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Colocasia esculenta (Taro) - An Important Culinary Plant of India: A Systematic Review

Sarita Diwakar[1], Rashmi Verma[1], Milan Hait[1], Amit Kumar Chaturwedi[1,2], Sanjoy Kumar Bera[3] and Nand Kumar Kashyap*[1,4]

[1]Department of Chemistry, Dr. C.V. Raman University, Kota, Bilaspur, C.G.-495113, India
[2]Lecturer Chemistry, Govt. SAGES, Maro, Nawagarh, Bemetara, C. G.-491340, India
[3]Department of Chemistry, Dr. C.V. Raman University, Vaishali, Bihar-844114, India
[4]Lecturer Chemistry, Government Higher Secondary School Hasuwa, Kasdol, Balodabazar-Bhatapara, C. G.-493344, India

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Corresponding Author: **Nand Kumar Kashyap** | E-Mail: **(nandk79@gmail.com)**

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ABSTRACT

Taro (Colocasia esculenta) is the fifth most important root crop in tropical and subtropical regions, valued for its nutritional, medicinal, and cultural significance. Its corms, rich in starch and bioactive compounds such as anthocyanins with antifungal and antioxidant properties, serve as a major dietary energy source. The crop is highly digestible due to its fine starch granules and mucilaginous gums, making it suitable for diverse food preparations. Taro leaves further enhance their nutritional profile by providing protein, minerals, fibre, and low calories. This review synthesizes evidence from ethnobotanical studies, nutritional analysis, and food security research, highlighting the health-promoting metabolites distributed across different plant parts and their potential applications in food and medicine. The data are presented narratively to highlight nutritional significance, therapeutic potential, food application, and security. Therefore, this review may serve as a valuable resource for future researchers to explore molecular aspects and to develop effective strategies for the nutraceutical and functional food of this important species.

Keywords: *Colocasia esculenta, nutritional composition, bioactive component, therapeutic potential, food application, food security*

1. Introduction

Colocasia esculenta (CE), one of the oldest cultivated crops, is an important source of dietary energy worldwide. Its nutritional value, health benefits, and versatile culinary applications have made it a notable plant since ancient times, especially amid growing interest in plant-based and traditional diets [1]. Various parts of the plant, including its leaves, rhizomes (corms), stem, flower, and roots, are consumed in different regions to prepare traditional dishes (Fig. 1). In India, *Colocasia esculenta* (taro) is recognized in Ayurveda for treating various ailments. Widely consumed across Asia, Africa, and the Pacific, it is valued for its adaptability, nutritional richness, and role as a staple food in low- and middle-income regions [2]. *Colocasia esculenta* (CE), a traditional root crop of the Araceae family, is widely cultivated and consumed for its corms, leaves, and petioles. Its flour is low in fat, protein, and ash but high in starch (≈24.5%) and dietary fibre, while the corms also contain anthocyanins. The starch granules are typically 5–6-sided and polygonal in shape [3]. CE *corms* are rich in water-soluble arabinogalactan proteoglycans, contributing to their pasty texture, and contain two major globulin families and characterized polyphenol oxidases. Naturally acidic, the raw corms can be used in brewing, and their small, highly digestible starch granules make them ideal for processed baby foods [4]. The soft, white corms of *Colocasia esculenta* are eaten boiled, fried, or roasted, used in fufu, soups, puddings, or processed into flour and fermented paste like 'poi'. Leaves and stalks serve as vegetables in soups and sauces, with dasheen types being less acrid than eddoe, and some varieties also provide edible stolons [5].

Medicinal uses of *Colocasia esculenta* are limited but include applying grated corms for boils, snakebites, and rheumatism in Gabon; consuming boiled young leaves for hypertension and liver issues in Mauritius; using leaf juice for eczema; and treating boils and ulcers with corms in Madagascar [6]. In Gabon, *C. esculenta* leaves mixed with *Tephrosia* are used as fish poison, while its highly perishable corms provide 20–48% of calorie intake and about 7.1% protein in many diets. In southern Nigeria, taro is a staple, supplying over 50% of the population's energy needs [7]. Taro contains 7–9% protein, notable calcium, and small starch granules, giving it nutritional advantages over other root crops. However, despite its richness in vitamins and minerals, it remains underutilized and is linked to adverse effects like oral irritation and astringency, when eaten raw or insufficiently cooked. Further research on its antinutritional factors is needed to identify the compounds responsible for these effects. [8]. The worked aimed to highlight the nutritional composition, anti-nutritional factors, therapeutic potentials, role in food security, and various applications of *Colocasia esculenta* plant.

1.1 Methodology

To execute the following procedure to gather various types of information on the *C. esculenta* plant details:

- **Databases searched:** PubMed, Scopus, Google Scholar, Web of Science,
- **Keywords:** *Colocasia esculenta*, taro, nutritional composition, phytochemicals, tuber crops, food security.
- **Inclusion criteria:** Articles published in English from 2000–2025, studies on human/animal nutrition, food science, and public health.

- **Exclusion criteria:** Articles with a non-nutritional focus or insufficient scientific data

1.2 Need for culinary plants

Culinary plants, also known as edible herbs, spices, and vegetables, have been fundamental to human civilization for millennia. Culinary plants offer nutrients, medicinal benefits, and cultural significance, and recent research highlights their potential to improve nutrition, combat non-communicable diseases, enhance food security, and support environmental sustainability [9]. Culinary plants are rich sources of vitamins and minerals (e.g., iron in spinach, vitamin C in parsley), phytochemicals like flavonoids, polyphenols, and carotenoids, dietary fibre, aiding in digestion and glycemic control, and antioxidants, which combat oxidative stress and inflammation. They play a crucial role in preventing malnutrition and micronutrient deficiencies, especially in developing regions [10]. CE culinary plants exhibit pharmacological effects, including, antibacterial and antiviral properties, anti-inflammatory effects, digestive aids, cholesterol and blood sugar regulation. Thus, CE plants act as functional foods promoting health and reducing disease risk. CE plants can be cultivated organically, reducing chemical inputs. They support biodiversity in home gardens, agroforestry, and intercropping systems [11]. Culinary plant farming supports rural livelihoods through local markets and value-added products (e.g., dried herbs, spice powders) [12]. Culinary plants support cottage industries, small-scale agribusiness, and export markets, and are well-suited for urban gardening and small spaces due to quick harvests and low input needs [13]. Their inclusion in daily diets enhances household food security, nutrition, and resilience, while promoting health, cultural values, and ecological sustainability [14].

1.3 Plant overview

Taro (CE*)* is a monocot root crop grown for its corms, leaves, and petioles, originating from Southeast Asia, Indian subcontinent and now cultivated across tropical and subtropical regions worldwide [15]. Valued for its nutritional, economic, and cultural importance, it thrives in diverse agroecosystems and is recognized as a functional food that supports food security and sustainable agriculture [16]. Conservation and research on its genetic diversity are essential to enhance utilization and climate resilience [17].

1.3.1 Origin:

C. esculenta originated in the moist tropics of Southeast Asia, including India, though its exact centre of domestication is uncertain [18]. Evidence from Papua New Guinea (10,000 years ago) and the Solomon Islands (28,000 years ago) suggests its very early use as a food crop [19]. Domestication occurred through multiple independent events across India, Southeast Asia, and Oceania, with indigenous practices creating a wide diversity of landraces [20]. Taro spread widely due to its adaptability and remains both a staple food and a culturally significant crop in Pacific and Asian societies [21]. Today, global production is led by Africa, followed by Asia and Oceania. In Asia, major producers include China (commercial scale), Japan (traditional cuisine), and the Philippines and Thailand (local use and trade) [22].

- **1.3.2 Plant growth**

In India, *C. esculenta* is cultivated locally as a vegetable, with its leaves, roots, and corms forming key dietary components. Due to calcium oxalate and other antinutrients, it must be well-cooked before consumption [23]. The crop grows best in humid conditions, fertile soils (pH 5.5–5.6), 1,000 mm annual rainfall, and temperatures of 21–27°C. Native to Southeast Asia and southern India, it adapts to both lowland and upland regions. Flowering and seed formation are rare, so propagation mainly occurs vegetatively through corms and cormels, ensuring stable yields [17].

