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Taro [*Colocasia esculenta* (L.) Schott]: a critical review of its nutritional value and potential for food application

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Abstract

Taro [*Colocasia esculenta* (L.) Schott] is an important food source worldwide, as it contains several macro- and micronutrients, standing out as a source of polysaccharides such as starch, mucilage, minerals, and bioactive compounds, including flavonoids. However, taro also contains antinutrients, such as oxalates, which impede its consumption in the fresh form. This critical review addresses the main studies on the physicochemical and nutritional composition of the tuber in fresh, cooked, or flour form, in addition to various food applications, aiming to improve the scientific and industrial visibility of this tuber.

Keywords: taro; starch; mucilage; oxalate; bioactive compounds; applications.

Practical Application: encourage research, consumption by the population, and safe and sustainable processing of taro.

1 INTRODUCTION

Taro [*Colocasia esculenta* (L.) Schott] is a tuberous plant belonging to the Araceae family, which is a large and ancient family of easily adaptable monocotyledonous plants grown mainly in subtropical and tropical climates (Balbino et al., 2018; Miyasaka et al., 2019; Paula, 2009), representing an important source of food for millions of people (Chaïr et al., 2016). For decades, taro has been considered an important staple food in the Asian region, as well as a source of income, employment generation, and rural poverty reduction (Onwueme, 1999).

Among the starchy roots and tubers (potato, cassava, sweet potato, yam, and taro), taro ranked fifth in the world in terms of production volume, but, in 2017, it represented only 1.2% of the total production of these crops (Puiatti, 2021). According to FAOSTAT (2021), the world taro production in 2019 was approximately 13 million tons, and China (3.8 million tons), Nigeria (2.8 million tons), and Cameroon (1.9 million tons) stood out with the highest production volume, while the largest cultivated areas are located in Africa, Asia, Oceania, and the Americas.

The lower taro production when compared with other tubers is due to the absence of agricultural technology for more efficient production in tropical regions (Puiatti, 2021). There is a lack of investment in field research to improve productivity and stimulate processing into higher value-added products, as observed for potatoes and cassava.

According to FAO data, there is no information on taro production and commercialization in Brazil, probably due to the difficulty of collecting information by the Brazilian agencies, and the different denominations among similar tubers, such as yam and *cará* (Pedralli et al., 2002), which will be addressed in Section 2 of this review.

Puiatti (2021) studied data from Brazilian state research and extension agencies, such as the Capixaba Institute for Research, Technical Assistance and Rural Extension (INCAPER) and the Technical Assistance and Rural Extension Company of Minas Gerais and Rio de Janeiro (EMATER MG and RJ). The author reported that Espírito Santo, Minas Gerais, São Paulo, and Rio de Janeiro states were the largest taro producers in Brazil, with an emphasis on Espírito Santo with the largest cultivated area, production, and productivity. Considering only these four states, Brazil has an estimated annual taro production of 180,504 tons/year. Therefore, Brazil would be ranked 10th in the world taro producer and the largest in the Americas in the FAO list (Puiatti, 2021).

The importance of taro for food security allows for fitting within the Sustainable Development Goals (SDG) defined by the United Nations in the "Agenda 2030," mainly Goal 1 designed to end poverty eradication and zero hunger, and Goal 2 designed for sustainable development, once its cultivation has the potential to contribute to a sustainable chain of income generation and health for Latin America, Africa, and Asia. Therefore, this review aims to present the state-of-the-art research of agro-industrial and development on taro, addressing the main studies on its composition, forms of processing, food applications, and future perspectives.

2 ORIGIN, NOMENCLATURE, AND MORPHOLOGY

Taro is probably one of the oldest plant species used by man as a food crop (Puiatti, 2021) although its origin is not

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yet well-defined. The most probable region of origin is the Indo-Malayan center (composed of the Indian subcontinent, southern China, Indochina, the Philippines, and the western half of Indonesia), which presents a greater genetic diversity (Chaïr et al., 2016; Miyasaka et al., 2019). Taro cultivation spread to the rest of the tropical and subtropical regions of the world along with human migrations (Puiatti, 2021).

The arrival of taro in Brazil has not yet been elucidated by official documents. Chaïr et al. (2016) reported that taro may have arrived from Africa in the 16th century along with African slaves. There is also the possibility that the Portuguese brought taro from India during the period of navigation between the 14th and 15th centuries (Chaïr et al., 2016). Clones of taro from Asia were also brought to Brazil between the 19th and 20th centuries by Chinese and Japanese immigrants, giving rise to the varieties of taro most produced in Brazil today (Puiatti, 2021).

Colocasia esculenta (L.) Schott nomenclature varies around the world, with reports of amandine, dasheen, eddoe, and cocoyam, among others. The name taro is also used to represent several genera of edible tuberous plants, which has confused the classification of taro worldwide (Balbino et al., 2018; Manhivi et al., 2018).

In Brazil, the terminology varies according to the cultivation region. In the South, Southeast, and Center-West, it is known as yam (Balbino et al., 2018) and is confused with "cará" in other regions. This confusion has also been reported in the Brazilian literature due to the genetic similarity between some types of subterranean Dioscorea and *Colocasia* species (Pedralli et al., 2002), which has led to an effort to standardize nomenclatures in Brazil. The International Code of Botanical Nomenclature in 2002 approved at the I National Symposium on Cará and Inhame crops, the fixed denomination of "taro" for *C. esculenta* (Figure 1), while the Dioscoreaceaes commonly called "cará" and "yam" in North/Northeast Brazil have the standardized denomination of "yam," considering "cará" as a yam variety (Pedralli et al., 2002).

Nabeshima et al. (2022) reported the differences between Dioscoreas and Colococasia with images, as well as their applications, pointing out that taro is also confused by the similarity of its leaves with another tuber of the Araceae family, Taioba (*Xanthosoma sagittifolium* Schott). Taioba leaves are distinguished by having a line that circles its entire edge, and lower oxalate contents when compared with taro leaves, which allows its consumption after cooking, unlike taro leaves and stem that should not be consumed.

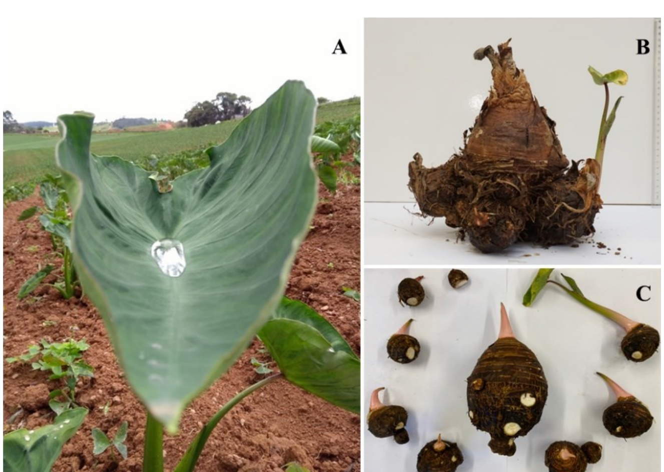

Figure 1. Taro plant in the field and central and lateral parts of the tuber. (A) Taro leaf. (B) Taro as soon as harvested viewed vertically. (C) Deconstructed taro separated into mother and daughter rhizomes.

