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Food, nutrients and phytochemical composition of country potato, *Plectranthus rotundifolius* (Poir) Spreng.: A review

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Abstract

Country potato, *Plectranthus rotundifolius* (Poir) Spreng., is a perennial herbaceous plant but cultivated as an annual crop that produces edible tubers. As a relatively underutilized crop, Chinese potato has much potential that have not yet been fully explored. The tubers of country potato are nutritious, containing high levels of starch, proteins, vitamins and minerals. Various phytochemicals were identified in the tubers and other plant parts which possess antioxidant, anticancer, anti-inflammatory, antimicrobial, antidiabetic, and neuroprotective effects. The crop can tolerate drought and can be grown in marginal soils, providing food security benefits for resource limited farmers. As a high value cash crop adapted to tropical conditions, country potato also has good income generation potentials. This manuscript offers a comprehensive overview of the existing knowledge on the importance of country potato as a food crop, medicinal plant, and also as a source of income generation. Breeding and biotechnology research to improve agronomic traits and enhance phytochemical content can further increase the future potentials of this underutilized but promising food security crop. The crop is encountering various production challenges such as photosensitivity, low yield, small sized tubers with varying shapes, inadequate tuberization and lack of postharvest technologies. With sufficient and targeted research focus, the country potato, being a fragile vegetable crop, has the potential to be widely adopted across various agro ecosystems of tropical regions, thus bolstering food security. More studies are still needed to fully tap into the potentials of country potato for food, health and wealth creation.

1. Introduction

Tuber crops rank as the second most vital source of carbohydrates, followed by leguminous grains and cereals (Gregory and Wojciechowski, 2020). It accounts for roughly six per cent of the world's nutritional supply (Suja and Nedunchezhiyan, 2018), with an annual production of about 836 million tonnes worldwide (Chandrasekara and Kumar, 2016). Edible tubers or storage organs abundant in carbohydrates which develop either entirely or partially underground from the stems of tuber crops (Gregory and Wojciechowski, 2020). Plants which accumulate starch based polysaccharides in their rhizomes, corms, subterranean stems, roots and tubers are categorized as starch containing roots and tubers, originating from diverse botanical origins (Akhila *et al*., 2022). Sweet potato, potato and cassava are some of the common tuber crops that are consumed globally and it contributes 90% of the total production (Chandrasekara and Kumar, 2016).

Major tropical root and tuber crops are potato (So*lanum tuberosum*.), cassava (*Manihot esculenta*), sweet potato (*Ipomea batata*), yam (*Dioscorea* spp.), aroids like elephant foot yam (*Amorphophallus paeoniifolius* Dennst.), taro (*Colocasia esculenta* L.) and tannia (*Xanthosoma sagittifolium* L.). Furthermore, there are minor tubers like country or Chinese potato (*Plectranthus rotundifolius* Poir.), arrowroot (*Maranta arundinacea* L.) and yam bean (*Pachyrhizus erosus* L.). These crops are reproduced through vegetative propagation and contribute significantly to the food industry by providing enormous quantities of nutrients and energy per unit area and time. They can withstand hazardous environmental conditions with less intensive management techniques. As a result, these crops are critical to fight against starvation brought by floods, droughts, civil unrest, and other climate-related disasters like pests and diseases, which in certain places seem to be never-ending threats (Chandrasekara and Kumar, 2016).

Country potato is a tuber crop that is commonly found in tropical countries, while its origins lies in central or eastern Africa, country potato has now disseminated to every tropical region around the world (Murugesan *et al*., 2020; Reddy, 2015; Kwarteng *et al*., 2018; Sugri *et al*., 2013; Anbuselvi and Balamurugan, 2013; Khairinisa *et al*., 2018; Paramita *et al*., 2019; Prematilake, 2005). It is exceedingly challenging to gather trustworthy data and coordinate the body of existing research on *P. rotundifolius* because it is known by several names in various African and Asian nations. It is alternatively known as 'country potato,' or 'chinese potato,' 'hausa potato,' or 'coleus potato' in English, and 'koorka' in Hindi or as 'sirukizhanku' in Tamil (Enyiukwu *et al*., 2014; Morton *et al*., 2004; Eleazu *et al*., 2017; Manikandan *et al*., 2016; Mishra *et al*., 2022). Country potato serves as a vital and reliable food crop for African nations such as Mali, Nigeria, Togo, Burkina Faso, Cameroon, Ghana, Chad, and South Africa (Hua *et al*., 2018; Nanema *et al*., 2019). During lean