1.3.3 Plant morphology:

C. esculenta is a perennial herb harvested 5–12 months after planting, reaching 1–2 metre in height. It develops a central underground corm as the main storage organ, from which large heart-shaped leaves grow on long petioles, and fibrous roots anchor the plant. Lateral growth produces cormels, daughter corms, and runners, enabling vegetative propagation and stable productivity [24]. The leaves of *C. esculenta* are nutrient-rich, providing vitamins, minerals, fibre, and about 23% protein, along with high water absorption that adds culinary value. They are large, heart-shaped, and vary in green to purplish shades depending on the variety [25]. The roots of *C. esculenta* are rich in carbohydrates (85–87% starch on a dry matter basis), making them an important energy source in tropical diets. They also provide essential minerals (Mg, Fe, P, K, Mn, Cu, Zn) and vitamins (A, E, B_6, C, thiamine, folate, riboflavin, niacin), contributing to both energy and micronutrient needs. [26]. The corm of *Colocasia esculenta* is a modified underground stem that stores carbohydrates and nutrients, supports vegetative propagation through cormels and daughter corms, and anchors the plant in the soil [6]. In *C. esculenta*, the stem includes an underground corm for storage and propagation and an above-ground pseudo-stem formed by overlapping leaf bases. The plant lacks a true woody stem, reflecting its herbaceous, semi-aquatic nature adapted to diverse environments [27]. The various plant parts of *C. esculenta* are given in Fig.1.

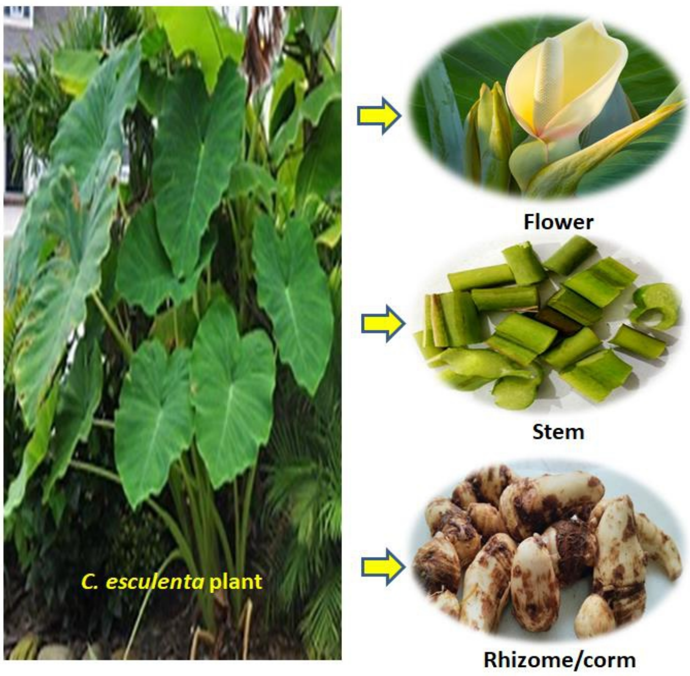


Fig. 1 C. esculenta plant and their various plant parts

1.3.5 Acridity in *C. esculenta*

Food products from *Colocasia esculenta* often irritate due to calcium oxalate crystals, which trigger acridity by damaging oral tissues [28]. This issue, linked to significant production losses (over 70% in Cameroon), is mitigated through traditional methods like peeling, soaking, and prolonged cooking, as well as advanced techniques such as fermentation, baking, and ethanol extraction. Extended cooking and skin removal remain the most effective approaches for reducing acridity and ensuring safety [29].

2. Nutritional compositions

On a fresh weight basis, the leaves of *Colocasia esculenta* are highly nutritious and composed of various essential constituents. The proximate composition of the leaves includes approximately 8.16% moisture, 51.31% carbohydrates, 25.57% protein, 4.11% fat, 1.46% crude fibre, and 10.65% ash, providing an estimated 3 kcal of energy per 100 g [30]. In terms of mineral content, the leaves are particularly rich in potassium (94.54 mg/100 g), with notable amounts of sodium (9.86 mg/100 g) and calcium (2.15 mg/100 g), making them a valuable source of micronutrients. Similarly, the corms of *C. esculenta* serve as an important energy source. The proximate composition consists of approximately 68.11% moisture, 26.83% carbohydrates, 0.34% protein, 0.11% fat, 2.53% crude fibre, and 1.91% ash. The corms are also a source of essential vitamins, including vitamin C (14.33 mg/100 g), thiamine (B_1, 0.028 mg/100 g), riboflavin (B_2, 0.029 mg/100 g), and niacin (0.78 mg/100 g), highlighting their nutritional relevance in human diets [26]. In terms of propagation, *C. esculenta* is primarily multiplied through vegetative propagation using rhizomes. However, this conventional method does not guarantee the phytosanitary quality of propagules, which can adversely affect cultivation and crop yield. To overcome this limitation, *in-vitro* regeneration techniques have been developed as an effective alternative, enabling the production of healthy, disease-free planting material while also supporting the conservation and large-scale propagation of this valuable crop [17]. Nutritional content of *C. esculenta* and its various plant parts are given in Table 1.

Table 1: Nutritional content of taro and their various plant parts

S. N	Plant parts	Nutrients	Values (g/100g)	References
1	Leaf	Carbohydrates	26.46	[28]
		Protein	1.5	[2]
		Fat	0.20	
		fibre	4.1	
		Ash	1.2	
		Total energy	112	
		Water	70.64	
2	Flower	Moisture	86	[31]
		Protein	17.67	
		Lipid	7.31	
		Carbohydrates	64.83	
		fibre	31.85	
		Ash	10.18	
3	Rhizome	Carbohydrates	13-19	[32]
		Protein	1.4-3	
		Fibre	0.6-1.18	
		Protein	10.9	[33]
		Fat	0.68	
		Amylose	8.2	
		Amylopectin	43.58	

(g= gram, kcal= kilo calori)

2.1 Macronutrients

Taro is a rich source of complex carbohydrates (approximately 20–25%), primarily in the form of starch, which constitutes about 70–80% of the corms dry weight. The starch granules in taro are exceptionally small (1–3µm) compared to those in other root crops, such as potatoes (15–100µm). This unique characteristic makes taro starch highly digestible, making it particularly beneficial for infants, the elderly, and individuals with gastrointestinal disorders. As a slow-digesting carbohydrate source, taro provides a sustained release of energy, helps prevent rapid spikes in blood sugar levels, promotes satiety, and supports weight management [34]. It contains 1.5–3% protein, with a moderate amino acid profile, including lysine and leucine. Though modest in content, taro protein is of good quality, containing several essential amino acids like lysine, leucine, valine, and threonine. This has potential health-promoting roles beyond nutrition. When combined with legumes (rich in methionine), taro provides a balanced amino acid intake important for combating malnutrition [35]. Taro is naturally low in fat, making it suitable for low-calorie and low-fat diets, (<0.2%), ideal for low-fat diets. The little fat it contains is mainly unsaturated fatty acids, such as linoleic and oleic acids, which support heart health. Because of negligible fat, taro is often combined with other foods to meet energy-dense diet requirements [36]. Dietary fibre contains 3–4% fibre, mainly insoluble, promoting digestive health. Mainly insoluble fibre (cellulose, hemicellulose, lignin), improves bowel movement and prevents constipation. Soluble fibre fraction (pectins and mucilage), slows glucose absorption, lowers cholesterol, and improves gut micro-biota balance, and mucilage exhibits gastro-protective and anti-inflammatory properties. Dietary fibre contributes to digestive health, diabetes management, and cardiovascular protection [37]. Micronutrient found in taro corns and leaves are characterized in Table 2.

Table 2: Micronutrient details found in taro corns and leaves (g/100g FW)*

S. N.	Components	Corms (FW*)	Leaves (FW*)	Characterization	References
1	Carbohydrates	26–30 g	8–15 g	Starch-rich in corms, lower in leaves	[37]
2	Protein	1.5–3 g	3–7 g	Leaves richer in protein, better amino acid balance	[35]
3	Fat	0.1–0.4 g	0.5–1 g	Both very low-fat, mostly unsaturated	[34]
4	Dietary Fiber	1–3 g	2-4 g	Good source of soluble and insoluble fibre	[36]
5	Energy	110–130 kcal	40–60 kcal**	Corms energy-dense, leaves nutrient-dense	[37]

*(*FW= Fresh weight, **kcal= Kilo calori, g= gram)*

Taro is a nutrient-dense, gluten-free tuber with easily digestible starch, moderate protein, low fat, and functional fibres, making it both a rich energy source and a functional food with health promoting properties [38].

