullucus (*Ullucus tuberosus*), Yambean (*Pachyrhizus spp.*), Ahipa (*P. ahipa*), an Andean tuber with purple skin and flesh rich in anthocyanins (Campos *et al.,* 2006).

5.6 Xanthophyll

Xanthophylls are carotenoid pigments formed through a series of enzymatic transformations. The process begins with the synthesis of isoprenoid precursors, leading to carotenoids such as â-carotene (Thomas and Johnson, 2018). Through hydroxylation and other modifications, xanthophylls like lutein and zeaxanthin are formed. These pigments contribute to plant coloration and photoprotection while also providing valuable antioxidant properties and supporting eye health (Eskling *et al.,* 1997). Yambean are notable for their yellow and orange flesh, rich in carotenoids, including xanthophylls. Ullucus and ahipa have yellowish varieties with these beneficial pigments.

5.7 Allatonin

Allantoin is a heterocyclic compound due to its regenerative properties it is widely used in cosmetic industries (Thornfeldt, 2005). Yams (*Dioscorea* sp.) contain higher levels of allantoin compared to other tuber crops like potatoes, sweet potatoes, and cassava (Chandrasekara, 2018). Allantoin aids in wound healing and cell regeneration, making it a common ingredient in skin lotions and cosmetics. Besides its antioxidant properties reduce the genotoxic effects of UV radiation and mitigate damage from reactive oxygen species (Rajalingam *et al.,* 2013). Allantoin content in Chinese yam tubers ranges from 2 to 15 mg/g, with skin containing larger amounts than flesh. The higher amount of allantoin, phenolic, and flavonoids in the peel of yams is probably the reason for its stronger anticancer action (Li *et al.,* 2023).

5.8 Saponin

According to Francis *et al.* (2002), high molecular weight secondary metabolites are called saponins that are glycosides with a sugar moiety connected to an aglycone of a triterpene or steroid. Precursors for the chemical manufacture of corticosteroids, comparable hormones, and birth control tablets containing progesterone and estrogen are called synthetic saponins. Recent research indicates that steroidal saponins may represent a unique class of prebiotics for lactic acid bacteria and are promising treatments for animal and human fungal and yeast infections (Huang *et al.,* 2012).

Apart from phenolics, as antitumor and anticancer drugs, saponins are indispensable. Numerous saponin classes have demonstrated anticancer effects on different forms of cancer, including steroids, cycloartanes, ammaranes, oleananes, and lupanes. Diosgenin, a steroidal sapogenin, is an essential precursor in the commercial production of steroid hormones such as cortisone, pregnenolone, and progesterone (Edwards *et al.,* 2002). It is prominently found in the cortex and tuber flesh of Chinese yams (Liu *et al.,* 2010).

Diosgenin has various pharmacological uses, including lowering blood lipid levels, treating cellulite and wrinkles, and managing cardiovascular disease by inhibiting cholesterol uptake (Zagoya *et al.,* 1971). It also shows antidiabetic effects by inhibiting α-amylase and α-glucosidase (Huang *et al.,* 2012), and has the potential to treat Alzheimer's disease and cancer by inducing apoptosis in tumor cells (Patel *et al.,* 2012). Additionally, diosgenin's antioxidant properties are linked to its capacity to increase the activity of enzymes that help reduce reactive oxygen species, such as superoxide dismutase and catalase. The phenolic chemicals in yams, including saponins and polysaccharide mucilage, are responsible for the bioactivities observed in yam extract. The primary copper chelators in the water yam extract are water-soluble mucilage polysaccharides. As a result, aqueous extracts from *D. alata* may be useful as therapeutic agents for oxidative diseases caused by copper (Wang *et al.,* 2011).

5.9 Rotenone

The complex organic compound rotenone is made up of 24.34% oxygen, 5.62% hydrogen, and 70.04% carbon which is soluble in organic solvents and has notable toxicological properties. According to FiaSriMumpuni (2014), rotenone irritates the respiratory system and exhibits higher toxicity at elevated temperatures, particularly above 15°C. Further, compared to alkaline conditions, its toxicity is more noticeable in fluids that are acidic to neutral. Furthermore, rotenone, which is found in yam bean seeds, stems, and leaves, has antifeedant, gastrointestinal, and contact toxicity properties. The powdered seeds of this plant are utilized as an insecticide (Yongkhamcha and Indrapichate, 2012).

5.10 Glucosinolates

Glucosinolates (GSLs) are sulfur-rich, anionic secondary metabolites predominantly found in plants of the order Brassicales. They are synthesized from amino acids such as methionine, tryptophan, or phenylalanine through enzymatic processes involving side-chain elongation and sulfur addition (Bakker and Elbersen, 2005). GSLs exhibit significant pharmacological activities, including potent anticancer effects by promoting apoptosis and inhibiting cancer cell growth. They also enhance antioxidant defenses, reduce oxidative stress, inflammation, and support detoxification by boosting phase II detoxification enzymes in the liver. Furthermore, GSLs offer cardiovascular benefits, including improved blood vessel function, reduced blood pressure, and contribute to antimicrobial defense. Certain underutilized tuber crops, such as Oca and rutabaga, are rich in glucosinolates (Murthy and Paek, 2020), contributing to their diverse nutritional, medicinal, and ecological roles.

6. Future prospect

To unlock the full potential of underutilized tuber crops as nutraceuticals, research should concentrate on identifying and characterizing their bioactive compounds through advanced screening techniques and metabolomics. Comprehensive pharmacological studies are essential to elucidate their mechanisms of action and validate their health benefits through rigorous clinical trials. Enhancing sustainable cultivation practices and genetic improvements will optimize their nutritional and therapeutic value. Additionally, developing innovative functional food products and increasing consumer awareness will support their integration into modern diets, while robust regulatory frameworks will ensure their safe and effective use. This integrated approach will maximize the benefits of these crops and contribute to addressing global nutritional challenges.

7. Conclusion

Underutilized tuber crops stand out for their exceptional nutraceutical potential, largely due to the diverse array of bioactive compounds. These compounds' substantial pharmacological advantages are offered by these substances, such as potent antibacterial, antioxidant and anti-inflammatory properties. The antioxidant qualities of these tubers help the body fend off harmful free radicals, which may reduce oxidative stress and the risk of chronic illness development. Their antibacterial qualities protect a range of infections, while their anti-inflammatory actions help reduce inflammation, a major contributing factor in many medical disorders. This complex pharmacological profile implies that these tubers may be important for improving general health and treating common nutritional deficiencies. Incorporating these lesser-known crops into regular dietary practices not only presents a chance to diversify food sources but also provides a strategic approach to improving health outcomes. By harnessing their therapeutic potential, there is a valuable opportunity to support both preventive health measures and therapeutic interventions, highlighting the significant contribution these underutilized tubers can make in advancing holistic health strategies. Future research should focus on advancing genetic improvements and optimizing cultivation techniques to enhance the yield and adaptability of these crops. Additionally, examining their market potential and nutritional benefits could boost their adoption and play a crucial role in food security.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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