The aerial part of *Colocasia* consists of a long, fleshy petiole, which supports the large, cordiform limbus (Balbino et al., 2018). Its leaves are heart-shaped with or without lines, spots, and pigments ranging from light green to dark purple depending on the genotype. Its peltate structure at the central point (when the petiole is attached in the middle of the blade) distinguishes it from *X. sagittifolium* (Mitharwal et al., 2022).

Due to the anatomy of the leaves, the plant requires a lot of water during planting (Balbino et al., 2018). However, according to Heredia-Zárate (1995; 1996) cited by Heredia Zárate and Vieira (2004), taro can survive different climatic conditions, including riverbanks or drier soils, which makes taro an ideal species for regions that lack advanced agricultural technologies.

The adult taro plant is characterized by a large underground stem that stores starch and other nutrients and fasciculated roots, with a part called the mother rhizome or corm, which is pear-shaped in the center. This central part gives rise to the daughter rhizomes (Figure 1), also known as secondary corms or cormels, with smaller, short, and thick shapes, which can be oval or elongated depending on the cultivar. Rhizomes are also popularly known as "heads" (central corms) and "fingers" (cormels) (Balbino et al., 2018; Mergedus et al., 2015; Paula, 2009).

Rhizomes can vary in size, shape, and color depending on the genetic structure, age, and interactions between the genotype and the environment (Balbino et al., 2018; Mergedus et al., 2015). Taro has dark brown skin with fine fibers and mucilaginous white or yellow flesh. The average weight of the daughter rhizomes varies between 30 and 250 g, and those weighing between 100 and 200 g are more commercially valued, while the mother rhizomes weighing between 100 and 1,000 g are less attractive to consumers (Paula, 2009; Puiatti, 2002).

Mother rhizomes, mainly those above 1 kg, are often used for animal feed due to their morphological and sensory characteristics (Paula, 2009), which can be a promising alternative for processing them into minimally processed products, cooked dishes, or flours to improve their commercialization.

However, the market's demand for an ideal pattern of tubers contributes to the increase in waste, mainly the lower rhizomes with defects, which were not properly subjected to the removal of roots and soil during cleaning and washing. Young rhizomes that are clean, without defects, and weighing more than 100 g are better placed on the market. In addition to the impacts caused by market preferences, there are also physiological losses (weight reduction and sprouting) due to mechanical damage and those caused by pests and diseases (Balbino et al., 2018).

According to Aboubakar et al. (2008), there is an estimated loss of 30% of tubers during storage. Post-harvest losses of taro have been reported in the literature, as described by Paula (2009) and Yu et al. (2016), who suggested the need for processing to reduce the initial moisture content of taro (~80%) or the water activity to increase shelf life. Therefore, processing techniques for industrial uses of these tubers are needed to extend their shelf life and reduce waste.

3 PHYSICOCHEMICAL COMPOSITION OF TARO IN NATURA, COOKED, AND IN THE FORM OF FLOUR

Table 1 shows the main results of the physicochemical composition of fresh, and cooked taro, and in the form of flour produced by different drying methods, which may vary depending on some factors including genotype, growth conditions, interaction between genotype and the environment, plant age, climate, agronomic factors during cultivation (Lewu et al., 2009; Mwenye et al., 2011), and processing conditions.

Taro stands out for its energy value with a significant content of carbohydrates (among them starch, fiber, and mucilage), ash composed of important minerals, and low lipid contents (Ertop et al., 2019). Only two studies evaluated the difference in composition between daughter rhizomes and mother rhizomes (Heredia Zárate & Vieira, 2004; Paula, 2009). The authors reported a similar behavior for fresh and flour rhizomes, which showed higher ash, protein, and total solids contents in daughter rhizomes, while mother rhizomes had higher moisture, lipids, and fiber contents (Paula, 2009).

Studies on the composition of fresh and cooked taro have been carried out, showing that cooking improves digestibility and palatability, despite the loss of some nutrients in the cooking water (Lewu et al., 2009), which can be beneficial, such as the decrease in antinutrients contents. Although cooking decreases the mineral contents of the tuber, there is an increase in protein and lipid availability (Table 1), which may be related to the destruction of the tannin-protein complex after cooking (Lewu et al., 2009). It is worth emphasizing that even when retaining nutrients, cooking by immersion in a water bath is very important to eliminate oxalates (Section 4).

Taro flours can be produced by different methodologies (Table 1) from fresh, blanched, or cooked rhizomes subjected to drying in a common oven (Lebot et al., 2011) or oven with air circulation (Alflen, 2014; Paula, 2009), electric dehydrator (Markusse et al., 2018), forced air dryer (Arıcı et al., 2016; Calle et al., 2020; Paula, 2009), combined air and oven drying method (Lewu et al. al., 2009), and also freeze-drying (Ertop et al., 2019; Pessôa, 2017; Ribeiro, 2017). All studies have shown the great potential for obtaining taro flour at scales that are adaptable to local production since different processing conditions can result in products suitable for human consumption.

Dilek and Bilgiçli (2021) studied the physicochemical composition of raw and cooked taro flour dried in an oven at 60°C for 24 h and reported that after drying the cooked flour had higher moisture, higher protein content, lower minerals availability, and lower lipid content when compared to the raw flour.

Markusse et al. (2018) evaluated the composition of raw and cooked taro flours in a pressure cooker with subsequent drying in an electric dehydrator at 45°C/48 h and found higher moisture and lipid contents in the cooked flour, which also had lower fiber contents. and total sugars. It was also reported that the total starch content, an important component of the flour, ranged from 47.26 to 66.59%.

In addition to the commonly used drying processes, Ertop et al. (2019) produced raw taro flour by freeze-drying at -65°C/72 h and reported 5.5% moisture and 4.8% protein content in the flour. Freeze-drying is a process known to provide greater conservation of nutrients because it does not use high temperatures, reducing nutrient decomposition reactions, which can be effective in obtaining flours with higher nutritional value. Carbohydrates are considered the most important macronutrients in taro, which are found in the form of starch, dietary fiber, and mucilage, and will be discussed in more detail below.

3.1. Starch

The interest in starch possessing value-added attributes has motivated studies on the physicochemical and technological properties of starch from different plant sources. Specific technological properties play an important role in improving the quality of various food products, and thus studies on novel starch sources that meet the needs of the food industry are required (Kumar & Belur, 2018; Tagliapietra et al., 2021).

Like potatoes, sweet potatoes, and cassava, taro can contain more than 85% of starch of its total dry matter, reaching an extraction yield of about 95% (Hazarika & Sit, 2016; Singla et al., 2020).

Concerning the amylose content of taro starch, Lebot et al. (2011) evaluated 315 genotypes and reported 10–49% amylose, corroborating 17.12% amylose reported by Wang et al. (2018), which was higher than the 4.3% amylose content reported by Sukhija et al. (2016). Tu et al. (2023) evaluated taro starch and found 17.21% amylose, 20.25% resistant starch, 17.59% soluble starch, and 62.16% rapidly digestible starch. According to Martens et al. (2018), the amylose content is directly influenced by its source and extraction method.

