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Ashish Patel
Assistant Professor, Department of Botany, Govt. College Pushprajgarh, Anuppur, Madhya Pradesh, India

Jay Singh
Assistant Professor, Department of Biotechnology, SIT College, Sidhi, Madhya Pradesh, India

Corresponding Author:
Ashish Patel
Assistant Professor, Department of Botany, Govt. College Pushprajgarh, Anuppur, Madhya Pradesh, India

Taro (*Colocasia esculenta* L): Review on its botany, morphology, ethno medical uses, phytochemistry and pharmacological activities

Ashish Patel and Jay Singh

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Abstract
Natural products are the best sources of drugs and drug leads and this remains true today although the fact that many pharmaceutical companies have focused on natural products research for two decades. *Colocasia esculenta* (L) Schott (*C. esculenta,* Family Araceae) is an annual herbaceous plant with a long history of usage in traditional medicine in several countries across the world and is grown for its edible corm as staple foods throughout the tropical and subtropical regions. In India it is known as Aravi, Alukam, Kesavedantu, Chamadumpa. Corm and leaves of this plant are widely used as vegetables in Indian traditional food system. It was a widely used as a vegetable crop for nutritional and medicinal purposes. Nutritionally, *C. esculenta* contains more than twice the carbohydrate content of potatoes and yield 135 kcals per 100 gm. *C. esculenta* contains about 11% protein on a dry weight basis. This is more than yam, cassava or sweet potato. It contains 85-87% starch on dry matter basis with small granules size of 3-18μm and other nutrients such as minerals, vitamin C, thiamin, riboflavin, oxalic acid and niacin better than other cereals. *C. esculenta* leaves, like higher plants, is rich in protein. Phytochemical analysis showed that the major constituents of *C. esculenta* leaves are flavonoids, *β*-sitosterol, steroids, tarin, polysaccharides (TPS1 and TPS2), alkaloids, polyphenols, and saponins ect., The plant also has the property to reduce fever and pain. The pharmacological studies revealed that the plant exerted many pharmacological activities, including central nervous effects, antioxidant, anti-inflammatory, analgesic, anti-lipid peroxidative activity, antidiabetic, anti-carcinogenic, hepatoprotective, immunoprotective and antimicrobial effects. There is requiring isolating active constituents, their biological test, molecular mechanisms, experimental defense and legalization of therapeutic uses of *C. esculenta*. Various traditional claims of the plant are still remain to be validated scientifically. Future research should focus on the pharmacological properties, phytochemistry, clinical trials and pharmacokinetics of *C. esculenta* which will enhance the therapeutic potential of the species. Clinical trials for the reported preclinical studies should be performed urgently to further validate the claims on humans.

Keywords: *Colocasia esculenta* (L) Schott, phytochemistry, pharmacological activity, ayurveda, medicinal uses

Introduction

Plants have been known as an integral part of traditional medicine because of their phytoconstituents with their miraculous substances. Numerous diseases prevailing in the society can be treated using medicines. Various parts of plants such as leaf, stem, roots and barks were used as medicines in Ayurveda, Siddha, Unani and Homeopathic treatments. Plants are significant to human being for his life. All plants phyla create official and illegal product of therapeutic significance. The antiquity of herbal medicine is as very old as human society. The treasure of India is stored in the huge natural flora, which has been advantage to mankind. India is almost herbarium of the planet [1, 2]. Although the biologically active phytoconstituents of certain herbal drugs are unidentified, they are prescribed normally owing to their effectiveness, least side effects in clinical information and moderately very low costs [3]. *Colocasia* is a genus of flowering plants in the family Araceae, native to southeastern Asia and the Indian subcontinent. Some species are widely cultivated and naturalized in other tropical and subtropical regions. The names elephant-ear and cocoyam are also used for some other large-leaved genera in the Araceae, notably *Xanthosoma* and *Caladium*. The generic name is derived from the ancient Greek word *kolokasion*, which in Greek, botanist Dioscorides (1st century AD) may have inferred the edible roots of both *Colocasia esculenta* and *Nelumbo nucifera*. The species *C. esculenta* is invasive in wetlands along the American Gulf coast, where it threatens to displace nativewetl and plants [4, 5].

