

Chapter

The Utilization of Cassava Leaves as a Functional Food Based on Local Wisdom

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Abstract

The global functional food market was valued at approximately USD 280.7 billion in 2021, with a projected growth rate of 8.5% from 2022 to 2030. Functional foods are attractive to a diverse global population due to their potential to improve and maintain human health. Plant-based diets contain numerous secondary metabolites that may influence health and disease prevention, with a primary focus on the potential bioactivity and nutritional relevance of several classes of phytochemicals, such as polyphenols, flavonoids, saponins, tannins, carotenoids, phytoestrogens, and fructooligosaccharides, many of which are found in cassava leaves (*Manihot esculenta* Crantz). The purpose of this chapter is to provide an in-depth overview of the potential use of cassava leaves as functional foods, with an emphasis on traditional knowledge and practices. Evidence from various regions in Indonesia indicates that cassava leaves have long been utilized, both as food and as conventional medicine. Its widespread use is due to its rich composition of nutrients, minerals, vitamins, and phytochemicals, including carbohydrates, essential amino acids, dietary fiber, β -carotene, phenolics, anthocyanins, flavonoids, tannins, and saponins, which are widely associated with its various beneficial properties for health such as antidiabetic, anti-inflammatory, antibacterial, and anti-obesity effects.

Keywords: cassava leaves, functional food, local wisdom, supporting public, health in Indonesia

1. Introduction

Cassava (*Manihot esculenta* Crantz.) is an agricultural commodity that has been cultivated for generations and is widely known in Indonesian society. In addition, this commodity has several benefits and uses, including food ingredients, industrial raw materials, and animal feed [1]. In addition to fulfilling basic human nutritional needs, food ingredients also play an essential role in improving the quality of life and health. This is evidenced by the increasing interest of global consumers in recent years towards functional foods containing bioactive compounds that can provide health benefits beyond their basic nutritional content [2]. Bioactive compounds are a diverse group of molecules with potential health benefits that exhibit various properties such

as antioxidant, anti-inflammatory, antimicrobial, antiatherogenic, antithrombotic, cardioprotective, and vasodilatory effects [3].

Functional foods are appealing to a wide range of global populations because they can improve and maintain human health and well-being [4]. Increasing health awareness and the prevalence of lifestyle-related diseases have led consumers to choose foods that provide additional health benefits, such as probiotic-enriched vitamins [3].

In addition to meeting nutritional needs, functional foods provide health benefits, especially in the prevention and treatment of diseases, which have been widely recognized by various international health organizations, including the World Health Organization (WHO). WHO emphasizes that a healthy and balanced diet, which includes the consumption of foods rich in fiber and antioxidants, is a key strategy to prevent noncommunicable diseases [5, 6]. Food, as one of the sources of vital needs in human life, is needed because it is a source of energy and also a builder of body cells [7]. According to reference [8] a plant-based diet contains many secondary metabolites that can affect health and disease prevention, which are primarily focused on the potential bioactivity and nutritional relevance of several classes of phytochemicals, such as polyphenols, flavonoids, carotenoids, phyto-estrogens, and fructo-oligosaccharides, and of these compounds are found in many fruits, spices, and vegetables. One of them is cassava leaves (*Manihot esculenta* Crantz).

Likewise, reference [9] reported that the health benefits of cassava leaves are due to their nutritional, mineral, and phytochemical content, such as carbohydrates, essential amino acids, dietary fiber, β -carotene, vitamins, phenolics, anthocyanins, and flavonoids. In addition, reference [10] explained that edible cassava leaves contain a large number of phenolic compounds, including flavonoids and tannins, which exhibit antidiabetic and anti-obesity properties. These compounds exhibit high inhibitory activity against enzymes such as α -amylase and lipase, making them beneficial for metabolic health.