2.2 Micronutrients

Taro is not only rich in macronutrients but also a valuable source of micronutrients (vitamins and minerals) that contribute significantly to health and food security.

2.2.1. Vitamins

a) Water-soluble vitamins

Taro is rich in water-soluble vitamins, especially vitamin C and B-complex, supporting energy metabolism, antioxidant defense, immunity, nervous system function, and DNA synthesis. While present in both corms and leaves, these vitamins are concentrated more in the leaves, enhancing their nutritional value.

Vitamin C (ascorbic acid)

Taro contains considerable amounts of vitamin C, an essential water-soluble antioxidant. The corms provide approximately 5–15 mg per 100 g fresh weight, while the leaves are much richer, containing 70–110 mg per 100 g FW. Vitamin C plays a crucial role in collagen synthesis, which supports skin, cartilage, and wound healing. It also functions as a potent antioxidant, protecting cells from oxidative stress and boosting the immune system. Furthermore, vitamin C enhances iron absorption, making it particularly beneficial when consumed alongside iron-rich foods [39]. Taro is also a notable source of B-complex vitamins, which are vital for maintaining energy production, nervous system health, red blood cell formation, and overall metabolic balance. Both corms and leaves contribute significantly, though the concentrations vary among different B vitamins [40].

1. Thiamine (vitamin B_1):

Taro provides about 0.1–0.15 mg per 100 g FW of thiamine, a vitamin essential for carbohydrate metabolism and energy production. It supports the nervous system by aiding in neurotransmission and proper nerve function, making it vital for maintaining mental and physical performance [41].

2. Riboflavin (vitamin B_2):

The riboflavin content in taro ranges from 0.03–0.1 mg per 100 g FW. Riboflavin plays an integral role in cellular energy production, supports skin and eye health, and acts as a cofactor for several enzymatic reactions involved in oxidation-reduction processes [41].

3. Niacin (vitamin B_3):

Taro contains about 0.6–0.8 mg per 100 g FW of niacin, which is essential for cellular energy production, DNA repair, and enzyme function. Niacin also contributes to nervous system stability and helps regulate lipid metabolism, making it crucial for overall metabolic health [42].

4. Vitamin B_6 (pyridoxine):

Pyridoxine is present in taro at levels of 0.3–0.4 mg per 100 g FW. This vitamin is indispensable for amino acid metabolism, neurotransmitter synthesis, and the regulation of homocysteine levels, thereby supporting both brain function and cardiovascular health [42].

5. Folate (vitamin B_9):

Taro is a good source of folate, with corms containing about 20–45 µg per 100 g FW, while the leaves provide more than 100 µg per 100 g FW. Folate is critical for DNA synthesis, cell division, and red blood cell formation. It is particularly important during pregnancy, as adequate folate intake reduces the risk of neural tube defects and supports healthy fetal development [40]. Taro, especially its leaves, is rich in vitamin C and B-complex vitamins, supporting energy metabolism, immunity, neurological function, and cellular health, making it a valuable component of both traditional and therapeutic diets [43].

b) Fat-soluble vitamins

Taro (*Colocasia esculenta*) leaves are nutrient-dense, providing key fat-soluble vitamins absent or minimal in the corms [42]. They are rich in β-carotene (2000–6500 µg/100 g FW), which converts to vitamin A for vision, immunity, and cell growth; vitamin E (2–4 mg/100 g FW), an antioxidant supporting cellular integrity, immunity, and skin health; and vitamin K (80–100 µg/100 g FW), essential for blood clotting and bone strength [32-33]. These vitamins collectively enhance antioxidant defense, skeletal health, and disease prevention, making taro leaves a valuable functional food [28]. Vitamin content of taro's various plant parts is given in Table 3.

Table 3: Vitamin content of taro various plant parts (mg/100g)

S. N	Plant parts	Vitamins	Values (mg/100g)	References
1	Leaf	Niacin	0.6	[28]
		Riboflavin	0.025	
		Thiamine	0.095	
		Folates	0.022	
		Vitamin C	4.5	
		Vitamin E	2.38	
2	Rhizome	Thiamine	0.18	[32]
		Niacin	0.9	
		Vitamin C	9	
		Riboflavin	0.04	
		Omega 6	0.2	[33]
		Vitamin A	0.5	
		Vitamin E	0.1	
		Vitamin D	24.8	

2.2.2 Minerals

a) Major minerals

Taro (*Colocasia esculenta*) is a nutritionally rich crop, particularly valued for its essential minerals that play significant roles in maintaining overall health and well-being [43]. Both the corms and leaves are excellent sources of vital nutrients, though their concentrations vary depending on the plant part [44]. Taro is a rich source of essential minerals, particularly potassium (400–700 mg/100 g FW in corms; 800–1200 mg/100 g FW in leaves), which supports fluid balance, nerve function, and cardiovascular health [45]. Its leaves also provide high calcium (200–400 mg/100 g FW), vital for bone, teeth, and muscle function, compared to lower levels in corms (15–50 mg/100 g FW) [46]. Additionally, taro supplies moderate amounts of magnesium (20–40 mg/100 g FW) for enzymatic and cardiovascular functions, and phosphorus (40–80 mg/100 g FW) important for bone mineralization and energy metabolism [33]. Taro is a nutrient-dense food that provides essential minerals potassium (K), calcium (Ca), magnesium (Mg), and phosphorus (P), supporting bone health, muscle function, energy metabolism, and cardiovascular regulation, making it valuable for a balanced diet.

b) Trace elements

Taro (*Colocasia esculenta*) provides essential trace minerals, with leaves generally richer than corms [47]. It supplies iron (0.5–1 mg/100 g FW in corms; 2–4 mg in leaves) for oxygen transport and anaemia prevention, zinc (0.2–0.5 mg) for immunity and growth, copper (0.1–0.2 mg) for antioxidant enzyme activity and iron metabolism, and manganese (0.3–0.5 mg) for bone health and antioxidant defense [48]. Selenium, though present in trace amounts, supports antioxidant protection, thyroid metabolism, and immune function [49]. The above mentioned together, they make taro an excellent staple crop for food security and nutrition improvement, especially in populations vulnerable to anaemia, vitamin A deficiency, and protein-energy malnutrition.

3 Phytochemicals and bioactive compounds

Colocasia esculenta, commonly known as taro, is a nutritionally important tuber crop widely consumed across tropical and subtropical regions. Beyond its macronutrient content, taro is increasingly recognized for its rich profile of phytochemicals and bioactive compounds**,** which contribute to its health-promoting properties such as antioxidant, anti-inflammatory, antimicrobial, and anticancer activities [6].

3.1 Phenolic compounds:

Phenolic compounds are one of the most important classes of bioactive phytochemicals in taro (*Colocasia esculenta*). They are present in both corms and leaves, including phenolic acids (e.g., caffeic acid, ferulic acid, gallic acid, chlorogenic acid) and polyphenols. These compounds have strong pharmacological significance and contribute to taro's value as a functional food. Phenolic compounds in taro exhibited, antioxidant, anti-inflammatory, anticancer, antidiabetic, cardioprotective, hepatoprotective, neuroprotective, antimicrobial, and antiviral activities. These pharmacological properties make taro an important functional food and nutraceutical resource, especially for preventing chronic lifestyle-related diseases.

3.2 Flavonoids:

Flavonoids are abundant, especially in taro leaves and pigmented (purple) corm varieties. Key flavonoids include- quercetin, kaempferol, rutin, and catechin. These compounds contribute to free radical scavenging, vascular protection, and anti-inflammatory responses [50]. Flavonoids are among the most abundant secondary metabolites in taro (*Colocasia esculenta*), present in both leaves and corms. They are polyphenolic compounds with diverse pharmacological activities, contributing significantly to taro's medicinal and functional food value. Flavonoids in taro possess antioxidant, anti-inflammatory, anticancer, cardioprotective, antidiabetic, hepatoprotective, neuroprotective, and antimicrobial activities. These bioactive compounds significantly contribute to taro's pharmacological and nutritional value, making it a promising functional food and medicinal plant [33].

3.3 Anthocyanins:

Found in high levels in purple-fleshed taro cultivars, anthocyanins are responsible for the vibrant coloration and offer potent antioxidant and anticancer properties. Common anthocyanins identified include- cyanidin-3-glucoside, pelargonidin derivatives. Anthocyanins also have neuroprotective and anti-obesity effects, free radical scavenging [30]. Taro contains anthocyanins, especially in purple-fleshed corms and petioles, which give them their characteristic violet color. Anthocyanins are water-soluble flavonoid pigments with strong bioactivity. Their pharmacological properties have made purple taro an emerging functional food and nutraceutical source. Anthocyanins in taro possess antioxidant, anticancer, antidiabetic, cardioprotective, anti-inflammatory, neuroprotective, anti-obesity, and hepatoprotective activities. Purple taro varieties, rich in anthocyanins, are especially valuable as functional foods for preventing chronic lifestyle diseases [6].