C. esculenta is an ancient food crop, with a history dating back over 9,000 years [6]. Originating in Southeast Asia, this ancient crop has spread over the world and is now a significant crop in Asia, the Pacific, Africa, and the Caribbean [7]. *C Esculenta* is a vegetative propagated monocotyledonous root crop. *C. esculenta*, also known as Nduma in Kiswahili, is a native African crop that has been farmed for millennia throughout Africa [8]. It is a nutrient-dense plant that is essential in people's diets. *C. esculenta* is one of the few main staple crops that have both leaf and subterranean components that are consumed by humans [9]. *C. esculenta* is a member of the aroid family (Aracaceae) and the genus *Colocasia*. When compared to other tuber crops, *C. esculenta* is one of the traditional crops with significant nutritional and medicinal potential. The available literature shows that different parts of the *C. esculenta* plant contain a combination of significant bioactive compounds [10]. Approximately 10% of the world's population, or almost half a billion people, rely on root crops like *C. esculenta* as their primary source of nutrition [11]. There are two primary types of agricultural plants in the *Colocasia* genus. One kind produces a big edible corm with a limited number of auxiliary cormels, often known as sucker corms. The other plant produces a small to medium corm as well as a huge number of little cormels in most cases [10]. Plants of this species are more prevalent in Japan and China. These plants may be cultivated in a broad range of climatological circumstances across the world, ranging from flooded lowlands to rain-fed uplands. The characterization of the different parts of taro plant is shown in Figure 1. *C. esculenta* is the 9th most widely grown food crop in the world, with cultivation throughout India [12]. In tropical and subtropical areas, *C. esculenta* tubers are essential sources of carbohydrates as an energy source and are eaten as a staple diet. It is primarily grown for the starch content of its subterranean corms, which range from 70 to 80 percent [13]. *C. esculenta* has a modest protein (1.5%) and fat (0.2%) content in its corm, which is similar to many other tuber crops. It contains a lot of starch (70–80 g/100 g dry *C. esculenta*), fibre (0.8%), and ash (1.2 percent). *C. esculenta* corms are high in starch, accounting for up to 85% of total dry matter. The quality of *C. esculenta* products is projected to be favorably connected to the quality of its starch, amylose, and dry matter composition [13]. Furthermore, it is an active ingredient in a variety of foods and pharmaceuticals, demonstrating its commercial viability. It also contains riboflavin, thiamine, phosphorus, iron, and zinc, as well as vitamin B6, vitamin C, niacin, potassium, copper, and manganese [12]. It is high in carbs and minerals that are easily digested. *C. esculenta* meals are good for those who are allergic to cereals and for newborns and toddlers who are lactose intolerant [14]. Due to these nutritional characteristics of *C. esculenta*, it possesses various therapeutic properties such as antiinflammatory, hypolipidemic, anticancer, anti-hepatotoxic, anti-lipid peroxidative and antidiabetic, ECT. The taxonomical classification of *C. esculenta* consists of Domain: Eukaryota, Kingdom: Plantae, Subkingdom: Tracheobionta, Super division: Spermatophytes, Division: Magnoliophyta, Phylum: Spermatophyta, Subphylum: Angiospermae, Class: Liliopsida (Monocotyledons), Subclass: Arecidae, Order: Arales, Family: Araceae (Arum family), Genus: *Colocasia* Schott (colocasia), Species: *Colocasia esculenta* (L.) Schott, Synonyms: Alocasia dussil Dammer, Alocasia illustris W. Bull [15]. International common names of plant English: Chinese potato; cocoyam; dasheen; dry taro; eddoe; Egyptian colocasia; elephant's ear; old cocoyam; small taro; sweet taro; true taro Spanish: Malanga; Malanga Islena; Oreja De Elefante; Papa China; Pituca; Tayoba; Yautía Malanga; Yautia Melendez French: Arouille Carri; Arum d'Egypte; Chou Caraibe; Colocase; Colocasie; Madere; Songe; Songe Blanc; Songe Sauvage Chinese: YU [16]. Common Indian Names: Assamese: Bon Kachu, Pani Kachu, Bengali: Banakochu, Ongli Kochu, Bhojpuri: ARUI, Kanda, Gujarati: Alavi, Hindi: Arabi, Aruwi, Banda, Ghuyan, Kachalu, Kachchu, Kala Kachchu, Kechuk, Manak Kanchu, Nalika Nalita, Nari Patra, Narich, Pechu, Van Kachu, Vishva Rochan, Vitanda, Kannada: Kesavu, Kesa, Kesu, Save (GADDE), Konkani: Terem, Venti, Malayalam: Chemp, Manam, Manipuri: Pan, Marathi: Alem, Alu, Odia: Kachu, Pechu, Saru, Punjabi: Gagli, Gawian, Kachalu, Sanskrit: Dalasarini, Kachu, Kachvi, Kalakachu, Kemuka, Nadicha, Nadipattra, Nalita, Pechu, Shakata, Trutibija, Vanakachu, Vishvarochana, Vitanda, Sindhi: Kachalu,Tamil: Chempu, Nir-C-Cempu, Peculam, Tangkhul: Pai, Telugu: Chama, Chema, Tulu Ambuge, Chevu, Thevu, Urdu: Aruwi, Ghuyan, Kachalu, Kachchu, Kechuk, Nalika, Nalita, Pechu, Narich, Vitanda [17]. Therefore, In This Study, The Ethno Pharmacological Review of *C. esculenta* was carried out aimed at providing a detailed précis of the botany, ethnomedicinal uses, pharmacological activities and chemical composition of the species.