2. Nutritional composition, bioactive constituents, and functional properties of cassava leaves

Cassava is a shrub, growing up to 5 m in height, and is part of the Euphorbiaceae family, considered one of the most complex and diverse families of Angiosperms, with about 300 genera and 8000 species [11]. Stem cuttings generally propagate Cassava. The leaves consist of palmate, heart-shaped leaflets with 3–9 lobes. The color of the leaves can change with age, such as purple, dark green, or light green in mature leaves, while young leaves have purple buds, which eventually turn green. The leaves also consist of petioles that vary from green to purple [12].

Besides tubers, other parts that are beneficial for human health are the leaves, because they contain crude protein ranging from 29.3 to 32% based on dry weight (DW), fat, carbohydrates, vitamin A, vitamin B, and vitamin C [13], and the crude protein content can reach 38.1% DW [11], as well as minerals (Ca, Mg, P, Zn, Mn) in high amounts [12, 14]. Cassava leaves are also an important source of essential amino acids, including valine and leucine [15], as well as methionine and phenylalanine [10]. **Table 1** presents data reported by the Ministry of Health of the Republic of Indonesia and the FAO Database [16] for comparison with the above values.

Cassava leaves, especially the buds, contain vitamins A and C, making them a very effective antioxidant against free radicals. The inhibitory activity was 88.09% and the IC₅₀ was 45.16 ppm [13]. Due to its protein, vitamin, and mineral content,

Component	Content per 100 g (fresh leaves)
Energy	64 kcal
Protein	6.8 g
Fiber	1.9 g
Carbohydrate	7.1 g
Vitamin A (β -carotene)	1310 mcg
Vitamin C	275 mg
Calcium	165 mg
Iron	1.4 mg

Table 1.
 Presenting data reported by the Ministry of Health of the Republic of Indonesia and FAO Database [16].

cassava leaves are a valuable source of additional nutrition for humans [17]. They can contribute to increasing mineral intake from food, especially essential elements such as calcium and iron [18].

Vitamin A deficiency is a public health problem, that can cause impaired vision and immunity, growth and development, epithelial cell integrity, and reproductive function [15]. According to traditional medicine in Nigeria, cassava leaves are used to reduce fever, headache, rheumatism, hemorrhoids, ringworm infections, conjunctivitis, wounds, and abscesses [9, 19], as well as inflammation and gastritis. Cassava leaves have been used for centuries for their antioxidant properties [19]. Furthermore, [19] explains that phenolic compounds, found in cassava leaves and tubers, contribute to the antidiabetic effect by inhibiting starch digestive enzymes such as α -amylase and α -glucosidase, and according to [9], the presence of flavonoids such as rutin and kaempferol in cassava leaves can increase antioxidant properties and support collagen synthesis.

Cassava has significant medicinal value, as its stems and leaves contain various phytochemical compounds (**Table 2**) that possess antioxidant, anthelmintic, and antidiabetic properties [12]. In particular, the compound isoginkgetin, which is the main component identified in cassava leaf extract, is associated with various biological activities such as antitumor and anti-inflammatory effects [17]. Furthermore, the potential of Cassava leaves as a cosmetic ingredient is related to its chemical composition, which contains rutin, apigenin, and kaempferol, and several high levels of beneficial bioactive components, such as antimelanogenesis, increased collagen synthesis, antiadipogenesis, antioxidation, and ultraviolet filtering capabilities [9].

Natural phenolic compounds are secondary metabolites [5, 20, 21], which are found in various plants that function as plant protectors from ultraviolet radiation, predators, pathogens, and so on [5]. Phenolic compounds are widely distributed in plants, mainly synthesized by lactic acid, pentose phosphate, and phenylpropanoid pathways [21]. Phenolic compounds (C_6H_5OH) have one or more hydroxyl groups directly bound to an aromatic ring [5]. According to reference [22], the importance of phenolic compounds is related to their function as defense or prevention of various diseases, such as antioxidant, anti-inflammatory, antidiabetic, antiproliferative, antimicrobial, anticancer, antihypertensive, anticardiovascular, and antiaging activities.