Wang et al. (2018) studied the technological and functional properties of starch from different plant sources (arrowroot, cassava, Chinese yam, beans, taro, corn, and potato) and reported that taro showed a swelling power of 9.82 g/g, similar to cassava starch (9.41 g/g) and corn starch (9.23 g/g), and a solubility index of 18.33%, equivalent to the solubility of cassava starch, which was higher when compared with starch from corn (5.02%), potato (12.22%), and arrowroot (17.22 %) and lower than bean starch (40.01%).

The properties of starch with potential application in the food industry should be evaluated by modern methods, such as instrumental analyses that allow analyzing their structure, including X-ray diffraction (XRD) analysis, which shows the crystalline characteristics of the starch granules, classified as amorphous type C, by Wang et al. (2018) and type A by Sukhija et al. (2016), demonstrating no consensus regarding the polymorphism of taro starch.

Table 1. Physical-chemical composition of fresh taro and different forms of processing.

Evaluated form *	Taro processing form	Gran.	Moisture %	Ash %	Protein %	Lipids %	Carb. %	T. D. F. %	C. Fiber %	Total Starch	Reference	Country [a]
Daughter rhizome	7 varieties of dried taro	n.s.	8.7–9.4	4.6–6.7 w.b.	4.6–7.2 w.b.	0.2–0.6 w.b.	67.8–68.4 w.b.	n.s.	9.6–12.6 w.b.	n.s.	Heredia Zárate and Vieira (2004)	Brazil
Mother rhizome	7 varieties of dried taro	n.s.	7.2–9.2	2.7–3.6 w.b.	3.8–7.4 w.b.	0.3–0.4 w.b.	63.8–69.6 w.b.	n.s.	10.9–19.4 w.b.	n.s.		
Flour	6 varieties of mother and daughter rhizomes, sliced and dried in air convection at 50°C	500 µm	8.2–9.6	1.3–5.5 u.b.	2.9–4.9 u.b.	0.3–0.5 u.b.	90.5–95.5 u.b.	n.s.	n.s.	n.s.	Aboubakar et al. (2008)	Cameroon
Flour	0.5-cm slices cooked in boiling water in groups (0, 20, 45, and 90 min) and dried at different temperatures (50, 60, 70, and 80°C) in an air convection oven	0.5 mm	2.8–9.9	4.4 d.b.	4.8 d.b.	0.54 d.b.	33.4 d.b. available carbs	n.s.	0.4 d.b.	n.s.	Njintang and Mbofung (2006)	Cameroon
Flour	Peeled tubers, cut into 2–3-cm-thick pieces, dried in a convection air dehydrator at 45°C/24 h	60 *mesh*	10.42	2.61 d.b.	6.18 d.b.	0.99 d.b.	n.s.	8.24 d.b.	n.s.	67.57 d.b.	Pérez et al. (2007)	Venezuela
Fresh daughter rhizome	Dried in an oven with air circulation at 70°C until constant weight	n.s.	78.4	1.1 w.b.	7.1 w.b.	0.3 w.b.	9.8 w.b.	n.s.	3.0 w.b.	n.s.	Paula (2009)	Brazil
Fresh mother rhizome	Dried in an oven with air circulation at 70°C until constant weight	n.s.	84.1	0.4 w.b.	5.7 w.b.	0.5 w.b.	3.2 w.b.	n.s.	5.8 w.b.	n.s.		
Flour daughter rhizome	Boiling water/5 min. Forced air dryer at 60º/12 h	n.s.	5.9	3.7 w.b.	6.5 w.b.	0.8 w.b.	78.1 w.b.	n.s.	4.8 w.b.	n.s.		
Flour mother rhizome	Boiling water/6 min. Forced air dryer at 60º/12 h	n.s.	6.9	2.1 w.b.	4.9 w.b.	0.9 w.b.	79.8 u.b.	n.s.	5.2 w.b.	n.s.		
Raw rhizomes	7 accessions dried in air and in an oven at 60°C until constant weight	n.s.	69.6–78.6	4.0–7.8 d.b.	6.4–17.0 d.b.	0.7–2.4 d.b.	67.8–82.5 d.b.	n.s.	2.6–5.2 d.b.	n.s.	Lewu et al. (2009)	South Africa
Cooked rhizomes	7 accessions cooked in water at 100°C/20 min, air-dried, and in an oven at 60°C until constant weight	n.s.	69.7–79.40	2.9–4.5 d.b.	7.8–16.2 d.b.	0.02–2.7 d.b.	72.3–85.3 d.b.	n.s.	1.7–4.0 d.b.	n.s.		
Rhizomes	Peeled, sliced, and oven-dried rhizomes at 60°C/48 h	n.s.	64.1	n.s.	4.6 d.b.	n.s.	n.s.	n.s.	n.s.	78.8 d.b.	Lebot et al. (2011)	França
Flour	Rhizomes washed, sliced, bleached (at 90°C with distilled water for 2 min), dried at 50°C in a hot air dryer/4 h, and ground	0.26 mm	10.2 w.b.	4.1 w.b.	12.2 w.b.	0.5 w.b.	72.1 w.b.	n.s.	0.7 w.b.	67.4 d.b.	Kaushal et al. (2012)	India
Flour	2-cm-thick slices were cooked in boiling water/5 min, then cut into 0.5 cm, and dried in an oven with renewal and air circulation at 60°C/12–21 h	n.s.	7.4	4.3 w.b.	10.2 w.b.	0.5 w.b.	72.4 w.b.	n.s.	4.9 w.b.	n.s.	Alflen (2014)	Brazil