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seasons in Africa, this crop plays a crucial role as a primary food source (Enyiukwu *et al*., 2014). It is also widely grown on modest scales in South-East Asia, especially in India, Sri Lanka, Thailand, Indonesia and Malaysia (Akhila *et al*., 2020; Sethuraman *et al*., 2020; Zhu and Cui, 2020; Kwarteng *et al*., 2018). In India, *P. rotundifolius* is cultivated in southern states such as Tamil Nadu, Kerala and Karnataka in small scale (Mishra *et al*., 2022). The crop is highly valuable because of its agronomic advantages in poor soils and its higher yield with minimal production inputs compared to other tuber crops. However, it is typically grown as a subsistence crop and it holds significant potential for commercialization (Sugri *et al*., 2019).

Country potato has good income generation potential as a high-value cash crop for local and export markets. Demand has increased due to recognition of its nutritional characters and health benefits driving commercial cultivation in sub-Saharan Africa (Namo and Opaleye, 2018). The crop fetches relatively higher price than common potato, cassava and sweet potato, providing better economic returns on investment for small farmers (Murugesan *et al*., 2020). In developing nations, country potato serve a crucial role in fulfilling food and nutritional needs, as well as generating income for farmers (Padulosi *et al*., 2013). The tubers are acknowledged for their superior taste, making them highly desirable. A portion of the harvest can be marketed to augment household income. *S. rotundifolius* holds considerable economic promise and could emerge as a profitable asset for the agricultural economy (Enyiukwu *et al*., 2014). Price surveys in domestic urban markets indicate that the wholesale price of country potato is $0.5-1 per kg and in retails at $1-2 per kg, which is 2 to 10 times higher than common potato. Markets exist for both the fresh tubers and powdered tuber flour. Additionally, the leaves are also sold as a leafy vegetable in markets (Plaisier *et al.,* 2019).

The good financial returns provide incentive for farmers to increase production. The high value crop can thus contribute to rural development as an income generator to improve livelihood of small farm holders. Realizing the full income potential requires support to the farmers in the form of clean planting material, agronomic training, and linking them to remunerative markets.

P. rotundifolius is employed in alleviating stomach pain, diarrhea, nausea, vomiting, mouth and throat infections. Additionally, it acts as a purgative, carminative and antihelminthic agent. It is the species most commonly referenced for the treatment of abdominal pain, burns, sores, wounds, insect bites, and allergies. Moreover, it is also used in the treatment of nervous and sensory disorders related to ear and eye conditions.

2. Potential of country potato

2.1 Botanical description of country potato

Country potato belongs to the genus *Plectranthus* comprising of approximately 300 species, found across the tropical regions (Retief, 2000; Suddee, 2004). The genus *Plectranthus* is one of the biggest genera within the Lamiaceae family, specifically in the subfamily Nepetoideae, tribe Ocimeae, and subtribe Plectranthinae (Eleazu, 2017; Anbuselvi and Balamurugan, 2013). The term '*Plectranthus*' originates from the fusion of two Greek terms: 'Plektron' and 'anthos', signifying 'spur' and 'flower' correspondingly, denoting the characteristic 'spur-shaped flower' exhibited by selected members of the genus. Within the genus, four tuber crops stand out as edible options, *viz., P. esculentus*, known as the African potato; *P. rotundifolius*, referred to as the Madagascar potato, *P. edulis*, recognized as the Ethiopian potato and *P. parviflorus*, commonly referred to as the Sudan potato. The species name r*otundifolius* refers to the round leaf shape. There are two varieties that have been documented as *Plectranthus rotundifolius* var. *rotundifolius* and *Plectranthus rotundifolius* var. *anceps*. However, the botanical varieties are not distinguished for agricultural purposes and the species is generally referred to as *P. rotundifolius* (Codd, 1985).