Flavonoids are secondary metabolites consisting mainly of benzopyrones with phenolic or polyphenolic groups at various positions [19], and have attracted

Functional components	Impact on human health
Phenolic	It has anticancer and anti-inflammatory properties, protecting against various diseases such as diabetes mellitus, arthritis, neurodegenerative disorders, and headaches.
Flavonoid	Flavonoid-derived compounds can reduce oxidative stress and inflammation, act as anti-inflammatories, help control cell growth, are anticancer agents, have antidiabetic effects, and show antiviral effects and antibacterial properties.
Carotenoids	Reduces the incidence of cataracts in the eyes and cardiovascular diseases, improves immune response, reduces the likelihood of diseases such as cancer, muscle, and degenerative diseases, contributes to the maintenance of heart cells, kidneys, and other organs, as well as reduces the risk of type 2 diabetes and metabolic syndrome.
Vitamin C	Inhibits the growth of cancer cells, reduces the oxidation of low and high-density lipoproteins, reduces oxidative stress, acts as an antihypertensive, improves the immune system, and is used to treat diseases such as scabies and the common cold, and is involved in collagen synthesis.
Dietary fiber	Improves the digestive process, prevents cancer, and has antidiabetic properties.

Table 2.
Several bioactive compounds in cassava leaves have properties functional and impact on human health [18].

considerable attention due to their potential as functional ingredients and natural food additives. Flavonoids are widely distributed in plant parts, including leaves, flowers, roots, stems, barks, and seeds [17, 18]. Approximately 10,000 flavonoids have been reported in the literature, placing flavonoids among the most abundant bioactive compounds in plants [15]. Flavonoids are common polyphenolic compounds that exhibit diverse biological and pharmacological potentials, such as anticancer, antiviral, antioxidant, anti-inflammatory, immunomodulatory, and antibacterial [20].

Carotenoids are isoprenoids widely distributed in food [21], which are the primary source of vitamin A in the diet of most of the world's population, and about 600 carotenoids are found in nature. Still, only three are essential precursors of vitamin A in humans, namely β -carotene, α -carotene, and β -cryptoxanthin [22]. Some carotenoids can be converted into retinoids that exhibit vitamin A activity, which are essential for humans and versatile, because they are not only relevant in food, but also as sources of vitamin A, natural pigments, antioxidants, and health-promoting compounds [21].

Carotenoids have different physiological and pathophysiological functions, ranging from fetal development to adult homeostasis [23]. Carotenoids also have a high potential to inhibit pancreatic lipase, which may indicate a potential anti-obesity effect [24]. In addition, carotenoids, which are natural antioxidants, can help neutralize free radicals produced by complex physiological reactions and, consequently, can protect the eye from oxidative stress, apoptosis, mitochondrial dysfunction, and warts [23]. Recently, carotenoids have also been studied in the context of nutraceuticals, because they have been shown to provide cosmetic benefits when consumed in appropriate amounts [21].

Vitamin C, also known as ascorbic acid, has attracted significant attention in both the medical and food sectors for many years [25]. Vitamin C is an essential nutritional antioxidant that protects the immune system from the detrimental effects of reactive oxygen species. Although it is one of the most essential nutrients, vitamin C cannot be

stored by the body, so it is necessary to maintain optimal levels of vitamin C through dietary intake [26]. It occurs naturally in various plants and fruits, thus playing an essential role in maintaining health [25].

The role of antioxidants is to prevent and slow down the oxidation process by interfering with the transfer of electrons between substances and reactive agents. This is important at the cellular level because oxidation reactions cause the formation of free radicals and contribute to various diseases [27]. A comprehensive analysis of the functional properties of vitamin C revealed that, in addition to its well-known antioxidant properties, vitamin C also exerts substantial effects on CD4+ cells [26], and other functional properties are primarily related to the oxidation-reduction properties of vitamin C [25].