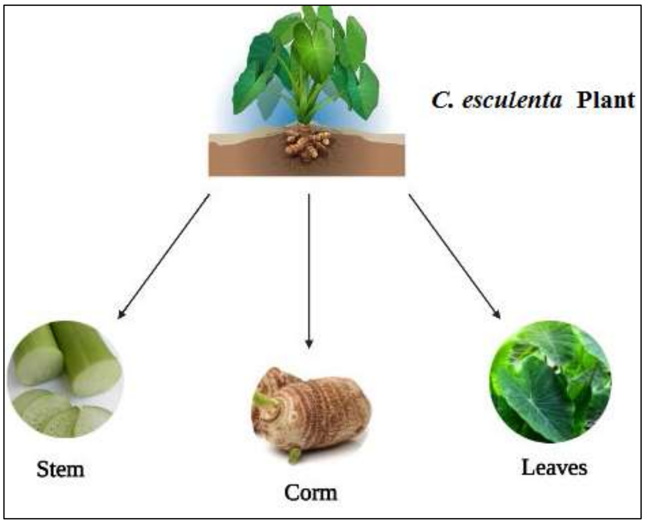

Fig 1: Different parts of the *C. esculenta* plant

Research methodology

To recognize pertinent information on the botany, medicinal uses, phytochemistry and biological activities of *C. esculenta*, a review was compiled based on scientific literature from various sources including Google Scholar, Web of Science, Sci Finder, Scopus, Science Direct, Pub Med, Scielo, Springerlink, Google Patents, Espacenet, Bio Med Central (BMC) and Medline. The keywords used for recognition of relevant data included dissimilar scientific name and synonyms, common English names and the terms: biological activities, medicinal uses, ethno botany, ethno pharmacology, medicinal, pharmacology, Phytochemistry and therapeutic value, *C. esculenta*, cocoyam, taro, arabi. Further literatures were obtained from books, book chapters, theses, websites and conference proceedings.

Taxonomy

C. esculenta belongs to genus Colocasia and family Araceae which is made up of at least 100 genera and more than 1500 species [18, 19]. According to Tumuhimbise *et al*. and Ubalua *et al*. [20, 21] the two most widely cultivated taxonomic varieties include *Colocasia esculenta* var *esculenta* and *Colocasia esculenta* var *antiquorum* which is commonly known as the dasheen type (*Colocasia esculenta* var. *esculenta*), which has a large central corm with suckers and stolons and the second is the eddoe type (*Colocasia esculenta* var. antiquorum), which has a small central corm and a large number of smaller cormels [22, 23]. The available growing genotypes of *C. esculenta* categorized in to wild and cultivated type. The wild type is not used for food. Quero-Garcia *et al*. reported as corms of the wild *C. esculenta* cannot be used as food due to an extremely high concentration of calcium oxalate crystals [24].

Morphology

C. esculenta is a tall herb having tuberous or a stout short caudex, leafing and flowering together. Leaves are simple and have a stout petiole, ovate-cordate or sagittate-cordate, lamina peltate. Spadix is shorter than the petiole and much it is shorter than the spathe rather than slender. Appendix much shorter than the inflorescence, style very short; stigma discoid [25]. It is erect, elongateconical or fusiform, subulate or abbreviate. Erect petiole is up to 1.2 m in length, with a dull and non-polished surface above, coloured or paler beneath. They are rarely glaucous. The leaf peduncle is shorter than the petiole. Spathe is pale yellow and measures 15 to 35 cm in length; tube greenish, oblong. The lamina is narrowly lanceolate, convolute, acuminate and curved slightly backwards in flower. Female inflorescence is short but male inflorescence is long, cylindrical and usually interposed neuters between the two. Seeds oblong, sulcate. Albumen copious; embryo axile. The plant stem is above ground and swollen slightly at the base of the leaf-sheaths, arising from a hard tapering rhizome; stolon's and a tuberous rhizome suckers are sometimes present. The sterile flower zone and the distal appendage shorter than the fertile zones. Fruit is a many-seeded berry, densely packed and forming a fruiting head. Seeds are ovoid to ellipsoid, less than 2 mm long, with copious endosperm [26].