The genus *Plectranthus* is a varied group of plants that encompasses many aromatic herbs. *P. rotundifolius* possess the capability to reach approximately 15 cm in height, although, this can expand up to 60 cm under favorable environmental conditions. The leaves of country potato are primarily green, accounting for over 90% of their coloration, displaying variations in shades such as green, light green and olive green with aromatic smell (Opoku-Agyeman *et al*., 2004) (Figure 1). Interestingly, these leaf colors do not correlate with the presence or location of anthocyanin pigmentation (Kwarteng *et al*., 2018). Stipules are absent, while the leaf base measures approximately 2-3 cm in length. The leaf blade has an ovate shape, measuring 2.5-8 cm by 2-5 cm, tapering at the base and the leaf shape varies from obtuse to acute at the apex. The margin exhibits crenate-dentate patterns, with slight pubescence, glandular dots on the underside, and distinct veining (Agnew and Agnew, 1994). Additionally, the inflorescence appears as a narrow pseudospike at the terminal end, reaching up to 15 cm length. It consists of compact sessile dichasia. It has a prostrate or ascending stem. It bears tiny, tubular flowers that are either pale lavender or white in color. The flowers are typically arranged in spikes or clusters. The flowers are hermaphroditic and zygomorphic, with pedicels measuring up to 1-2 mm in length (Enyiukwu *et al*., 2014). The plant is adapted to tropical climates and is often grown in regions with warm temperatures.

The crop flowers profusely but sets no seeds. Vegetative propagation is the rule wherein both tubers and stem cuttings are used as planting materials. Smaller tubers are preferred to larger ones for planting. Storage time is essential for tubers to break dormancy before they can sprout. A tuber may sprout in storage before it is planted in the field. During planting, care must be taken not to bruise or break the sprout because it takes a long time for a new sprout to develop in replacement. Any part of the tuber will sprout but usually the sprout comes from its proximal end. Deep planting of tubers should be avoided. In case of tuber that has already sprouted before planting, the growing tip of the shoot must not be buried. Deep sowing or burial of shoot tip delays initial growth and establishment of the crop. Soft wood stem cuttings can also be used for propagation but the method is not practiced by farmers. It was, however, observed that plants propagated through cuttings produce larger but fewer tubers than tuber propagated plants. This observation by farmers contradicts with that of Irvine (1969) who indicated that the stem propagated crops give lower yields than tuber propagated ones.

The country potato plant yields plump, round tubers, typically occurs 4 to 6 months after planting (Neeraj *et al*., 2021), coinciding with the flowering of the plant and the senescence of the aerial parts. Tubers are found in clusters of 3 to 7, positioned either at the stem's base or at the nodes beneath the soil surface (Tindall, 1983 and Opoku-Agyemang *et al*., 2007). In tropical conditions, year-round production is not there because of photosensitive nature. Dimensions of the tubers ranged between 3.0 to 5.0 cm long and 1.0 to 2.0 cm diameter (Gomathy Sethuraman *et al*., 2020). Although, some can use tubers with the diameter as large as 8 cm and tubers, typically weighing around 28 g, can reach weights up to 480 g (Opoku-Agyeman *et al*., 2004). Large sized tubers are more common in India and Sri Lanka, where harvests also generally surpass those in semi-arid regions of Africa. The country potato can withstand high temperature and heavy rainfall, thriving in well-drained, porous or sandy soil exposed to direct sunlight (Mortan *et al*., 2004; Anbuselvi and Balamurugan, 2013; Manikandan *et al*., 2016; Paramita *et al*., 2019). These aromatic tubers are the main edible part of the plant which is dark brown in colour (Figure 2).

Figure 1: Field view of country potato plant.

Figure 2: Harvesting and harvested tubers of country potato tubers.

2.2 Nutritional value of country potato

The main edible part of country potato is the tubers, which resemble potato tubers but are generally smaller in size, which is abundant in both essential and trace nutrients, all of which are deemed essential for maintaining optimal bodily functions, as indicated by Kana *et al.* (2012). The tubers are nutritious with balanced contents of carbohydrates, proteins, vitamins and minerals (Figure 3). On dry weight basis, the tubers contain 60-80% carbohydrates comprising mainly of starch. Country potato contains 21 g of carbohydrates/ 100 g, just a bit more than the corresponding amount of regular potato (17 g) and sweet potato (20 g) (Kwarteng *et al*., 2018; Enyiukwu, *et al*., 2014; Khairinisa *et al*., 2018; Paramita *et al*., 2019; Mitra *et al*., 2021). The protein content ranges between 5 to 10% and is higher than common potato. The tubers also have high fiber content of 9-15%.