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Table 1. Continuation

Evaluated form *	Taro processing form	Gran.	Moisture %	Ash %	Protein %	Lipids %	Carb. %	T. D. F. %	C. Fiber %	Total Starch	Reference	Country [a]
Rhizomes	Peeled and sliced rhizomes were boiled in water for 10–15 min and mashed for analysis	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	14.9 w.b.	Simsek and El (2015)	Türkiye
Rhizomes	The peeled and sliced rhizomes were microwaved for 3.5 min, chopped, and sent for analysis	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	18.0 w.b.		
Flour	Grated slices, placed on trays (0.4 cm thick), dried at different temperatures (40, 50, and 60°C) and air speeds (0.5, 1.25, and 2.0 m/s)/7–10 h	n.s.	9.0–12.2	1.6–3.1 u.b.	14.7–16.2 u.b.	n.s.	n.s.	12.8–14.0 u.b.	n.s.	58.5–68.8 u.b.	Arici et al. (2016)	Türkiye
Fresh taros	n.s.	n.s.	82.8	0.7 w.b.	2.1 w.b.	0.09 w.b.	n.s.	n.s.	1.3 w.b.	13.4 w.b.	Yu et al. (2016)	China
Lyophilized flour	Chips of 1–3 cm dipped in water at 100°C/1 min, frozen, and lyophilized at –60º until constant weight	35 *mesh* 0.5mm	9.4	3.9 w.b.	6.7 w.b.	0.4 w.b.	79.3 w.b.	n.s.	n.s.	n.s.	Pessôa (2017)	Brazil
Flour	Chips of 1–3 cm dipped in water at 100°C/1 min, frozen, and lyophilized at –60º until constant weight	0.5 mm	9.48 w.b.	3.97 w.b.	6.79 w.b.	0.43 w.b.	79.33 w.b.	n.s.	n.s.	n.s.	Ribeiro (2017)	Brazil
Fresh rhizome	Peeled rhizomes, weighed, cut into flakes, dried at 70°C, and ground	100 *mesh*	68.9–81.0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	51.2 to 64.1 d.b.	Zhu et al. (2018)	China
Raw flour	n.s.	800 µm	9.5	4.3 d.b.	4.3 d.b.	0.1 d.b.	n.s.	n.s.	1.7 d.b.	49.6 d.b.	Markusse et al. (2018)	Cameroon
Cooked flour	Rhizomes cooked in a pressure cooker/40 min, cut into 0.5-cm chips, and dried in an electric dehydrator at 45°C/48 h	800 µm	10.6	4.2 d.b.	4.3 d.b.	0.3 d.b.	n.s.	n.s.	1.5 d.b.	47.26 d.b.		
Flour	Crushed rhizomes to obtain a viscous mass; dried in an oven until complete dehydration at 60°C	n.s.	9.7	3.1 d.b.	5.4 d.b.	0.1 d.b.	87.7 d.b.	n.s.	3.5	53.25 d.b.	Sá et al. (2018)	Brazil
Lyophilized flour	Tubers washed, cut, lyophilized at -65°C/72 h, and ground	500 µm	5.5	5.9 u.b.	4.8 u.b.	0.9 u.b.	72.7 u.b.	n.s.	n.s.	n.s.	Ertop et al. (2019)	Türkiye
Flour	1-cm slices dried in a forced convection dryer at 45°C/24 h	n.s.	6.3	5.0 d.b.	8.2 d.b.	0.5 d.b.	75.4 d.b.	n.s.	4.3	n.s.	Calle et al. (2020)	Spain
Flour	2–3-mm slices. Boiling water/2 min, then dried in an oven at 60°C	150 µm	5.9	2.8 d.b.	9.1 d.b.	0.6 d.b.	n.s.	n.s.	n.s.	n.s.	Cankurtaran et al. (2020)	Türkiye
Flour	1-cm slices dried in a forced convection dryer at 45°C/24 h	0.300 mm	6.5	5.6 d.b.	10.3 d.b.	1.0 d.b.	n.s.	n.s.	4.3 d.b.	53.07 d.b.	Calle et al. (2021)	Spain
Raw flour	Dried slices in the oven at 60º/24 h	150 *mesh*	4.5	6.5 d.b.	8.0 d.b.	0.8 d.b.	n.s.	n.s.	n.s.	n.s.	Dilek and Bilgiçli (2021)	Türkiye
Cooked flour	Slices cooked in boiling water with lemon juice/30 min and dried in the oven at 60º/24 h	150 *mesh*	7.5	5.2 d.b.	8.4 d.b.	0.7 d.b.	n.s.	n.s.	n.s.	n.s.		
Flour	Tubers peeled, sliced, and dried in an oven at 40°C/24 h	100 *mesh*	9.1 d.b.	1.0 d.b.	7.7 d.b.	0.3 d.b.	n.s.	2.1 d.b.	n.s.	79.13 d.b.	Tu et al. (2023)	China

*Assessed form described by the author; *Gran.*: granulometry; *Carb.*: carbohydrates; TDF: total dietary fiber; C. Fiber: crude fiber; [a]Corresponding author's country of origin; d.b.: dry base; n.s.: not specified; u.b.: unspecified dry or wet basis; w.b.: wet base.

Scanning electron microscopy (SEM) of taro starch granules showed compacted agglomerates with irregular or cubic and polygonal forms with a diameter of 1–2 μm, smaller in size than arrowroot (4–13 μm), cassava (5–18 μm), Chinese yam (8–25 μm), beans (5–15 μm), maize (5–20 μm), and potato (10–50 μm) (Wang et al., 2018). Small starch granules are more digestible due to their larger surface area and higher digestion by enzymes (Sukhija et al., 2016).

As shown in Figure 2, taro starch can have different sizes and shapes, with rounded, polyhedral granules and agglomerated pockets. In general, there is a lack of uniformity in the physicochemical characteristics and properties of taro starch, and thus instrumental analyses such as XRD and SEM may be important to explain the behavior of starch during the gelatinization and retrogradation stages.

3.2 Fibers

Most of the studies in Table 1 determined only the crude fiber content in taro rhizomes and their flours, which varied from study to study and was different in the mother rhizome and daughter rhizome. The dry daughter rhizomes presented 9.6–12.6% of fibers, while the mother rhizomes presented higher values between 10.9 and 19.4%. The higher crude fiber content of mother rhizomes can be advantageous as fiber consumption is related to health benefits (Paula, 2009) and can be an incentive to consume mother rhizomes that are undervalued by the market. However, this determination may be underestimated, as the enzymatic-gravimetric method for determining dietary fiber is the most suitable for human consumption foods, which have higher values than crude fiber.

Only three studies (Table 1) determined the total dietary fiber (TDF) of taro roots and/or its flour. Arıcı et al. (2016) evaluated the composition of flours obtained by different drying temperatures and air speeds and reported from 12.8 to 14.0% of TDF. Pérez et al. (2007) reported 8.24% TDF for taro flour, corresponding to 3.03% soluble fiber and 5.76% insoluble fiber. The presence of soluble and insoluble dietary fibers can improve intestinal transit and help in the prevention of colorectal cancer (Pereira et al., 2021).

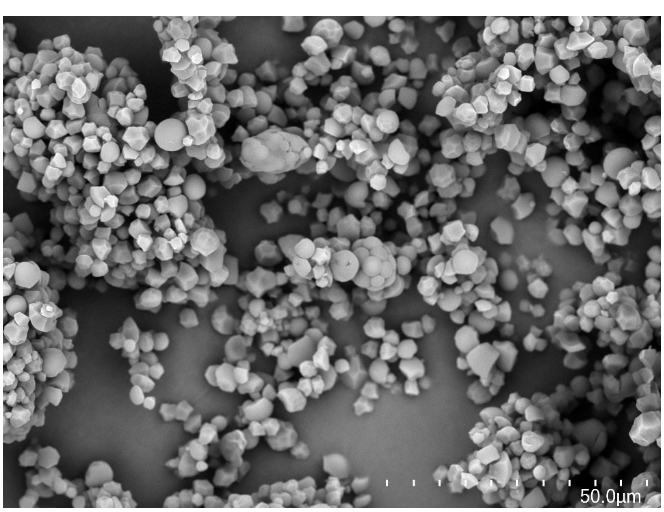

Figure 2. Taro starch by scanning electron microscopy.