Distribution

C. esculenta is a tropically grown plant and considered as one of the primitive cultivated plants. It was probably believed to be first native to the low and wetlands of Malaysia. It is estimated that it was being cultivated in wet tropical India before 5000 BC. Apparently coming from Malaysia, and from India it was further on transported towards west to ancient Egypt, where it was portrayed by Greek and Roman historians as an important crop. In Kenya taro root is referred to as arrow root. In India, it is found in moist and shady situations inside forests, at an altitude of 2,440 m. In Karnataka, it is common in wet and marshy places like Udupi and Dakshina Kannada district, also seen in places with cool weather like Chikmagalur, Coorg, Hassan, Mysore and Shimoga [27]. Different researchers conclude that it is not possible to determine a single centre of origin for *C. esculenta* [28]. Evidence from the highlands of Papua New Guinea, indicates that *C. esculenta* processing was active by at least 10,000 years, while Alocasia and Colocasia starch residues have been found on stone implements from Buka, Solomon Islands that date back some 28000 years ago. The species is now found throughout the Pacific islands and worldwide.

Morphological characterization

Morphological *C. esculenta* characterization can be done based on its corm, stolon, leaf, petiole and floral characters and other quantitative traits. According to Lebot, *et al*. there was high morphological variability in *C. esculenta* accessions in Southeast Asia and Oceania [29]. The variability with regard to morphological traits includes colour, shape and size of tuber, petiole length and colour, and stolon formation. Moreover, Manzano, *et al*. reported presence of greatest morphological variability in root colour, cormel flesh colour, corm dry matter percentage, corm shape and cormel shape in *Colocasia esculenta* collected from Asia, Africa and America [30]. Concentration on morphological variability study in Asia might be due to large cultivation area and growing in the region. Similarly, Bhattacharjee *et al*. reported wide degree of variation in leaf colour and shape corm weight and number of petiole per plant existed among different selected genotypes in India indicating greater possibility of improvement through selection [31]. Such quantitative and qualitative morphological variation might contribute desirable character that has to be included in breeding for further improvement of the crop. Furthermore, agro-morphological evaluation of *C. esculenta* accessions resulted in variability in Sierra Leone [32] and among 2,298 accessions collected in Indonesia, Malaysia, Thailand, Vietnam, the Philippines, Papua New Guinea and Vanuatu [33]. On the other hand, Orji and Ogbonna reported as morphological analysis of five *C. esculenta* cultivars in Nigeria resulted in limited variability except that three were able to flower and the authors recommended observed variability for further utilization in breeding [34]. In Ethiopia, Tewodros *et al*. evaluated *C. esculenta* genetic variability among domestic accessions collected in growing areas and indicated the existence of variability in their report [35]. The variability might be due to its long term cultivation in the country. Wild type *C. esculenta* exists but its natural range not well documented. The report can be used in improving genotypes, enhancing conservation and cultivation for economic advantages as well as provide reasonable status diversity including the wild type.

Chemical and molecular characterization

Multiple techniques used in identifying crop genetic diversity. From the findings of Mace and Godwin, Lakhanpaul, *et al*., Dai, *et al*. random amplified polymorphic DNA genetics analysis of *C. esculenta* accessions resulted in high diversity and heterogeneous forms [36-38]. Furthermore, Chaïr *et al*. reported variability in cultivars of Asia, Africa and America out of total of 321 cultivars collected and analyzed indicated as most West Africa *C. esculenta* cultivars were found to have originated from India and as this might be introduced by human migration [39]. Polymorphic microsatellite analysis helps in depth evaluation of genetic situation of crop and divergence analysis used in reducing genetic loss through supporting crop improvement. Bhattacharjee *et al*. suggested *C. esculenta* genotypes for further utilization up on the result of molecular characterization done in India [31].

Leaf microscopy

Histological features of *C. esculenta* leaf are summarised below [40].