3.4 Dietary fibre and mucilage:

Taro is not only a source of starch and phytochemicals, but also of dietary fibre and mucilage (a polysaccharide-rich, sticky substance in corms and leaves). Both play key roles in nutrition and pharmacological activity, contributing to taro's value as a functional food [51]. Taro contains non-starch polysaccharides and mucilage, which function as:

- **Prebiotics**: Enhancing gut microbiota [52].
- **Digestive aids**: Promoting bowel regularity [52].
- **Immunomodulators**: Supporting immune system health [52].
- **Dietary fibre in taro**: improves digestion, lowers cholesterol, controls blood sugar, prevents obesity, and supports gut microbiota. [52].
- **Mucilage in taro**: provides soothing, protective, hypoglycemic, hypocholesterolemic, anti-inflammatory, and wound-healing effects [52].

Together, they make taro a functional food with significant pharmacological and therapeutic potential in managing diabetes, cardiovascular disease, gastrointestinal disorders, and chronic inflammation. These also support gut microbiota and improve bowel movements.

3.5 Lectin (Tarin)

Tarin is a bioactive glycoprotein found in taro corms. Taro (*Colocasia esculenta*) contains a unique lectin called Tarin (a mannose-binding lectin/glycoprotein). Unlike some toxic plant lectins, (tarin) has been shown to possess diverse pharmacological activities with important biomedical applications. Taro lectin (tarin) exhibits anticancer, immunomodulatory, antiviral, antimicrobial, anti-inflammatory, and potential antidiabetic activities. Its ability to bind specific carbohydrates makes it valuable for biomedical research, immunotherapy, and functional food applications. Unlike many plant lectins (tarin), is non-toxic, which enhances its therapeutic potential [42].

3.6 Saponins

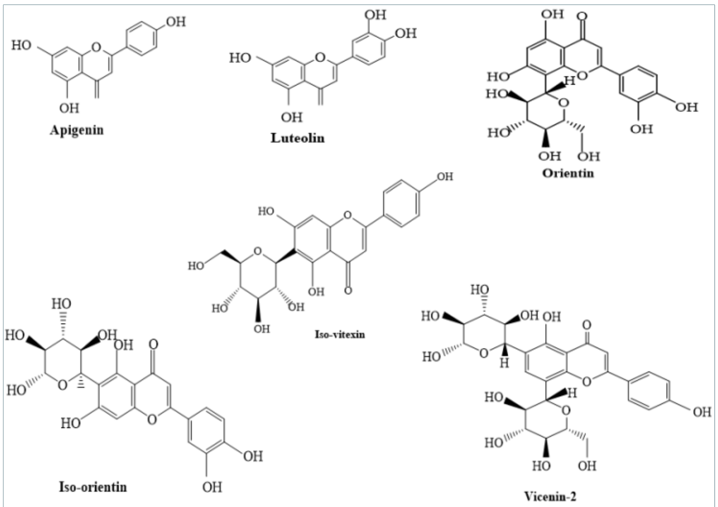
Saponins are among the important bioactive phytochemicals in taro, especially concentrated in the leaves and petioles, with smaller amounts in corms. They contribute to both nutritional drawbacks (bitterness, reduced absorption) and pharmacological benefits. Although present in lower concentrations, saponins contribute to possess antimicrobial, antioxidant, anti-inflammatory, anticancer, antidiabetic, cholesterol-lowering, and immunomodulatory activities. Despite its antinutritional effects, these compounds contribute greatly to taro's pharmacological and therapeutic value, making taro not just a staple food but also a functional food with medicinal potential [41,53].

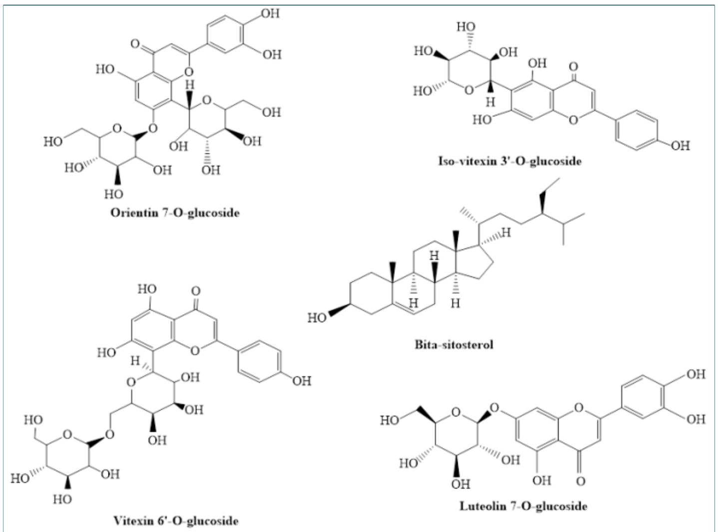
3.7 Alkaloids

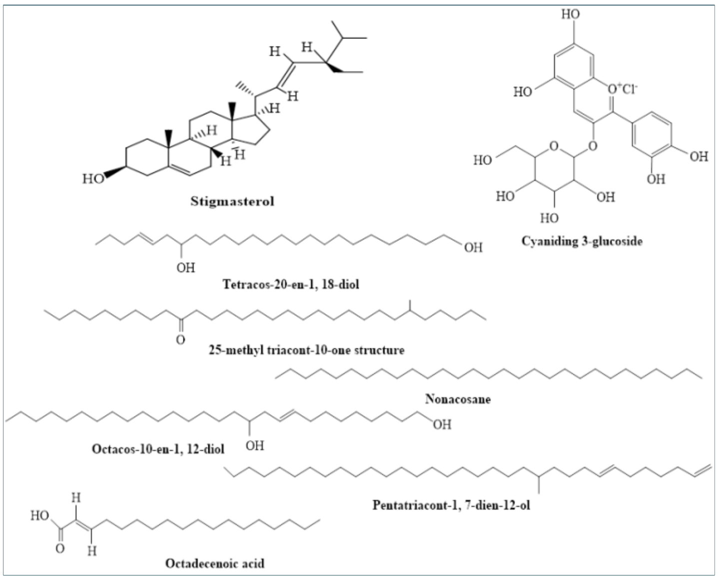
Alkaloids in taro are present in relatively small amounts, compared to oxalates or phenolics. Still, studies have reported that taro (particularly the leaves, petioles, and corms**)** contains bioactive alkaloids that may contribute to its pharmacological and therapeutic potential. Alkaloids in taro contribute to antimicrobial, antioxidant, anti-inflammatory, analgesic, anticancer, antidiabetic, and cardioprotective activities. Although present in small amounts, they work synergistically with taro's other phytochemicals (flavonoids, phenols, saponins, etc.), supporting its pharmacological value in traditional and modern medicine [41,54]. Bioactive constituents found in taro and its plant parts are given in Table 4.

Table 4: Bioactive constituent found in taro and their plant parts

S. N.	Plant Parts	Bioactive constituents	References
1	**Leaves**	Apigenin	[28]
		Luteolin	
		Orientin	
		Iso-orientin	
		Iso-vitexin	
		Vicenin-2	
		Orientin 7-O-glucoside	
		Iso-vitexin 3'-O-glucoside	
		Vitexin 6'-O-glucoside	
		Luteolin 7-O-glucoside	
		Anthocyanin	
		Flavanoids	
2	**Rhizome**	Starch	[28]
		Natural polysaccharide	
		Oxalate	
		Amino acid	
		Lipid	
		Phosphate monoester derivatives	
		Dihydroxysterols	
		β-sitosterol	
		Stigmasterol	
		Nonacosane	
		Cyaniding 3-glucoside	
		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	
		Lipoxygenase	
		Lipid hydro peroxide-converting enzyme	
3	**Stem**	Carbohydrates	[28]
		Anthocyanins	
		Minerals	
		Amino acid	







Structures of isolated bioactive compounds in C. esculenta various plant parts

4. Therapeutic potentials

The pharmacological importance of plants has been gaining attention due to their zero toxicity and lower cost. Potential components from various parts of the plants have been identified and their extract is used for the formulation of drugs [17]. The natural extracts possess natural bioactive compounds such as alkaloids, glycosides, proteins, carbohydrates, lipids, fats, and oils, hence they are known for the lower incidence of adverse effects caused by drugs and play a major role in modern clinical drugs [55].