In contrast to other tubers, a standard serving offers a substantial portion of the daily recommended intake of calcium and vitamin A, as well as exceeding the daily requirement for iron (Kwarteng *et al*., 2018; Tortoe *et al*., 2018). The lack of gluten in these tubers may prove advantageous in providing substitute food option for individuals who have sensitivity to gluten or suffer from celiac disease (Lakmali *et al*., 2019). It has been documented as the finest staple tuber crops due to its unique flavor, characteristic aroma, nutritional benefits, and medicinal properties (Namo and Opaleye, 2018).

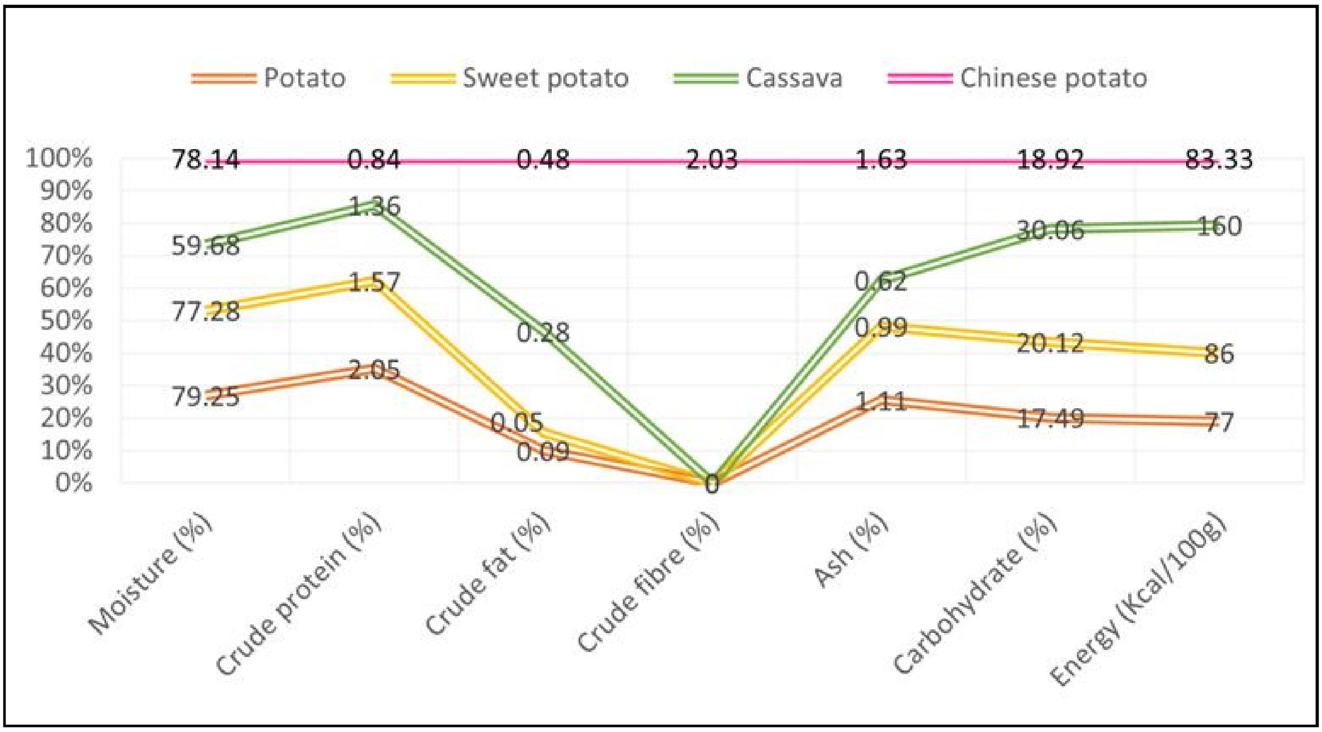

Figure 3: Comparison of the basic constituent composition of country potato with major tubers.
Source: USDA; Food Data Central, (2020) and Gomathy Sethuraman *et al*. (2020).