- **Epidermis:** Single layer of spherical to polygonal cells with cutinized upper surface are present in upper epidermis of the leaf. The shapes of the cells are straight to slightly beaded anticlinal walls and wavy with presence of Chlorophyll in epidermal cells. Lower epidermis shows single layer of polygonal cells which have straight to slightly beaded anticlinal walls. The lower epidermis also shows presence of papillae and paracytic type of stomata.
- **Mesophyll:** Mesophyll shows dorsiventral arrangement, differentiated into palisade and spongy parenchyma. Chlorophyll and phenolic compounds are present in palisade cells.
- **Spongy parenchyma:** The leaf shows presence of vacuoles and is made up of parenchymatous a cell which varies in sizes and shapes measuring about 7-9 cells in thickness. Interspersed vascular elements are present intermittently. A majority of cells are filled with compound-type starch grains which are simple, spherical with centric helium and less prominent striations.
- **Conducting tissue system:** Layer of parenchymatous bundle. The larger vascular bundles are surrounded by sclerenchymatous bundle sheath which extends up to the upper or lower or both epidermis [40]. The vascular bundles present are simple and each one of them is surrounded by a single.

Phytochemistry

Flavonoids and triterpenoids are the two pharmacologically active groups of compounds mainly present in the *C. esculenta* leaf extracts. The flavanoids that are present in the *C. esculenta* leaf extracts are vicenin-2, iso-vitexin, iso-vitexin 3'-O-glucoside, vitexin X''-Oglucoside, iso-orientin, orientin, orientin7-O-glucoside, leteolin 7-Oglucoside [41]. The leaves of the plant also contains fibres, calcium oxalate, minerals (Calcium phosphorus etc.), and starch, Vitamin A, B, C, etc. [42]. Phytochemical investigations on the *C. esculenta* extracts have shown the presence of anthocyanins viz. cyanidin-3-rhamnoside, cyanidin-3-glucoside and pelargonidin-3-glucoside. These anthocyanins have antioxidant activities as evident from previous studies [43-45]. It is due to these anthocyanins that the *C. esculenta* plant leaves showcases hepatoprotective as well as anti-lipid peroxidative activity. The tubers of *C. esculenta* contain globulins that accounts for around 80% of the total tuber proteins present. The starch content present in the flour varies from 73-76% and the starch yields are in the range of 51-58% [46]. The starch contains 0.23-0.52% lipid and 0.017-0.025% phosphorus in the form of phosphate monoester derivatives [46]. The nitrogen content of the flours varies from 0.33-1.35%. Table 1 shows chemical constituents of different parts of *C. esculenta* plant.

Table 1: Chemical constituents of different parts of *C. esculenta* plant

Plant part	Chemical constituents	
Leaves	Calcium oxalate, minerals like calcium phosphorus, fibres, starch, vitamin A, B, C	
	Apigenin	
	Luteolin	
	Anthocyanin	
	Flavanoids	Orientin
		Iso-orientin
		Iso-vitexin
		Vicenin-2
		Orientin 7-O-glucoside
		Iso-vitexin 3'-O-glucoside
		Vitexin X" -O-glucoside
		Luteolin 7-O-glucoside
Tubers	Starch	73-76%
	Natural polysaccharide	56% Natural sugars
		40% Anionic components
	Oxalate	Soluble-19-87 mg/100 g
		Insoluble-33-156 mg/ 100 g
	Amino acids	13 to 23%
	Nitrogen content	0.33 to 1.35%
	Lipid	0.23 to 0.52%
	Phosphate monoester derivatives	0.017 to 0.025%
	Dihydroxysterols	
	β-sitosterol	
	Stigmasterol	
	Nonacosane	
	Cyaniding 3-glucoside	
	Aliphatic compounds	Tetracos-20-en-1, 18-diol
		25-methyl triacont-10-one
		Octacos-10-en-1, 12-diol
		Pentatriacont-1, 7-dien-12-ol
		25-methyl-tritriacont-2-en-1, 9, 11-triol
	Octadecenoic acid	
	Enzymes	Lipoxygenase
		Lipid hydro peroxide-converting enzyme
Petiole	Anthocyanins	3.29%