The vital biological functions and health benefits of vitamin C are extensive, making it a subject of ongoing research and interest among health professionals and scientists [25]. As research in the health field advances, a deeper understanding of the role of vitamin C in shaping T cell-mediated adaptive immune responses may open new avenues for personalized approaches to immune modulation [26].

Dietary fiber is a food macromolecule that is resistant to digestion and breakdown in the human digestive tract up to the large intestine, where a number of microbial organisms can begin to break it down [28]. In the dynamic intestinal ecosystem, dietary fiber plays an important role in fermentation and serves as a significant nutrient source for gut bacteria. Several studies have shown that a high-fiber diet is closely associated with increased production of short-chain fatty acids [29]. Dietary fiber is classified as soluble and insoluble fiber, with each having a unique function in gut health. Unlike other nutrients, fiber cannot be digested by the intestine [30].

Dietary fiber found in plant foods functions as a prebiotic, meaning it plays a role in nourishing good bacteria in the gut and supporting microbial diversity and overall digestive function [30]. Dietary fiber also plays a vital role in the regulation of metabolism, inflammation, and microbiome composition [31]. In addition, several studies have shown that high fiber intake of foods, such as cereals and whole grains, is associated with a reduced risk of type 2 diabetes, cancer, and cardiovascular disease [32], reduced systemic inflammation, and altered microbial and metabolic profiles in experimental periodontitis [32]. Meanwhile, a persistent decrease in dietary fiber consumption over time can contribute to an imbalance in the gut microbiota, which can negatively impact human health and contribute to the global increase in diabetes, cancer, and other noncommunicable diseases [29].

3. Local wisdom in the use of cassava leaves

Local wisdom is a cultural heritage that has been acquired and passed down from generation to generation within a community or society. Specifically, it encompasses the knowledge, values, technology, practices, and expertise possessed by a community in utilizing the natural resources around them [20]. One form of integration between nature and culture is the local wisdom of communities in utilizing natural food ingredients, namely, cassava leaves. The use of cassava leaves is location-specific and important, considering their potential for development in various regions for future plant breeding to better utilize their use and consumption globally [15].

Cassava leaves in Indonesia are used as a vegetable, either boiled or mashed. For example, all Padang restaurants and local Indonesian restaurants generally serve cassava leaf vegetables [13]. One of the famous traditional dishes from

West Sumatra, Indonesia, is cassava leaf rendang. This type of dish is made from cassava leaves, which have their own uniqueness because they use many types of leaves, in addition to the leaves that are usually added to make rendang. This dish is often served at traditional events such as weddings, circumcisions, turun mandi events, batagak pangulu, and others [33]. **Table 3** presents a selection of conventional Indonesian vegetable dishes made from cassava leaves, as reported in several unpublished sources.

No	Type of cuisine	Region of origin	Characteristic
1.	Cassava leaf curry 	South Sulawesi & West Sumatra (Minang)	Cooked with thick coconut milk, with curry spices such as shallots, galangal, turmeric, and chilies.
2.	Mashed cassava leaves 	North Sumatra (Batak)	It uses finely ground young cassava leaves, then cooked with coconut milk, anchovies, and traditional Batak spices like andaliman. The pounding process gives it a unique texture and enhances the flavor.
3.	Cassava leaf salad 	Java and Bali	Cassava leaves are boiled and then mixed with grated coconut seasoned with onions, galangal, and chilies, so that the taste is fresh, savory, and slightly spicy.
4.	Cassava leaf salad 	East Java	Boiled cassava leaves are served with peanut sauce, so they taste sweet, spicy, and savory.