4.1 Antioxidant potential

Plants harness sunlight for energy through photosynthesis, a process that produces free radicals and reactive oxygen species (ROS). Excess ROS, along with ultraviolet radiation, can damage lipids, proteins, and nucleic acids, leading to oxidative stress. To counter this, plants produce antioxidants such as vitamins, polyphenols, carotenoids, and xanthophylls, which protect both plants and humans from free radical damage [56]. Oxidative stress contributes to diseases such as cardiovascular disorders, cancer, diabetes, and neurodegeneration. Plant-based foods, rich in antioxidants like flavonoids, help reduce these risks, highlighting the importance of combining traditional knowledge with modern science to support health [57]. The antioxidant activities in plants vary widely, ranging from very low to exceptionally high levels. Natural antioxidants play multiple roles, including acting as reducing agents, free radical scavengers, metal ion chelators, and quenchers of singlet oxygen formation. The major naturally occurring antioxidants include flavonoids (such as flavanols, isoflavones, flavones, catechins, and flavanones), cinnamic acid derivatives, coumarins, tocopherols, and various polyfunctional organic acids [58].

4.2 Anticancer potential

Various *in-vitro* studies on different carcinoma cell lines and in vivo experiments using animal models have demonstrated the anticancer properties of taro roots and tubers, primarily attributed to their rich phytochemical composition [37]. Taro is a significant source of vitamins A and C, along with a wide range of phenolic antioxidants, flavonoids, carotenoids, and other bioactive compounds, which play a crucial role in enhancing immune function and combating oxidative stress.

These antioxidants help neutralize free radicals, highly reactive by-products of cellular metabolism that can damage DNA, proteins, and lipids, potentially leading to cellular mutations and the transformation of normal cells into cancerous ones [17]. Additionally, taro contains cryptoxanthin, a naturally occurring carotenoid with strong antioxidant activity, which has been associated with a reduced risk of developing lung and oral cancers. Cryptoxanthin works by scavenging reactive oxygen species, protecting cellular structures, and regulating gene expression involved in cell proliferation and apoptosis. Regular consumption of taro and other antioxidant-rich foods may therefore contribute to the prevention of cancer initiation, progression by strengthening the immune system, reducing oxidative DNA damage, and inhibiting tumor growth pathways [23].

4.3 Antimicrobial properties:

Foodborne diseases are brought on by eating food that has been infected with toxic substances or pathogenic microorganisms [48]. Peoples are globally being affected by this growing health problem. The most typical signs of foodborne illnesses were stomach pain, vomiting, diarrhea, and nausea [59]. Antimicrobial activity of *C. esculenta* was attributed to its aqueous accumulation, and *E. tarda*, *Flavobacterium* sp., *Klebsiella* sp., *V. cholerae*, *A. hydrophila*, *E. coli*, *Salmonella* sp., *V. parahaemolyticus*, *V. alginolyticus*, and *P. aeruginosa* were among the microorganisms studied. Several low-fixation microscopic species and parasites were shown to have high antibacterial action in *C. esculenta* [60]. Certain researchers [61] reported on the antibacterial and proximate analyses of fermented taro skin that was purchased from a nearby manufacturer of Poi (traditional staple food, made from taro). One of the strains recovered from the material, *Leuconostoc mesenteroides*, was found to antibiotic activity against the examined bacterial strains. Poi was shown to encourage the growth of bacteria that produce bacteriocin [38]. In research, the antimicrobial effects of leaf and taro tuber against nine clinical infections were evaluated by [62]. Antimicrobial testing showed that leaf extract was most effective against *Proteus mirabilis* at 100 mg/mL, while tuber extract showed the largest inhibition against *Klebsiella* and overall exhibited stronger antimicrobial action than leaf extract [6, 62].

4.4 Anti-diabetic activity:

Diabetes is one of the most challenging diseases of the 21st century, significantly affecting vital biochemical processes in the body, including the metabolism of carbohydrates, proteins, and lipids. Its global incidence is rising at an alarming rate, particularly among rural populations [63]. Conventional treatments for diabetes are often inadequate and costly, especially in developing countries. Medicinal plants provide an accessible, affordable, and effective alternative, improving quality of life in rural areas, as diabetes continues to rise globally, with over 350 million projected cases by 2035 [64]. Research has also highlighted the potential benefits of dietary interventions using locally available plant sources. Many researchers reported that incorporating *Colocasia esculenta* and immature plantain flour into diets may help regulate blood glucose, and slow down diabetic nephropathy in type-2 diabetes, highlighting the potential of plant-based herbaceous approaches to managing diabetes, especially in resource-limited settings [65].

4.5 Anticancer activities

Cancer remains one of the leading causes of mortality worldwide, largely driven by poor dietary habits and sedentary lifestyles. Preventive strategies, particularly those involving bioactive dietary components from plant-based foods, are essential for reducing cancer risk. Since cancer is a multistage disease, interventions at any stage, initiation, promotion, or progression can help mitigate its severity. Phytochemicals derived from the roots and tubers of various plants, including taro, have demonstrated significant anticancer properties in multiple carcinoma cell lines and animal models [66]. The *in-vitro* effects of taro-derived compounds on colon carcinoma cells were highlighting their potential role in colorectal cancer prevention [67]. In a comparative study involving many plant species, taro was the only plant capable of inhibiting lanosterol synthase (hOSC), a key human enzyme responsible for cholesterol synthesis [68]. Since elevated blood cholesterol levels are strongly associated with a higher risk of colorectal carcinoma (CRC), reducing triglyceride synthesis and cholesterol formation through taro-derived compounds offers a promising therapeutic pathway [69]. Moreover, tarin, a glycoprotein extracted from taro, has emerged as a potential anticancer agent due to its ability to modulate immune responses, inhibit tumor cell proliferation, and suppress metastasis [42]. While preliminary findings are encouraging, more comprehensive *in-vivo* studies and clinical trials are needed to establish tarin's effectiveness and its potential as a sustainable, plant-based strategy for preventing cancer spread, colonization, and migration [6].

4.6 Peroxidative activity against lipids

Taro (*Colocasia esculenta*) contains numerous phytochemicals that play a significant role in preventing lipid peroxidation and reducing oxidative stress. Compounds such as vitamins, tannins, carotenoids, alkaloids, flavonoids, and saponins are believed to contribute to its strong antioxidant properties [70]. Studies have demonstrated the free radical scavenging potential of taro, particularly using the whole leaf juice of *C. esculenta*. *In-vivo* experiments were conducted on animal liver slice models to evaluate their protective effects against oxidative damage [70]. The liver slices were exposed to cytotoxic concentrations of acetaminophen and carbon tetrachloride (CCl_4), both known to induce oxidative stress, and liver injury. Results indicated that taro leaf extracts exhibited a significant protective effect, reducing oxidative damage by neutralizing free radicals, and supporting hepatic cell integrity [71].

4.7 Activity against metastasis

Metastatic disease remains the leading cause of mortality in breast cancer patients. Many compounds extracted from the roots of *Colocasia esculenta* (taro) have shown significant potential inhibited tumor growth, and metastasis, both in theory and experimental studies. In a preclinical breast carcinoma model, taro extracts exhibited strong anti-metastatic activity, effectively reducing tumor cell mobility, and invasion [72]. Research indicates that taro compounds help regulate key molecular pathways by downregulating the expression of cyclooxygenase-1 (COX-1), cyclooxygenase-2 (COX-2), and prostaglandin E2 (PGE2), which are closely associated with inflammation-driven cancer progression. Additionally, taro extract has been shown to significantly inhibit the proliferation of several breast and testicular cancer cell lines and, in some cases, completely block tumor cell migration, suggesting its potential as a promising natural anticancer agent [6].

4.8 Antifungal properties

Researchers employed recombinant expression techniques, and molecular cloning to investigate the antifungal activity of a cysteine–protease inhibitor, CeCPI (cystatin), identified in the corms of *Colocasia esculenta* (taro). The study demonstrated that the recombinant CeCPI protein exhibited significant cysteine–protease inhibitory activity, effectively suppressing the enzymatic functions essential for fungal growth. The findings revealed that taro possesses a strong antifungal property, specifically showing a toxic effect on the mycelial development of phytopathogenic fungi, suggesting its potential role in plant defense mechanisms, and agricultural disease management [73,6].