Traditional uses

The pressed juice of the *C. esculenta* petiole is styptic, and may be used to arrest arterial hemorrhage. It is used in ear ache and otorrhoea (discharge from ear), and also as stimulant and rubefacient and also in internal hemorrhages [47]. Leaf juice is stimulant, expectorant, astringent, appetizer, and otalgia. Juice of the corm is used in cases of alopecia (baldness). *C. esculenta* corms were used as a remedy for body ache. The juice extracted from the petioles with salt is used as an absorbent in case of inflamed glands and buboes i.e. swelling of the lymph nodes. Cooked vegetable contains mucilage and found to be an effective nervine tonic. Decoction of the peel is given as a folk medicine to cure diarrhea, increases body weight, prevents excessive secretion of sputum in asthamatic individuals. It acts as a laxative, demulcent, anodyne, galactagogue and is used in case of piles and congestion of the portal system; also used as an antidote to the stings of wasps and other insects. Kaulau, a traditional Polynesian desert known as coconut pudding in which, boiled dasheen is mixed with coconut milk and brown sugar. *C. esculenta* corms are also used in the preparations of burger, bread, flakes, chips, flour, cookies, ice-cream, etc. *C. esculenta* leaves used to prepare soups, pakore in some parts of coastal south India. *C. esculenta* corm is an important staple food in West Africa, also an excellent energy supplier [48], source of carbohydrate for diabetics and for those with gastrointestinal disorders [49]. In the Indian subcontinent both the roots and leaves are used for human consumption. In Karnataka state, they are used to make Patrode. In Kerala state, the leaves are used to make chembila curry, and the roots are used in chembupuzhukku, a traditional accompaniment to Kerala congee. The stem and root are also used in the preparation of Ishtu and Moru curry. In Tamil Nadu, it is boiled, peeled and fried and used as a side-dish with rice. In Andhra Pradesh, the roots are boiled, peeled, and fried as an entree with rice, or they may be boiled along with gravy called “Pulusu”, and the leaves are also used. In Nagaland, the leaves are dried, powdered, kneaded into dough and baked into biscuits that are burnt and then dissolved in boiled water before being added into meat dishes to create thick, flavoured dry gravy [50].

Nutritional composition of *C. esculenta*

When a crop is being considered as a food source, the nutritional value of the crop is the most significant factor to consider. Because consumers place such a high value on foods nutritional worth, there is a considerable need for information on the nutritional contents of root crops. Most root crops are regarded as great energy providers due to their high starch content, but they are marginal to poor protein suppliers. A wide variety of minerals and trace elements are abundant in root crops, including considerable levels of iron and calcium, potassium, and magnesium [51]. Root crops are often high in vitamins; for example, yellow sweet potato cultivars and gigantic swamp *C. esculenta* are said to be significant sources of b-carotene [52]. The most significant component of *C. esculenta* (73-80%) is starch [53]. Its composition varies by variety, growing circumstances, soil type, moisture and fertilizer treatment, harvest ripeness, and post-harvest care and storage [54]. Protein and fat content are generally low in the corm, but it is strong in carbs, fibre, and minerals [55]. The average nutritional composition of *C. esculenta* is represented in Table 2. *C. esculenta* is a one-of-kind food because of its digestibility and hypoallergenic properties, due to its tiny starch granules [13]. On a dry weight basis, *C. esculenta* has roughly 11% protein. The essential amino acids trionine, leucine, arganine, valine, and phenylalanine are abundant in the protein fraction. Methionine, lycine, cystine, phenylalanine, and leucine are more prevalent in the leaf than in the corm among the necessary amino acids. The protein content of the corm is higher in the perimeter than it is in the centre. *C. esculenta* is high in calcium, phosphorus, iron, vitamin c, thiamine, riboflavin, and niacin, all of which are essential nutrients in human nutrition [52]. The moisture level of *C. esculenta* varies with variety, growing state, and harvest season, in general, the moisture content of *C. esculenta* ranges from 60 to 83 percent. Angami, *et al*., 2015 [56] also found that the dry matter content ranged from 27.50 percent to 17.17 percent at harvest, while the moisture content ranged from 82.83 percent to 72.50 percent in the cultivars was determined. *C. esculenta* has a substantial bit of ash in it. As a result, it's safe to assume that it's mineral-rich. *C. esculenta* had ash concentrations ranging from 3.54 to 7.78 percent [57].

Table 2: Nutritional profile of *C. esculenta*

Nutrients (100 g/dry weight)	Crude *C. esculenta*
Water	70.64
Energy	112 kcal
Carbohydrates	26.46 g
Protein	1.5 g
Total fat	0.20 g
Dietary Fibers	4.1 g
Ash	1.2 g
Vitamins	
Niacin	0.600 mg
Riboflavin	0.025 mg
Thiamine	0.095 mg
Folates	0.022 mg
Vitamin C	4.5 mg
Vitamin E	2.38 mg
Minerals	
Calcium	43 mg
Copper	0.172mg
Magnesium	33 mg
Iron	0.550 mg
Zinc	0.230 mg
Manganese	0.383 mg
Sodium	11 mg
Potassium	591 mg