Despite the few studies on the fiber from taro roots, it is extremely important to explore its health benefits as well as its composition because taro fiber contains mucilage, which is an important polysaccharide that will be discussed below.

3.2.1 Mucilage

Araceae plants, such as *Colocascia esculenta*, have characteristic rhizomes, rich in polysaccharides, including mucilage (Mijinyawa et al., 2018), which is considered a potential mucilage source with approximately 3–19% mucilage (Njintang et al., 2014). Manhivi et al. (2018) studied the composition of taro mucilage and obtained an extraction yield of 4.4%. The mucilage was composed of 68.5% of total sugars, 6.5% of proteins, and 24.01 mg/g of bound phenolics, in addition to the presence of monosaccharides, corresponding to 28.2% of glucose, 36.7% of galactose, 4.7% of arabinose, 2.1% of xylose, and 11.8% of mannose.

Mucilage is part of the fiber fraction of these tubers, which is a gummy substance consisting of a liquid and lyophilic colloidal system, that is, a hydrogel consisting of complex polymers, composed mainly of water, pectin, sugars, some glycoproteins, and organic acids (Andrade et al., 2020; Sepúlveda et al., 2007; Tavares et al., 2011). According to Manhivi et al. (2018), mucilage has different polymeric units and multiple functionalities, such as excellent viscosity, water retention capacity, and antimicrobial activity, and therefore it can be used as a stabilizer and thickener in the food and pharmaceutical industries (Biswas et al., 2023).

It is believed that taro mucilage has a high emulsifying capacity due to its protein fraction, composed mainly of the amino acids leucine, isoleucine, and tryptophan, with completely or partially hydrophobic radicals (Andrade et al., 2015; Biswas et al., 2023; Tosif et al., 2022). It is hypothesized that the AGP glycoprotein (arabinogalactan protein) is primarily responsible for the emulsifying property of taro mucilage, while the hydrophobic part is related to the protein fraction containing apolar radicals, and the hydrophilic part is related to carbohydrates (Andrade et al., 2015; Biswas et al., 2023; Tosif et al., 2022) and has a high capacity to bind water due to the high content of hydroxyl groups (Mijinyawa et al., 2018).

There is a growing interest in the use of hydrocolloids in the food industry, mainly plant viscous polysaccharides, due to their biocompatibility, safety, and ease of commercialization of products modified with natural biopolymers (Manhivi et al., 2018; Saha & Bhattacharya, 2010). In this sense, taro mucilage attracts attention because it is a natural product and easy to extract, presenting high yield and low production cost when compared with some synthetic additives (Andrade et al., 2015).

The use of taro mucilage in powdered form is the most practical use in industrial processes. Tavares et al. (2011) investigated taro mucilage subjected to freeze-drying aimed to maintain its physicochemical characteristics. Mucilage is considered thermally stable and can be used as a natural emulsifier in bakery products and low-viscosity products, such as beverages, jellies, and sweets, replacing gum Arabic (Andrade et al., 2015; Manhivi et al., 2018).

The bioactive properties of dehydrated taro mucilage were also studied. Chukwuma et al. (2018) concluded that mucilage has anti-glycemic and anti-lipidemic potential, suggesting its use as a dietary supplement for the control of oxidative stress, hyperglycemia, overweight, and obesity.

3.3 Micronutrients

Table 2 shows the main studies about the mineral composition of fresh taro rhizomes and taro flour produced by different drying methods. Studies have shown that the most abundant minerals are potassium, magnesium, phosphorus, and calcium, in addition to significant amounts of zinc (Lewu et al., 2010; Mwenye et al., 2011). The nutritional composition of taro can vary due to several factors, including genotype, growing conditions, the interaction between genotype and environment (Mwenye et al., 2011), and plant age (Mergedus et al., 2015).

It is known that salts regulate the body's acid-base balance and the intake of foods that are rich in micronutrients helps to improve the immune system, aiding in the absorption and digestion of nutrients (Njoku & Ohia, 2007). High potassium intake has a preventive role against hypertension, stroke, heart disease, kidney disease, and osteoporosis (Christian et al., 2004).

Drying conditions such as temperature and air velocity affect the composition of nutrients and micronutrients in the flour, and thus the manufacturing process should be adjusted to maintain the quality characteristics and nutritional value (Arıcı et al., 2016). In addition, the recipients used during the process must be inert to prevent reactions with minerals causing incrustations, avoiding the use of materials other than stainless steel.

When comparing cooked and raw flours, a reduction in calcium, iron, potassium, magnesium, phosphorus, and zinc was observed. However, the cooked flours maintained a high content of these minerals, with values of 2,089.80, 257.3, 276.3, 129.0, and 1.9 mg/100 g for K, Ca, P, Mg, and Zn, respectively (Dilek & Bilgiçli, 2021) (Table 2). Although the cooking process affects the amount of minerals that migrate into the water, it still preserves a large amount of minerals.

Thus, based on the amounts of minerals quantified by Dilek and Bilgiçli (2021) in cooked flour (Table 2), and compared with the recommended daily intake (RDI) for Brazilians by the Resolution of the Collegiate Board of Directors—RDC 269 of the National Health Surveillance Agency, ANVISA (Brasil, 2005), the consumption of a portion of taro flour (50 g) corresponds to an RDI (adults) of 25% calcium, 19% phosphorus, 24% magnesium, and 13% zinc. The same analysis can be done considering the WHO recommendation (2012) on potassium intake, as a portion of flour corresponds to 29% of the RDI. According to Normative Instruction—IN 75 of ANVISA (Brasil, 2020), cooked taro flour can be considered a source of magnesium and phosphorus and has high contents of potassium and calcium.

Mergedus et al. (2015) evaluated mineral distribution in different portions of the taro rhizome (upper, center, lower, and marginal) and reported that the upper portion contained high levels of P, Mg, Zn, Fe, Mn, Cu, and Cd. The center exhibited the highest levels of K, P, Mg, Zn, Fe, Cu, and Cd, while Ca was concentrated in the lower side portions. Although deep peeling can impact the mineral concentrations in the upper, lower, and marginal portions of the rhizome, it did not significantly affect the daily intake of K, P, Mg, Zn, Fe, and Cu and is important for removing the oxalate that is more concentrated on the side of the rhizome (Section 4).

Knowledge about the composition of the different portions of the rhizome is important in several areas, including the taro chip industry, which should standardize the cutting of rhizomes to obtain slices that are more nutritionally representative and safer for consumption as the undesirable parts can be eliminated (Mergedus et al., 2015).

3.5 Bioactive compounds

Taro roots have been used since antiquity to treat diseases, arousing interest in the scientific community, which has identified several bioactive compounds with health benefits, in addition to the antioxidant, anticancer, antidiabetic, immunomodulatory, and antimicrobial activities (Aditika et al., 2022).

These benefits are mainly due to the presence of polyphenols, proteins, mucilage, polysaccharides, lipids, and non-polyphenol antioxidants. Several molecules with bioactive activities have already been identified in taro roots, indicating that its biological effect is synergistic with multiple compounds, identified even in cooked taro and after consumption (Pereira et al., 2021).