No	Type of cuisine	Region of origin	Characteristic
5.	Cassava leaf lodeh 	Central Java	Cassava leaves are cooked in coconut milk with pumpkin, tempeh, and lodeh spices, so they taste soft, savory, and slightly sweet.
6.	Sour vegetables with cassava leaves 	Javanese (Betawi)	Cassava leaves are added as a filling in a fresh sour sauce containing other vegetables such as melinjo, long beans, and others, resulting in a fresh, sour, and slightly sweet taste.
7.	Cassava leaf, coconut milk, and vegetable soup 	Common in various regions of Indonesia	Cassava leaves are boiled and then cooked in a light coconut milk sauce with simple spices. The vegetable has a soft, savory flavor, perfect as a side dish with fried tempeh or tofu.

Table 3.
Various types of typical Indonesian dishes based on cassava leaves.

Seven types of Indonesian cassava leaf vegetable dishes are prepared using various methods. One method involves separating the Cassava leaves from their stalks, cutting them into pieces approximately 2 cm wide and 4 cm long, washing them, and cooking them [34]. At the household level, the most common preparation method is washing, pounding, and boiling or cooking the cassava leaves [35]. Another technique involves slicing and pounding the cassava leaves, then cooking them for approximately 2 hours [36].

The seven types of cassava leaf preparations mentioned above are generally prepared by boiling them in water, a standard method in food preparation [37]. Traditional processing techniques include chopping, pounding, fermentation for one or 2 days, or longer boiling to reduce cyanide content [35]. Additional detoxification approaches include drying, soaking in water, and kinetic washing of the pounded cassava leaves [37, 38].

The cyanide content in Cassava leaves ranges from 141.64 mg/100 g dry weight [39], with an average of 52.9 mg/100 g for all varieties. Boiling can reduce the bound cyanide level to 5.9 mg/kg [36]. To enhance detoxification, it is recommended to boil cassava leaves in a pan without a lid to allow the hydrogen cyanide to evaporate [34].

Among the various processing methods, boiling is the most widely used and effective for cyanide removal [36]. However, heat treatment causes significant losses of protein, thiamine, riboflavin, nicotinic acid, vitamin C, and amino acids, especially methionine and cysteine [35]. Pre-cooking treatments, such as pounding or grinding, further reduce the content of ascorbic acid and thiamine, with slightly higher losses observed in grinding (78.61 and 38.95%, respectively), compared to mashing (76.87 and 35.14%, respectively). These nutrient losses are mainly due to the immersion in the cooking water and are accompanied by a 4.40% decrease in protein content [40].

Unboiled cassava leaves contain 20.73 ppm cyanide, while the safe range for humans is 0.5–3.4 mg/kg body weight; WHO (2019) recommends a maximum of 10 mg/kg in raw materials [41]. A study involving 20 volunteers who consumed 200 g of boiled cassava leaves twice daily for 12 consecutive days reported a significant decrease in triiodothyronine and thyroxine levels within 9 days, leading to a reduction in urinary iodine excretion and potential risk of goiter. Based on these findings, a daily intake of 50–100 g of boiled cassava leaves is recommended [42].

4. Innovation of functional food products based on cassava leaves

Given its nutritional composition and health benefits, cassava leaves have great potential for development into various functional food products. Converting cassava leaves into flour facilitates their incorporation into various formulations [13]. For example, partially replacing wheat flour with cassava leaf flour in cake making (Table 4) has been shown to increase protein and fiber content while reducing gluten levels, making this product suitable for individuals with gluten intolerance [43]. In addition, cassava leaves can be processed into jerky with a crunchy texture and flavor profile comparable to beef jerky. This process usually involves partially replacing the formula with tapioca flour to improve

No	Product name	Utility	Reference
1.	Cookie cake	The addition of cassava leaf flour in making cookies, to increase the protein and fiber content, while reducing the gluten content, for individuals who are intolerant to gluten.	[43]
2.	Cassava leaf jerky	Making cassava leaf flour jerky with tapioca flour substitution can improve the quality, making it a source of protein and fiber, which is a traditional food typical of the people of Bukittinggi City.	[44, 45]
3.	Tempeh	The addition of cassava leaves in the manufacture of tempeh is to increase nutritional value and to increase the diversity of alternative food products.	[46]
4.	Mushroom nuggets	The addition of cassava leaf flour in making mushroom nuggets is an alternative food choice that vegetarians can eat.	[47]
5.	Sago crackers	The addition of cassava leaf flour in making sago crackers increases the nutritional content and provides an attractive color to the resulting sago crackers.	[48]
6.	Cassava leaf granules	Instant granules are a practical and easy-to-consume pharmaceutical preparation. To be well-received by the public, they must have a pleasant taste.	[49]