Acridity in *C. esculenta*

Foods produced from *C. esculenta* suffer from the presence of acrid factors, which causes itchiness and considerable inflammation of tissues to some consumers. As a result of high rate of post-harvest loss and lack of proper scientific attention to this problem, a reduction in the annual production estimated at more than 70 % has been reported in Cameroon [58]. *C. esculenta* consumption has been affected by the presence of acridity factors, which cause sharp irritation and burning sensation in the throat and mouth on ingestion [59]. Presumably, itchiness arises when the calcium oxalate crystals are released and inflict minute punctures on the skin when in contact with it. Bradbury and Holloway (1988) [60] suggest that the crystals have to interact with a certain chemical on the raphide surface before acridity is experienced. The acridity factor can be reduced by peeling, grating, soaking and fermentation operations during processing. Removal of the thick layer of skin and long period of cooking is required to remove acridity. Other methods of removal of acridity include fermentation, baking or extraction with ethanol [61].

Reported pharmacological activities of *C. esculenta*

Internal hemorrhages, neurological disorders, digestive issues, diarrhea, snakebite, anemia, inflammation, skin disorders, and cancer are some of the ailments for which *C. esculenta* has been utilized in traditional medicine [62, 63]. *C. esculenta* has become a dietary staple as well as a cultural symbol in a number of countries throughout the world. *C. esculenta* is not only a component of the local diet, but it is also used for medical purposes. *C. esculenta* has a lot of potential as a functional food because it contains both dietary and therapeutic characteristics. The antimicrobial, antibacterial, its anti-carcinogenic, anti-oxidative, anti-diabetic, hepato-protective and the positive role in immune system are discussed below. The biological activities of different bio activate molecules present in *C. esculenta* are also shown in Figure 2.

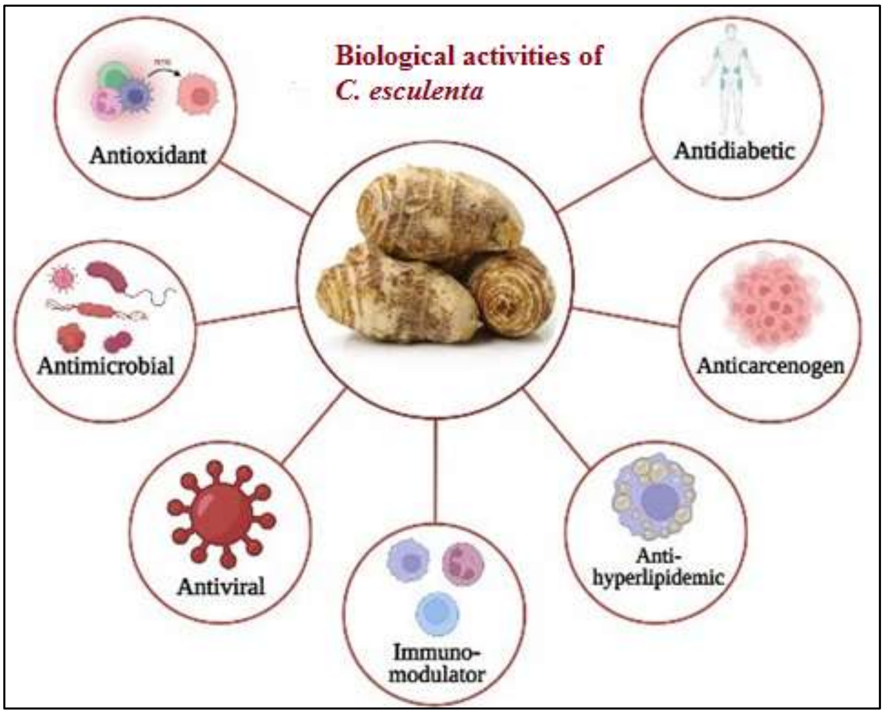

Fig 2: The biological activities of various bioactive molecules present in *C. esculenta*