Phenolic compounds, including flavonoids (such as anthocyanins and flavonols) and phenolic acids (such as cinnamic acid), are important polyphenolic plant metabolites. It has been reported that the consumption of phenolic compounds such as anthocyanins is associated with several health benefits, arousing research interest in these compounds from different plant sources (Champagne et al., 2011).

Colocasia esculenta showed an abundant presence of flavonol glycosides, with a range of 20 compounds, with one of them at a high concentration of 88.678 mg QGE/100 g fresh weight (QCE = quercitin-3-glycoside equivalent). Another group of flavonoids, flavanols, which includes catechin and epicatechin, were also identified up to 0.233 and 0.493 mg/100 g, respectively. However, a low total anthocyanins content was identified, corresponding to 3.32 mg CGE/100 g fresh weight (CGE = cyanidin-3-glucoside equivalent) (Champagne et al., 2011).

Anthocyanins and carotenoids are the main compounds responsible for the colors of taro rhizomes, which can be white, yellow, green, pink, red, light purple, and dark purple. The variety of carotenoids includes phytopigments such as lutein, zeaxanthin, phytoene, and carotene (Champagne et al., 2013).

Taro flour showed a total phenolics content of 14.17 mg GAE/100 g (gallic acid equivalent/g dry sample), total flavonoids of 10.78 mg RE/100 g (rutin equivalent/g dry sample), DPPH radical scavenging activity of 21.80%, ferric reducing antioxidant power (FRAP) of 63.78 mg BHT Eq/100 g, and total antioxidant activity of 63.47 mg AAE/100 g (ascorbic acid equivalents/g extract). Liquid chromatography-mass spectrometry revealed that

Table 2. Mineral composition (mg/100 g) of fresh and dried taro by different processing methods.

Evaluated form *	Taro processing form	Ca	Cu	Fe	K	Mg	Na	Mn	P	Zn	Reference	Country
Rhizomes	Peeled, grated, air-dried, and ground rhizomes	132.4 d.b.	1.04 d.b.	8.66 d.b.	4276.0 d.b.	415.0 d.b.	1521.3 d.b.	0.13 d.b.	72.21 d.b.	2.63 d.b.	Njoku and Ohia (2007)	Nigeria
Flour	6 varieties of mother and daughter rhizomes, sliced and dried in air convection at 50°C	25.4–192.0 u.b.	0.04–0.18 u.b. [a]	0.2–4.1 u.b. [a]	3.5–59.7 u.b.	32.9–382.0 u.b.	< 0.5–5.6 u.b.	0.64–13.0 u.b.[a]	1.3–1.9 u.b.	0.04–4.2 u.b.	Aboubakar et al. (2008)	Cameroon
Raw rhizome	7 accessions of air-dried and oven-dried tubers at 60°C to constant weight	27.6–36.5 d.b.	0.2–1.3 d.b.	n.s.	315.6–783.7 d.b.	297.7–359.1 d.b.	41.5–20.9 d.b.	n.s. d.b.	8.7–20.8 d.b.	10.8–71.1 d.b.	Lewu et al. (2010)	South Africa
Cooked rhizomes	7 accessions of tubers cooked in water at 100°C/20 min, dried in air, and in an oven at 60°C until constant weight	16.3–27.8 d.b.	0.2–1.1 d.b.	n.s.	161.9–285.0 d.b.	289.3–380.3 d.b.	61.4–117.1 d.b.	n.s.	6.4–13.6 d.b.	9.1–65.7 d.b.		
Rhizomes	7 rhizomes without skin and bark, sectioned, sliced, and lyophilized/2 days and stored at -75°C	8.6 d.b. [b]	0.6 d.b. [b]	1.1 d.b. [b]	2240.0 d.b. [c]	100.0 d.b. [b]	n.s.	1.1 d.b. [b]	139.0 d.b. [c]	5.1 d.b. [b]	Mergedus et al. (2015)	Slovenia
Flour	Grated slices, placed on trays (0.4 cm thick), dried at different temperatures (40, 50, and 60°C) and air speeds (0.5, 1.25, and 2.0 m/s)/7–10 h	n.s.	1.1–1.3 u.b. [a]	1.9–2.5 u.b. [a]	28.4–39.5 u.b.	129.0–163.0 u.b.	n.s.	0.2–0.5 u.b. [a]	n.s.	1.8–2.9 u.b. [a]	Arıcı et al. (2016)	Türkiye
Flour	2–3-mm slices. Boiling water/2 min, then dried in an oven at 60°C	324.8 d.b.	0.9 d.b.	1.8 d.b.	1114.9 d.b.	137.8 d.b.	n.s.	0.3 d.b.	250.4 d.b.	2.6 d.b.	Cankurtaran et al. (2020)	Türkiye
Raw flour	Dried slices in the oven at 60º/24 h	362.1 d.b.	n.s.	2.0 d.b.	2275.4 d.b.	175.2 d.b.	n.s.	n.s.	284.6 d.b.	2.8 d.b.	Dilek and Bilgiçli (2021)	Türkiye
Cooked flour	Slices cooked in boiling water with lemon juice/30 min and dried in the oven at 60º/24 h	257.3 d.b.	n.s.	1.7 d.b.	2089.8 d.b.	129.0 d.b.	n.s.	n.s.	276.3 d.b.	1.9 d.b.		

*Assessed form described by the author; Ca: calcium; Cu: copper; Fe: iron; K: potassium; Mg: magnesium; Na: sodium; Mn: manganese; P: phosphorus; Zn: zinc; d.b.: dry base; n.s.: not specified; u.b.: unspecified dry or wet basis; w.b.: wet base. [a]Results expressed by the author in ppm and converted into mg/100 g. [b]Results expressed by the author in mg/kg and converted into mg/100 g. [c]Results expressed by the author in % and converted into mg/100 g.

caffeic acid, gallic acid, chlorogenic acid, catechin, epicatechin 3, and flavonols were the major compounds present in the taro flour extract (Kumar & Sharma, 2017).

According to the literature, *C. esculenta* is a source of bioactive compounds even after being processed into flour and can be used as a functional food and nutraceutical, with potential health benefits, such as improvement in oxidative stress, diabetes, and cardiovascular diseases (Adefegha, 2018; Kumar & Sharma, 2017).

4 ANTINUTRIENTS

Taro roots contain significant amounts of antinutrients, mainly calcium oxalate (265.0–552.5 mg/100 g), tannins (495.0–1,518.8 mg/100 g), and phytates (36.8–70.7 mg/100 g), as well as alkaloids, steroids, and cyanogenic glycosides (Lewu et al., 2010). The presence of antinutrients impedes the consumption of taro in natura, requiring proper processing aimed at eliminating these compounds (Kristl et al., 2021; Lewu et al., 2010; Moro et al., 2009). Table 3 presents the concentrations of the main antinutrients (calcium oxalate, tannins, and phytates) found in fresh and cooked taro rhizomes and raw and cooked flour.