Table 4.
Functional food innovation products based on cassava leaves.

product quality, resulting in jerky that serves as a valuable source of protein and dietary fiber and can be classified as a functional food [44, 45].

In addition, cassava leaves can be incorporated into tempeh products to increase the diversity of alternative food products [46]. Cassava leaf flour has also been used in the manufacture of straw mushroom nuggets [47] and sago crackers [48]. In the latter, its addition not only increases the nutritional value but also provides an attractive green color to the final product. Furthermore, considering the antibacterial properties of the bioactive compounds present in cassava leaves, a study formulated cassava leaf granules combined with mannitol, sucrose, and honey. Antibacterial testing of this combination showed that the optimum mixture exhibited potent inhibitory activity [49].

5. Cassava leaves as a strategic resource for resilience food and health promotion

Approximately 800 million people worldwide depend on Cassava as a staple food, with approximately 500 million of these people in sub-Saharan Africa [50]. In this region, Cassava accounts for 61 percent of annual production [19] and plays a crucial role in food security. Globally, Cassava ranks fifth in terms of production, after maize, rice, wheat, and potatoes. Cassava is a drought-tolerant crop that requires relatively few inputs, can grow on marginal land where other crops cannot survive, and is available for up to 10 months each year in East Africa [50].

Food security encompasses efforts to ensure adequate food supplies, which can be supported by production systems rooted in local wisdom and cultural practices while maintaining nutritional quality. Strategies include replacing commonly consumed foods with nutrient-rich alternatives and diversifying processed food products [7]. Raising awareness of the dietary benefits of native leafy vegetables such as cassava leaves can contribute significantly to food security, as these leaves provide essential nutrients [28].

In Cameroon, cassava tubers are a staple food, and the leaves are used to treat malnutrition because they are rich in protein, phenolics, carotenoids, vitamin B, and vitamin E [10]. Cassava leaves are a source of the minerals Ca, Mg, Fe, Mn, Zn, vitamin A, and vitamin B2 (riboflavin) [51], as well as carbohydrates, protein, and other vitamins and minerals [15]. According to [13], cassava leaves are low in calories and can increase satiety, improve digestion, and relieve constipation. Cassava leaves are also traditionally used to relieve headaches, treat the flu, expel worms, treat rheumatism, heal boils, treat diarrhea, and increase stamina.

6. Conclusion

Cassava leaves are known as a functional food that is gaining global popularity due to their ability to improve and maintain health. Beyond meeting basic needs, functional foods made from cassava leaves offer additional health benefits, particularly in disease prevention and management, through their antioxidant, anti-inflammatory, antidiabetic, antiproliferative, antimicrobial, anticancer, antihypertensive, cardio-protective, and antiaging activities.

A key example of the integration of nature and culture is reflected in the local wisdom of communities utilizing cassava leaves as a natural food source. In Indonesia, Cassava is commonly consumed as a vegetable, boiled or mashed, not only as a component of traditional dishes but also as a practical way to reduce cyanide levels.

Processing cassava leaves into flour facilitates their incorporation into various processed products, expanding their potential applications. A practical approach to increasing food availability is to raise public awareness of the diverse benefits of cassava leaves, particularly their role in preventing and managing degenerative diseases, while also providing essential nutrients. Such efforts can strengthen cassava leaves' position as a valuable functional food in both traditional and modern food systems.

Conflict of interest

The author declares that there is no conflict of interest, either moral or financial, arising from the writing of this chapter.

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