Reported pharmacological activities of *C. esculenta*

Activity	Plant parts / Solvent	Model	Ref.
Cytotoxicity and antimicrobial	Leaves and tuber/Methanol	MTT assay, human osteosarcoma cell line (MG 63); Agar well diffusion method, *Pseudomonas aeruginosa. Serratia* sp. *Escherichia coli, Shigella* sp., *Staphylococcus aureus, Salmonella* sp., *Klebsiella* sp., *Proteus mirabilis, Enterococcus* sp.	64
Antimicrobial and anticancer	Corm, stem and leave/ Methanol	Agar well diffusion method, *Edwardsiella tarda Escherichia coli, Pseudomonas aeruginosa, Flavobacterium sp., Vibrio cholerae, Klebsiella sp., Aeromonas hydrophila, Vibrio alginolyticus, Salmonella sp.* and *Vibrio parahaemolyticus*; MTT assay, human breast cancer (MCF-7)	65
Antimicrobial	Leaves/ Methanolic and aqueous	Agar well diffusion method, *Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, Klebsiella* sp., *Candida albicans*	66
Antimicrobial	Leaves/ Chloroform and methanol	Agar well diffusion method, *Staphylococcus aureus, Bacillus subtilis, E. coli, Proteus vulgaris, Aspergillus niger, Candida albicans, Aspergillus flavus*	67
Antimicrobial	Leaves/ Ethanolic	Agar disc diffusion method, *Staphylococcus aureus, Klebsiella, Escherichia coli, Pseudomonas aeruginosa, Candida albicans.*	68
Anticancer	Poi/ Phosphate buffered saline	YYT colon cancer cells	69
Anticancer	Rhizomes/Methanol	Human lanosterol synthase (hOSC)	70
Anticancer	Polysaccharides/ Cold water	Lung metastasis of B16BL6	71
Anticancer	Root/ Phosphate buffered saline	Murine mammary tumor cell lines (66.1, 66.1-luciferase, and 410.4)	72
Anticancer	Leaf/ Ethanol	BHK-21 fibroblast cells	73
Antidiabetic	Seed, root/Ethanol	Streptozotocin-induced diabetic rats, malic enzyme (ME), isocitrate dehydrogenase (IDH), and glucose6-phosphate dehydrogenase (G6PD) activities.	74
Antidiabetic	Stem/Aqueous	Alloxan induced diabetic rats, body weight, blood sugar level, glycosylated haemoglobin, haematological parameters	75

Antidiabetic	Leaves/ Ethanolic	Alloxan induced diabetic rats, body weight, blood sugar level,	76
Analgesic	Leaves/ Ethanolic	Hot plate, tail immersion, acetic acid induced writhing model in mice	77
Hepatoprotective	Leaves/Aqueous	Thioacetamide-induced hepatotoxicity in rats, ALT, AST, ALP, Albumin	78
Wound healing	Leaf stalk extract ointment	Wound healing time, Wound diameter, Healing percentage	79
Neuropharmacological	Leaf/ Hydroalcoholic	Elevated plus maze test, Behavior despair test, Thiopental-induced sleeping time, Test for motor coordination (rotarod performance)	80
Nerve stimulation activity	Uracil and glycol-protein lectin	Dorsal root ganglion (DRG) neurons from GCaMP transgenic mice	81
Immunomodulatory	Corms/ Water, non-starch polysaccharides termed TPS-1 and TPS-2	Determination of NO and cytokines level, Phagocytic capacity determination of TPS-2, Investigation of pattern recognition receptor for TPS-2	82
Immunomodulatory	Corms/ 0.05 M sodium phosphate buffer pH 7.2	haematopoietic cells of C*57*BL*/6* and BALB/c mice	83
Antimycelial	Leaves/Aqueous	*Aspergillus niger, Botryodiplodia theobromae*	84
Antioxidant	Leaves/ Methanolic	FRAP, DPPH, ABTS scavenging assay	85
Antioxidant	Corms/ Methanolic	DPPH scavenging assay	86
Antibacterial	Leaves/ Ethanolic	*Staphylococcus aureus, Vibrio parahaemolyticus,* disc diffusion assay (DDA), minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC) and killing time curve by using Clinical and Laboratory Standard Institute (CLSI) methods.	87
Antifungal	Leaves/Alcoholic, aqueous	*Alternaria solani, Alternaria ricini*, food poisoning technique	88

Conclusion

C. esculenta is a largely cultivated plant used from ages as food and medicine. Flavonoids and triterpenoid's are the two major therapeutically active groups of compounds found in the plant. Pharmacologically, the plant is antimicrobial, antihepatotoxic, antidiabetic, anti-lipid peroxidative, antimetastatic, antifungal and anti-inflammatory. There are also many pharmaceutical applications for the plant. There is a lot of scope for usage of *C. esculenta* in pharmaceutical industries as well as in research work. More research work can be done on structural investigation and applications of the gum obtained from *C. esculenta*. The starch and the gum obtained from the tubers can be commercially made use of in pharmaceutical industries in form of binder, matrix forming agent, thickening agent etc. Thus, there is need to explore this plant so as to make use of its medicinal and pharmaceutical properties to its fullest.

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