The micronutrients concentration in taro roots is unfavorably impacted by the presence of needle-shaped oxalate crystals (raphides), which cause sour taste (very acidic and unpleasant), acute irritation, swelling, and blisters in the mucous membranes of the mouth and throat, which are characteristics that limit the consumption of fresh rhizomes (Kristl et al., 2021; Lewu et al., 2010; Moro et al., 2009).

Kristl et al. (2021) presented an extensive study of taro oxalates, with the following results:

- Water-soluble and insoluble oxalate contents in taro rhizomes are up to 10 times higher in the peels when compared with the pulp, and thus the peels are removed for consumption, which significantly reduces the oxalate contents. However, there are also reports of oxalate concentrations in different portions of the corms, with a high accumulation in the margins between 2 and 3 mm;
- Different taro cultivars showed insoluble and soluble oxalate contents ranging from 33 to 120 and 47 to 185 mg/100 g, respectively. The authors concluded that the oxalate contents can vary according to the portion of the rhizome and cultivar. Moreover, water-soluble oxalates are found in a higher proportion in the center and lower portion of the

Table 3. Antinutrient composition of different forms of taro processing.

Evaluated form*	Taro processing form	Antinutrient (mg/100 g)			Reference	Country
		Calcium oxalate	Tannins	Phytates		
Raw rhizome	n.s.	73.2–171.4 f.w.	n.s.	n.s.	Savage and Catherwood (2007)	New Zealand
Cooked rhizomes	In 4 varieties of taros, 5 mm of the outer skin was removed, sliced into 20-mm^3 cubes, and boiled in water or roasted at 180°C/40 min.	22.2–50.6 f.w.	n.s.	n.s.		
Roasted rhizome		171.6–328.3 f.w.	n.s.	n.s.		
Raw rhizome	n.s.	294–694 d.b.	n.s.	n.s.	Savage and Mårtensson (2010)	New Zealand
Cooked rhizomes	In 4 varieties of taros, 5 mm of the outer skin was removed, sliced into 20-mm^3 cubes, and boiled in water or roasted at 180°C/40 min.	146–293 d.b.	n.s.	n.s.		
Roasted rhizome		321–705 d.b.	n.s.	n.s.		
Raw rhizome	7 accessions of air-dried and oven-dried tubers at 60°C to constant weight	265.2–552.5 d.b.	495.0–1518.8 d.b.	36.8–70.7 d.b.	Lewu et al. (2010)	South Africa
Cooked rhizomes	7 accessions of tubers cooked in water at 100°C/20 min, dried in air, and in an oven at 60°C until constant weight	140.2–411.8 d.b.	239.6–841.7 d.b.	23.8–47.8 d.b.		
Flour	Rhizomes were washed, sliced, bleached (at 90°C with distilled water for 2 min), dried at 50°C in a hot air dryer/4 h, and ground	23.31 w.b.	n.s.	n.s.	Kaushal et al. (2012)	India
Raw flour	n.s.	3.67 d.b.	n.s.	n.s.	Markusse et al. (2018)	Cameroon
Cooked flour	Rhizomes were cooked in a pressure cooker for 40 min, cut into 0.5-cm chips, and dried in an electric dehydrator at 45°C/48 h	0.82 d.b.	n.s.	n.s.		
Flour	Seven peeled cultivars, divided into 4 parts (lower, upper, marginal, and central), sliced, lyophilized, ground, and packed in cryogenic flasks at -70°C	84.1–234.0 d.b.	–	–	Kristl et al. (2021)	Slovenia
Flour	1-cm slices were soaked in water with sodium metabisulfite solution/30 min and dehydrated in a forced convection dryer at 45°C/24 h	320.0 d.b. [a]	n.s.	n.s.	Calle et al. (2021)	Spain

*Assessed form described by the author; d.b.: dry base; f.w.: fresh weight; n.s.: not specified; [a]Results expressed by the author in % and converted into mg/100 g.

rhizomes, while insoluble oxalates are present in a higher proportion in the margins of the rhizomes;

- An important information for the processing of these tubers is the possibility of reducing the insoluble oxalate content by approximately 50% with the removal of the peel to a depth margin of about 1 cm. A lower total oxalate concentration was also observed in tubers harvested 8 months after planting, which implies the quality of the rhizomes that should have their maturity assessed before harvesting.

Markusse et al. (2018) evaluated the properties of raw and cooked taro flour and reported low oxalate contents in both flours with a significant reduction of oxalates after cooking. Immersion in boiling water can promote leaching (solubilization and consequent removal) of soluble oxalates (Huang et al., 2006).

The presence of oxalate is a challenge for the extraction of high-quality starch from taro roots. Therefore, an enzymatic treatment with oxalate oxidase can be used to reduce the oxalate content in starch extracted from taro flour, resulting in a 97% reduction in total oxalate content (Kumar & Belur, 2018).

Lewu et al. (2010) reported that cooking can reduce tannins and phytate contents in taro rhizomes. Tannins form complexes with proteins reducing digestibility and palatability, while phytates (inositol hexaphosphate esters) act in the gastrointestinal tract, binding to minerals and making them unavailable for absorption, significantly decreasing calcium bioavailability, and forming calcium-phytate complexes that inhibit Fe and Zn absorption. Even after the reduction of nutrients and micronutrients during cooking, it is worth noting that the practice is necessary to reduce anti-nutritional factors and produce safe food for consumption (Lewu et al., 2010).

Cooking in boiling water for 40 min reduced gastric soluble oxalates by up to 74.1% and intestinal soluble oxalates by up to 81.7%. In contrast, rhizomes roasted at 180°C for 40 min showed similar oxalate concentrations to the raw tuber, demonstrating that roasting alone does not remove oxalate compounds. In addition, roasted rhizomes should be avoided, especially by people at risk of kidney stone formation, due to their high levels of intestinal soluble oxalates (Savage & Catherwood, 2007).

4 FOOD APPLICATIONS

Given the importance of adequate processing of taro rhizomes to promote a safe food as an alternative for consumption, Table 4 shows the flours used for incorporation into different products such as cookies with partial substitution of wheat flour (Alflen, 2014), gluten-free cookies, and bread (Calle et al., 2020; Dilek & Bilgiçli, 2021), fermented preparation, soup formulations (Cankurtaran et al., 2020; Njintang et al., 2007), composite flour for infant porridge (André et al., 2009), noodles (Rosario et al., 1999), and ice cream (Penso et al., 2016).

Raw and cooked taro flours have been studied for different food applications, due to their technological and functional properties, such as small particle size (1–5 μm) and high mucilage content, indicated as an alternative to replace corn or wheat flour (Kaushal et al., 2015). Due to the growing demand for gluten-free and/or reduced gluten products (Aditika et al., 2022), taro flours have the potential for the production of nutritionally enriched cookies, gluten-free cookies, and bread, composite flours for infant feeding, pasta production, soups, noodles, and as a potential hydrocolloid ingredient for the manufacture of pudding.

Taro bagasse flour has also been reported as a fat substitute, and its extract is used to replace cow's milk in the manufacture of ice cream without compromising its technological and rheological properties (Penso et al., 2016).