4.9 Prebiotic potential

Dietary fibres, particularly water-soluble non-starch polysaccharides (WS-NSPs), play a crucial role in promoting gut health and immune function [74]. The beneficial effects of WS-NSPs are attributed to their ability to modulate digestion, serve as a nutrient source for beneficial gut micro-biota, and interact with intestinal epithelial cells (IECs) within the gastrointestinal (GI) tract [75]. However, limited data exist on the digestibility of taro carbohydrates, the cytotoxicity of its WS-NSPs in HT-29 colon cells, their prebiotic effects, and the impact on cytokine regulation, particularly IL-8. The HT-29 cell line serves as a standard *in-vitro* model to study enterocyte–immune interactions and IL-8 secretion [76]. Water-soluble non-starch polysaccharides (WS-NSPs) act as prebiotics by resisting upper gastrointestinal digestion, reaching the colon where they are fermented to feed beneficial gut microbes, thereby supporting gut health, immune function, and micro-biota balance [77]. Various types of experimental work applied of different extract, their impact and outcomes are tabulated in Table 5.

Table 5: Various types of experimental work applied of different extract, their impact and outcomes

S. N.	Extract	Experimental works	Impacts	Outcomes	References
1	2% (w/v) CE	*In-vitro* growth of *Lactobacillus* species	The prebiotic potential of CE may help strengthen the gut micro-biota of people.	*L. acidophilus, L. paracasei, L. plantarum* growth and self-agglutination of *L. paracasei*	[78]
2	Water extract of CE	Streptococcus mutans	Antimicrobial action	Lowering to growth	[60]
3	EtOH extract of CE	Alloxan-induced diabetic mice	Antihyperglycemic effect	Lowering glycemic impact	[60]
4	CE extract 400 mg/kg BW	Male sprague dawley rats	Anti-diabetic and anti-anaemic impact	Inhibited aldose, reductase, enzyme activity, increased production of haemoglobin	[79]
5	EtOH extract of CE leaves	Wister rats, granuloma model	Anti-inflammatory activity	Calmed the inflammation	[80]
6	EtOH and water extract produced five digalactosyl-diacylglycerols (DGDG) and three monogalactosyldiacylglycerols (MGDG)	Human Caco cell lines	synthesis, declined cholesterol-induced colorectal cancer (CRC)	Inhibition of human lanosterol synthase (hOSC), declining risk of CRC	[80]
7	EtOH CE leave extracts 10–50 mg/mL	Earth worms	*In-vitro* anthelmintic activity	Potent paralysis and death time	[81]
8	25% Alcoholic concentration of CE leaf extract	*Alternaria ricini* and *Alternaria solani*	*In-vitro* antifungal activity	Inhibition of pathogenic growth	[82]
9	CE leaf juice	*In-vitro* rat liver slice model	Hepatotoxins (CCl_4 and acetaminophen) induced lipid peroxidative reactions	Prevented the elicit of these reactions and protected liver	[83]
10	MeOH extract of CE Leaf	MTT assay	Cytotoxicity against human osteosarcoma cell line (MG 63)	Effective impact were seen against cell line	[28,62]
11	MeOH extract of CE rhizome	Agar well diffusion	*P. aeruginosa, E. coli, S. aureus, Salmonella sp., Klebsiella sp., Proteus mirabilis, Enterococcus sp.*	Impactful against microbes	[28,62]
12	MeOH extract of CE Leaf	MTT assay	human breast cancer (MCF-7)		[84]
13	TCM and MeOH extract of CE leaf	Agar well diffusion method	*S. aureus, B. subtilis, E. coli, P. vulgaris, A. niger, C. albicans, A. flavus*	Impactful against microbes	[85]
14	EtOH extract of CE Leaf	Agar well diffusion method	*S. aureus, B.subtilis, Klebsiella, E. coli, P. aeruginosa, C. albicans*.	Impactful against microbes	[81]
15	Phosphate buffered saline of CE leaf	MTT assay (anticancer)	YYT colon cancer cells	Impactful against cell line	[67]
16	MeOH extract of CE rhizome	*In-vitro* cell line	Human lanosterol synthase (hOSC)	Impactful against cell line	[68]
17	Cold water extract of CE leaf	*In-vitro* cell line	Lung metastasis of B16BL6	Effective impact were seen against cell line	[86]
18	Phosphate buffered saline of CE rhizome	*In-vitro* cell line	Murine mammary tumor cell lines (66.1, 66.1-luciferase, and 410.4)	Effective impact were seen against cell line	[72]
19	EtOH extract of CE Leaf	*In-vitro* cell line	BHK-21 fibroblast cells	Effective impact were seen against cell line	[87]
20	EtOH extract of CE rhizome	*In-vivo* antidiabetics	Streptozotocin-induced diabetic rats, malic enzyme (ME), isocitrate dehydrogenase (IDH), and glucose6-phosphate dehydrogenase (G6PD)	Reduced sugar level and effective against anti-diabetic action	[71]
21	Aqueous extract of CE stem	*In-vivo* antidiabetics	Alloxan induced diabetic rats, blood sugar level, glycosylated haemoglobin, haematological	Reduced sugar level and effective against anti-diabetic action	[88]
22	EtOH extract of CE leaf	*In-vivo* anti-diabetics	Alloxan induced diabetic rats, body weight, blood sugar level,	Reduced sugar level and effective against anti-diabetic action	[89]

23	EtOH extract of CE leaf	*In-vivo* analgesic	Hot plate, tail immersion, acetic acid induced writhing model in mice	Effective impact were seen against analgesic action	[90]
24	Aqueous extract of CE leaf	Hepato-protective	Thioacetamide-induced hepatotoxicity in rats, ALT, AST, ALP, Albumin	Effective impact were seen against hepatoprotective action	[45]
25	Leaf stalk extract ointment	Wound healing	Wound healing time, Wound diameter, Healing percentage	Better wound healer	[69]
26	Hydroalcoholic extract of CE leaf	Neuro pharmacological	Elevated plus maze test, Behavior despair test, Thiopental-induced sleeping time, rotarod performance	Excellent performance against neurological disorder	[91]
27	Uracil and glycol-protein lectine of CE stem	*In-vivo* nerve stimulation	Dorsal root ganglion (DRG) neurons from GCaMP transgenic mice	Better nervous stimulator	[92]
28	Aqueous extract of CE stem	*In-vitro* Immuno-modulatory	Determination of NO and cytokines level, Phagocytic capacity determination of TPS-2, Investigation of pattern recognition receptor for TPS-2	Immuno-modulatory rehabilator	[93]
29	Corms/ 0.05 M sodium phosphate buffer pH 7.2	*In-vivo* immune-modulatory	haematopoietic cells of C57BL/6 and BALB/c mice	Impactful against immune-modulatory cell line	[94]
30	Aqueous extract of CE leaf	*In-vitro* anti-mycelial	*A. niger*, *B. theobromae*	Impactful against microbes	[95]
31	MeOH extract of CE leaf	*In-vitro* antioxidant	FRAP, DPPH, ABTS scavenging assay	Greater IC_{50} concentration and good scavenger	[96]
32	MeOH extract of CE stem	*In-vitro* antioxidant	DPPH scavenging assay	Greater IC_{50} concentration and good scavenger	[97]
33	EtOH extract of CE leaf	*In-vitro* antibacterial	*S. aureus*, *V. parahaemolyticus*, disc diffusion assay (DDA), MIC, MBC, and killing time curve by using Clinical and Laboratory Standard Institute (CLSI) methods	Inhibition of pathogenic growth	[98]
34	EtOH extract of CE leaf	*In-vitro* antifungal	*A. solani*, *A. ricini*, food poisoning technique	Inhibition of pathogenic growth	[82]

5. Anti-nutritional factors

Taro is a staple root crop rich in carbohydrates, dietary fibre, vitamins, and minerals. However, like many tubers and leafy plants, it contains anti-nutritional factors (ANFs) that can reduce nutrient bioavailability, affect digestibility, or cause adverse health effects if consumed raw or improperly processed. Below is a detailed overview of the major anti-nutritional factors of taro:

5. 1 Oxalates

Oxalate is generally found in soluble form as oxalic acid and insoluble form like calcium oxalate crystals. Due to oxalate present in taro causes irritation of the mouth, throat, and gastrointestinal tract (due to needle-shaped raphides), and reduces calcium bioavailability by forming insoluble calcium oxalate complexes. Excess intake may contribute to kidney stone formation. Oxalate content in taro 200–500 mg/100 g in raw corms, varies with cultivar and part of the plant [99]. The total oxalate content in the leaves ranged from 433.8 to 856.1 mg/100g wet matter (WM), while the soluble oxalate content varied between 147.8, and 339.7 mg/100g (WM). Soluble oxalates accounted for 28% to 41% of the total oxalate content, with an overall mean of 35%. In contrast, insoluble oxalates constituted 59% to 72% of the total oxalate content, and 65% overall [100]. Reduction of oxalate content impact, it should boiling, soaking, fermenting, or adding calcium salts can significantly lower oxalate levels.

5.2 Tannins

Tannins are naturally occurring plant metabolites predominantly present in taro, with higher concentrations found in the leaves and peel compared to the corm. These compounds play a significant role in the plant's defense mechanisms but can influence human nutrition in various ways. It has a strong tendency to bind with dietary proteins and digestive enzymes, which can reduce protein digestibility and limit the efficient utilization of dietary proteins. Additionally, polyphenols are known to interfere with iron absorption by forming insoluble complexes, potentially increasing the risk of iron-deficiency anaemia when consumed in excessive amounts. While it contribute to the characteristic taste and nutritional profile of taro, their higher levels in leaves and peel make proper processing and preparation essential to minimize potential adverse effects [101].

5.3 Phytates

Phytate, a common anti-nutrient found in grains, legumes, nuts, seeds, and taro, consists of a six-carbon ring esterified with multiple phosphate groups [102]. When dephosphorylated by phytase, it produces smaller phosphoric esters (IP1–IP5) [103]. Although phytates reduce mineral bioavailability by binding essential cations, since human enzymes cannot digest them [104]. They also exhibit antioxidant and neuro-protective properties, potentially improving autophagy and mitochondrial function in Alzheimer's models [105]. Processing or enzymatic breakdown enhances mineral absorption and lowers health risks [106]. In taro corms, phytate levels range from 275–528 mg/100g, consistent with earlier reports of 63–105 mg/100g [107]. In taro-based products like taro crackers, phytate content is measured by acid extraction followed by centrifugation 108].

5.4 Protease inhibitors

Taro contains protease inhibitors, including trypsin and chymotrypsin inhibitors, which are naturally occurring anti-nutritional compounds found in various plant parts, particularly in the corms, leaves, and peels. These inhibitors act by binding to digestive enzymes such as trypsin and chymotrypsin in the small intestine, thereby reducing their enzymatic activity. The breakdown of dietary proteins into absorbable amino acids is hindered, which can lead to reduced protein digestibility, limited amino acid absorption, and, in cases of excessive intake, may cause poor growth and nutritional deficiencies [109]. In taro, the concentration of protease inhibitors is generally higher in the peels and leaves compared to the corms, as these compounds are part of the plant's defense mechanism against pests and pathogens. However, their nutritional impact can be significantly minimized through thermal processing methods. Heat treatments such as boiling, steaming, baking, or roasting effectively denature and inactivate protease inhibitors, thereby improving the digestibility and nutritional quality of taro-based foods. Among these methods, boiling is particularly effective, as prolonged exposure to heat inactivates most protease inhibitors present in both the corms, and leaves, making taro safer, and more suitable for human consumption [110].

5.5 Saponins

Saponins are naturally occurring glycosidic compounds found in various parts of the taro plant, including leaves, petioles, corms, and peels, with higher concentrations in the leaves and peels. They play a key role in the plant's defense against pests and pathogens, but act as anti-nutritional factors, when consumed in excess, causing bitterness, gastrointestinal irritation, and reduced nutrient absorption. However, saponins also exhibit beneficial properties such as antioxidant, anti-inflammatory, and anticancer effects. Their levels can be significantly reduced through processing methods like boiling, steaming, baking, soaking, and fermentation, which enhance the palatability, safety, and nutritional quality of taro-based foods [111].

5.6 Alkaloids

Alkaloids are a diverse group of naturally occurring nitrogen-containing compounds found in various parts of the taro plant, including the leaves, petioles, peels, and, to a lesser extent, the corms. It is a part of the plant's secondary metabolites and plays an important role in defense mechanisms against insects, herbivores, and pathogens due to their toxic, bitter, and deterrent properties [101]. In taro, the concentration of alkaloids is generally higher in the leaves and peels compared to the corms. While these compounds help protect the plant, they are considered anti-nutritional factors because, when consumed in excess, they may cause bitterness, nausea, vomiting, and gastrointestinal discomfort. Some alkaloids can also interfere with nutrient absorption, and may have mild toxic effects if intake levels are higher [111]. However, not all alkaloids are harmful, in controlled amounts, certain taro alkaloids exhibit pharmacological properties, including antimicrobial, anti-inflammatory, and antioxidant activities, making them potentially beneficial from a nutraceutical perspective. To minimize its adverse effects, processing methods such as boiling, steaming, baking, soaking, and fermentation are effective in reducing alkaloid content, especially in the leaves and peels, thereby improving the safety, palatability, and nutritional value of taro-based foods [112].

5.7 Cyanogenic glycosides

Cyanogenic glycosides are naturally occurring plant compounds capable of releasing hydrogen cyanide when it is hydrolyzed. In taro (*Colocasia esculenta*), these compounds are present only in trace amounts, primarily localized in the leaves, and petioles, while the corms generally contain negligible levels. This distinguishes taro from other root crops like cassava, which contain significantly higher concentrations of cyanogenic glycosides [101].

When consumed in greater quantities, cyanogenic glycosides can release HCN, a toxic compound that may cause dizziness, headache, respiratory distress, or even poisoning in extreme cases. However, the risk from taro is very low due to its naturally low content [113]. Ensure safety, processing techniques like boiling, steaming, baking, soaking, and fermentation are highly effective in reducing or eliminating cyanogenic glycosides. These methods facilitate the breakdown and evaporation of HCN, making taro leaves and other edible parts safe for consumption [114]. Taro contains several antinutritional factors, mainly oxalates, tannins, phytates, protease inhibitors, and saponins. These compounds can impair nutrient absorption and irritate if taro is consumed raw. Traditional processing methods such as boiling, baking, fermenting, soaking, and adding lime or coconut milk in cooking are effective in reducing or neutralizing these ANFs, making taro safe and nutritious for consumption [115]. The antinutritional components in *C. esculenta* and their health impact are given in Fig.2.