Some studies have also evaluated the application of extruded taro flour and the impact of the process on their technological characteristics. Extrusion cooking can convert a perishable food matrix into a non-perishable food while maintaining its nutritional characteristics, and thus it is a smart choice for processing taro rhizomes, which have limited consumption and present many post-harvest losses due to their high moisture content (Rodríguez-Miranda et al., 2011). In this sense, some authors have studied the extrusion of taro flour for the production of snacks and composite food for infant feeding (Maga et al., 1993; Onwulata & Konstance, 2002; Rodríguez-Miranda et al., 2011), as elucidated in Table 4.

In addition to the application of taro flour, taro starch also has the potential for use in food processing due to its technological characteristics, including small particle size, low amylose content, high swelling capacity, and good water and oil retention stability. These properties make taro starch viable for food production such as noodles, bread, infant formulas, fillers (Singla et al., 2020; Wang et al., 2018), edible films (Mohite & Chandel, 2020), and flavor encapsulation (Sukhija et al., 2016), in addition to the use in food formulations that require starch stability at low temperature (Kaur et al., 2013). Taro starch can also be applied in cosmetic formulations, such as aerosol products and facial powders (Nand et al., 2008).

5 FUTURE PERSPECTIVES

The enhancement of the taro crop as a staple food and the reduction of post-harvest losses are the biggest challenges as it is still an underexploited tuber that lacks studies and development of novel processing technologies.

It is important to consider that the mother rhizome, as well as the daughter rhizome, can be consumed and used by the industry, no longer being discarded by the market flow. Protocols are needed for efficient processing in different drying processes, focused on the entire production chain from the rural producer to the food industry. Therefore, processes that eliminate calcium oxalate from the products promoting a safe food for consumption are required. Wild cassava stands out as an example of success, which is safe for consumption after the removal of cyanogenic compounds, followed by processing into flour or used for starch extraction.

The use of taro flour or extraction of taro mucilage and starch is the best alternative to expand the consumption of taro

Table 4. Food applications of taro.

Product	Insertion form of taro	Other ingredients	Main results	Reference	Country
Extruded snacks	Flour	n.s.	Optimum expansion properties were found in extrusion at 120°C. Potential to produce snacks. Negatively affected taste.	Maga et al. (1993)	United States of America
Pasta	Flour	Red wheat flour, eggs, and water	↑ viscosity and cooked weight. Darker color. ↓ descriptors of aroma, flavor, and general acceptance of the product.	Rosario et al. (1999)	Mexico
Extruded infant weaning food	Flour	Whey protein concentrate, whey protein isolate, or lactalbumin	Good expansion, grinding, and easy rehydration to form a paste with good consistency.	Onwulata and Konstance (2002)	United States of America
Achu [a]	Cooked flour	Water	Hardness, relaxation strength, and adhesion strength similar to traditional paste (made with fresh cooked taros).	Njintang et al. (2007)	Cameroon
Compound flour	Flour	Wheat flour	The incorporation of up to 10% of taro flour did not affect the functional and alveograph properties of wheat flour.	Njintang et al. (2008)	Cameroon
Mixed infant flour for making porridge	Flour	Pigeon Pea (*Cajanus cajan*), Malted Maize (*Zea mays*), and sucrose	Significant amounts of minerals, essential amino acids, and fatty acids such as linoleic acid. Good consistency, good dry matter content, and high energy density are enough for children.	André et al. (2009)	Pakistan
Restructured fried	Flour and mashed mother and daughter rhizomes	Sucrose, salt, sodium alginate, calcium sulfate dihydrate, and sodium tripolyphosphate	High yield. Low lipid content. High elasticity and cohesiveness, low chewiness, firmness, and gumminess.	Paula (2009)	Brazil
Extruded snacks	Flour	Nixtamalized corn flour	Increased expansion and water solubility indexes. Decreased rate of fat absorption. Good consumer acceptance.	Rodríguez-Miranda et al. (2011)	Mexico
Cookie	Flour	Wheat flour, distilled water, hydrogenated vegetable fat, refined sugar, chemical yeast, and salt	↑ moisture, ash, fiber, and darker color in biscuits produced with 70:30 (wheat flour: taro flour) compared with the control. Sensory acceptability without significant difference between taro flour and control.	Alflen (2014)	Brazil
Ice cream	Extract and bagasse flour	Sugar, glucose syrup, hydrogenated vegetable fat, emulsifier, stabilizer, and cocoa powder	Replacement of hydrogenated fat by bagasse flour showed a 13-fold decrease in lipid content. ↓ 2.81% in the incorporation of air in ice cream. The extract was adequate to replace cow's milk in formulations.	Penso et al. (2016)	Brazil
Milk pudding	Lyophilized flour	Rice flour and cornstarch, sugar, vanilla, eggs, and milk	↑ ash, protein, fiber, fat, minerals, and viscosity. ↑ sensory score for thickness and viscosity. ↓ sensory score, grittiness/smoothness. Potential fortifying ingredient and hydrocolloid.	Ertop et al. (2019)	Türkiye
Tarhana [b]	Flour	Wheat flour, Jerusalem artichoke flour, yogurt, tomato paste, onion, yeast, paprika, and salt	↑ash, antioxidant activity, and mineral composition. ↑ soup consistency. ↓ taste-odor and sensory acceptance.	Cankurtaran et al. (2020)	Türkiye

Continue...

Table 4. Continuation

Product	Insertion form of taro	Other ingredients	Main results	Reference	Country
Gluten-free bread	Flour	Water, salt, compressed yeast, sugar, oil, hydrocolloids, enzymes, and potato starch	Improves glycemic index. Technological quality similar to common gluten-free flours. ↑ nutritional value. Need to use protease and strategies to obtain a light crumb volume and structure.	Calle et al. (2020)	Spain
Gluten-free cookie	Raw and cooked flour	Rice flour, corn starch, lecithin, powdered sugar, vegetable fat, salt, chemicals, vanillin, and skimmed milk powder	↑ moisture, protein, ash, minerals. ↑ hardness with 20, 40, and 60% increments of taro flour. Better overall acceptance with 20% taro flour. It improves the technological quality using cooked taro flour and 50% fat.	Dilek and Bilgiçli (2021)	Türkiye

↑ increased; ↓ decreased; [a]Achu (taro-based paste); [b]Fermented preparation for making soups; n.s.: not specified.

with no waste production, which can be applied in various food formulations such as bread, cookies, pasta, composites, and extruded foods. In addition, it may be an effective alternative for replacing other starch sources, such as gluten-free alternatives.

In addition, taro compounds can be exploited for use in the packaging, pharmaceutical, and cosmetic industries as their small-sized starch granules with hydrocolloid properties have several attractive technological properties for the food industry. Its mucilage, for example, is an environmentally friendly, non-toxic, and economical biopolymer, which can also be used in the encapsulation of products and medicines.

After ensuring the food safety of taro roots, an in-depth study of their bioactive compounds is fundamental to encourage consumption due to their various health benefits.

Taro roots have great potential for promoting sustainability and can be widely exploited for different applications. The valorization of taro can enhance the economic development of regions that can expand its cultivation, also contributing to a diversification of consumption of tubers with health benefits.

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