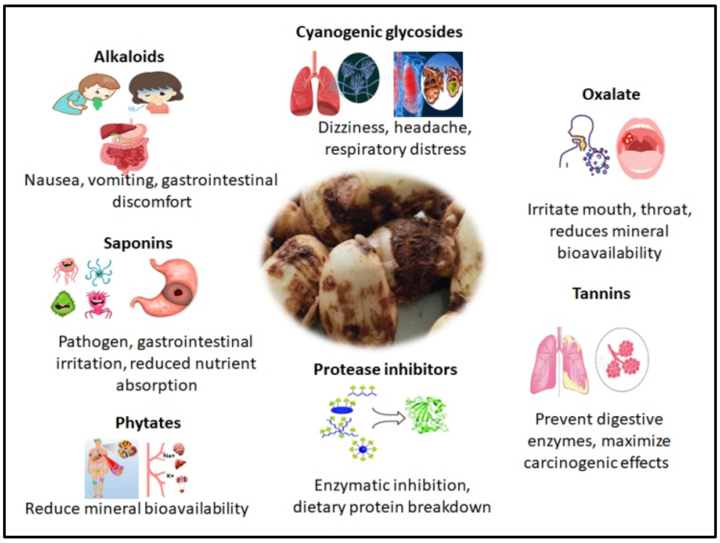


Fig. 2: Antinutritional components in C. esculenta and their health impact

6. Functional food applications

Sensory evaluation showed that bread prepared with a balanced blend of wheat and taro starch received the highest ratings for appearance, flavor, and overall acceptability. However, as the proportion of taro flour increased, the acceptability of taro–wheat bread gradually declined due to the development of a briny taste and unfamiliar flavour [116]. Gluten-free bread (GFB) samples formulated with taro flour exhibited a higher resistant starch content compared to wheat-based bread (WFB). Additionally, increasing the taro flour substitution significantly enhanced the dietary fibre content of the products [117]. Taro starch itself contains approximately 67.7% total starch, with 23.8% amylose, 14.8% swelling power, and 21.9% solubility [118]. Furthermore, a sensory study revealed that cookies prepared using modified taro starch were highly preferred by most panelists, demonstrating taro's potential as a valuable functional ingredient in baked products [119]. The concept of probiotics extends beyond the conventional strains traditionally recognized in food, and medicine. Future candidate probiotics are expected to be isolated from novel sources, potentially exhibiting new functionalities and health-promoting effects that have not yet been fully explored. Probiotics are most commonly delivered through fermented dairy products, pharmaceutical formulations, nutritional supplements and they play a significant role in maintaining human health, particularly by supporting gut micro-biota balance, modulating immune responses, and enhancing nutrient absorption [47]. One of the key challenges in probiotic application is the survivability of microorganisms during food processing, storage, and passage through the harsh gastrointestinal (GI) environment. Address this, probiotic bacteria are often encapsulated in protective matrices that improve their stability and ensure targeted release in the intestine [49]. A variety of biopolymers have been employed for encapsulation, including whey protein isolate, alginate, gelatin, chitosan, and cellulose derivatives, which serve to shield probiotics from heat, oxygen, stomach acidity, and bile salts. Several encapsulation techniques have been developed and widely studied, such as extrusion, spray drying, emulsion-based methods, and coacervation, each offering advantages in terms of scalability, cost, and protective efficiency [120]. From a regulatory perspective, the European Food Safety Authority (EFSA) has maintained, since 2007, a list of microbial species considered safe for human consumption in foods. This is guided by the Qualified Presumption of Safety (QPS) framework, which evaluates the safety of microorganisms not only based on their history of use but also through a rigorous risk assessment process, taking into account potential for pathogenicity, antimicrobial resistance, and toxin production [121]. This ensures that probiotics incorporated into food and health products are both effective and safe for consumers. The QPS approach provides an evidence-based framework for assessing the safety of microorganisms used in food and health applications [122]. Probiotic stability and viability can be improved through microencapsulation, which uses biopolymers like alginate, chitosan, gelatin, cellulose derivatives, or whey protein to protect bioactives from environmental stress, control release, and ensure targeted delivery [6]. This technology is applied in functional foods, beverages, and supplements. Additionally, taro leaves are rich in iron and vitamins A and C but require proper cooking to reduce antinutrients and enhance safety [123].

7. Relevance of food security

Taro is more than just a traditional root crop; it has significant relevance to food and nutritional security, especially in tropical and subtropical regions.

7.1 Contribution to caloric security

Taro is a nutrient-dense root crop known for its high carbohydrate content, which constitutes about 70–80% of its dry matter, primarily in the form of starch. This makes it an excellent staple energy source, comparable to other major carbohydrate-rich crops such as rice, maize, and cassava. One of the distinguishing features of taro starch is its fine granule size and easy digestibility, which makes taro-based foods highly suitable for infants, the elderly, and individuals with digestive disorders, including those with compromised nutrient absorption [2]. In addition to its nutritional value, taro plays a significant role in food security, particularly in regions vulnerable to cereal shortages. Its adaptability to diverse agro-climatic conditions and ability to thrive in marginal soils make taro a reliable buffer crop during periods of limited availability of traditional staples. This versatility highlights its importance as both a dietary energy source and a strategic food resource in ensuring nutritional stability for vulnerable populations [124].

7.2 Nutritional benefits

Taro is a nutrient-rich root crop, that offers several health-promoting benefits due to its diverse composition of dietary fibre, proteins, micronutrients, and hypoallergenic properties. Taro is a nutritious, hypoallergenic food rich in dietary fibre, which supports gut health and lowers chronic disease risk [101]. Its corms provide modest protein (2–3%), while the leaves are protein-rich and abundant in micronutrients like potassium (K), magnesium (Mg), calcium (Ca), iron (Fe), vitamin C, vitamin E, folates, and pro-vitamin A [2]. Being gluten-free and less allergenic than wheat or soya, taro is suitable for sensitive diets and helps combat hidden hunger, making it a valuable functional food for improving health and nutritional security [125].

7.3 Climate and agro-ecological importance

Taro is an adaptable root crop that thrives in diverse agro-ecological conditions, making it highly significant for food security and climate resilience. It grows successfully even in marginal lands, including swampy areas, riverbanks, uplands, and mixed cropping systems, where many conventional crops struggle to survive. Its ability to tolerate a wide range of humid tropical conditions with variable rainfall patterns makes it a reliable crop in regions with unpredictable weather [124]. Certain taro varieties also demonstrate remarkable resilience to drought and saline soil conditions, making the crop especially important in the context of climate change adaptation. In areas frequently affected by cyclones, floods, and prolonged dry spells, taro serves as a dependable food source when staple cereals like rice, wheat, and maize fail [101]. Due to its climatic adaptability and ability to sustain production under challenging environmental conditions, taro plays a vital role in supporting food security, particularly in vulnerable and disaster-prone regions.

7.4 Socioeconomic role

Taro holds significant cultural, nutritional, and economic value across many regions of the world, particularly in Africa, the Pacific Islands, and South Asia, where it is deeply embedded in traditional diets and culinary practices. Beyond its role as a staple food, taro cultivation provides important income-generating opportunities for smallholder farmers and women in rural communities through its contribution to local and regional markets [2]. The crop's value is further enhanced by the fact that not only the corms but also the leaves and petioles are edible, offering an additional source of nutrients while reducing food waste. Furthermore, taro lends itself well to value addition through processing into flour, chips, baby food, and gluten-free bakery products, supporting the growth of agribusinesses and small-scale food industries [1]. Through its cultural significance, nutritional benefits, and economic potential, taro serves as both a traditional food source and a modern agribusiness commodity, making it vital for livelihood improvement and food system sustainability in many regions.

7.5 Food security during crises

Taro has historically served as a famine-reserve crop, providing a reliable source of food during periods of was natural disasters, and widespread crop failures. Its ability to thrive under challenging environmental conditions has made it a critical safety net for communities facing food scarcity [124]. One of taro's key advantages is its extended shelf life when processed into products such as dried chips, flour, and starch, which ensures year-round food availability even in regions prone to seasonal shortages.

Beyond providing energy, taro plays an essential role in nutrition-sensitive agriculture, as it supplies both calories and vital micronutrients like potassium, iron, calcium, and vitamins [1]. By combining nutritional benefits, storage stability, and resilience in times of crisis, taro significantly contributes to household food security and supports the dietary needs of vulnerable populations.

7.6 Challenges affecting food security contribution

Despite its nutritional and economic potential, taro faces several challenges that limit its wider utilization and commercialization. One major concern is the presence of anti-nutritional factors such as oxalates, phytates, tannins, and saponins, which can affect nutrient bioavailability and digestibility. Therefore, proper processing methods, including boiling, steaming, fermenting, or soaking, are essential to ensure food safety and improved palatability [102]. Another limitation is the high perishability of fresh taro corms, which restricts long-term storage and transportation, reducing its market potential. Additionally, pests and diseases, particularly taro leaf blight and infestations by aphids, beetles, and nematodes, significantly impact crop productivity, and yield stability [104]. Furthermore, compared to global staples like maize, rice, and potato, taro remains underutilized and receives limited attention in international food security policies and research investments. This lack of awareness hampers its promotion as a climate-resilient, nutrient-rich crop that could play a greater role in addressing food, and nutritional security worldwide. Taro is a resilient and underutilized crop that supports sustainable food, and nutrition security. Its adaptability, nutrient richness, and economic importance make it a valuable crop for future food systems under climate change.

8. Conclusions

Colocasia esculenta (taro) is a nutritionally rich and agronomically important crop, especially in tropical and subtropical regions. Its starchy corms provide easily digestible carbohydrates, while its nutrient-dense leaves supply proteins, vitamins, minerals, and dietary fibre, contributing to balanced diets, food security, and the prevention of micronutrient deficiencies. Taro contains bioactive compounds with antioxidant, anti-inflammatory, hypoglycemic, and cholesterol-lowering properties, suggesting potential in managing chronic diseases, though more clinical validation is needed. Its starch is valuable in microencapsulation, while its gluten-free nature supports use in baby foods, baked goods, and functional beverages. As a nutrient-rich, affordable, and climate-resilient crop, taro enhances food and nutrition security, supports rural livelihoods, and strengthens sustainable food systems. Biofortification, breeding, agro-processing, and value addition further expand its role in health, industry, and economic development.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

Supporting Information

Not applicable.

9. References

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