According to Gomathy Sethuraman *et al*. (2020), the Chinese potato showed a greater concentration of all analyzed minerals compared to other tubers. Potassium and magnesium levels were particularly notable, with potassium at 12,025 mg/kg almost three times higher than in potato and six times higher than in cassava. Magnesium, at 1,347 mg/kg, was five times greater than in all the tubers. Phosphorus, at 978 mg/kg, was nearly double that of potatoes and almost four times that of cassava (Figure 4). The vitamin content in tubers includes vitamin C, B complex (thiamine, riboflavin, niacin) and vitamin E. Relative to other tuber staples such as tapioca, sweet potato, country potato and yams contains elevated levels of protein, calcium, magnesium, iron and fiber (Kwarteng *et al*., 2018).

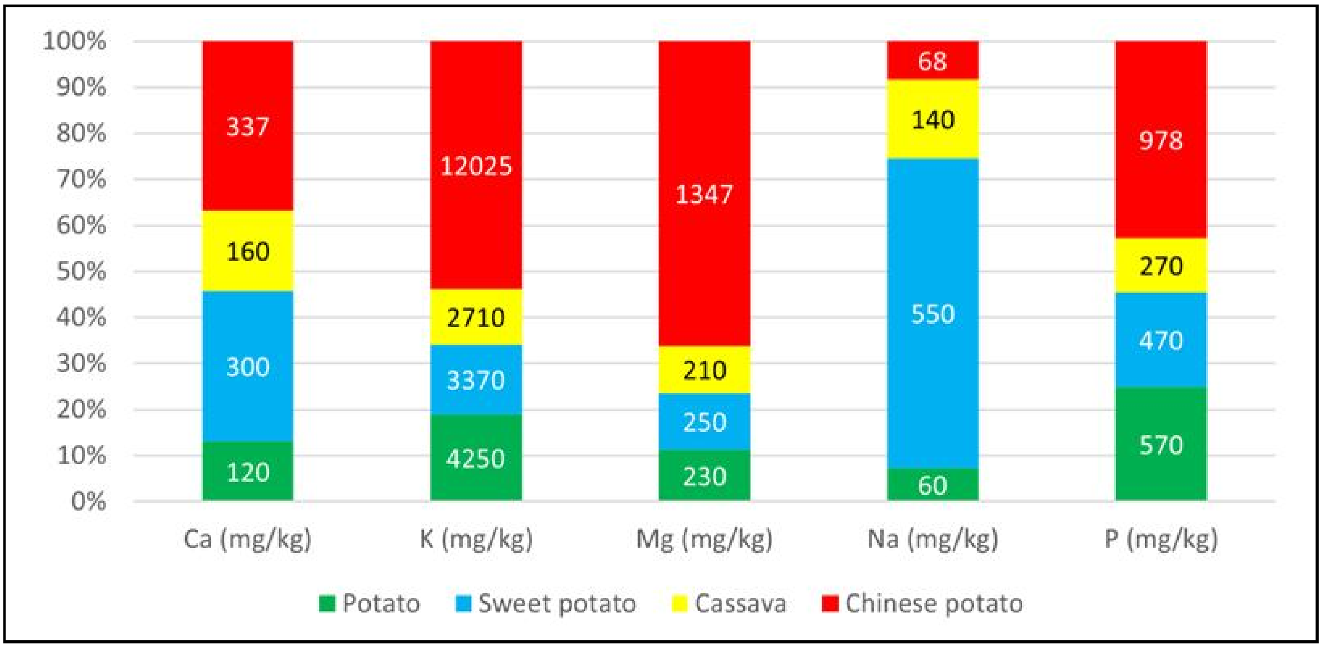

Figure 4: Mineral content of chinese potato compared with major tubers.
Source: USDA; Food Data Central, (2020): Gomathy Sethuraman *et al*. (2020).

The high nutritional value makes the tubers useful in supplementing staple foods that may be deficient in essential nutrients. The crop can therefore contribute for the alleviation of hidden hunger in marginal areas (Akhila *et al*., 2022). The tubers of chinese potato contain a significant amount of reducing sugars, measuring 26 mg (Anbuselvi and Balamurugan 2013) (Figure 5).

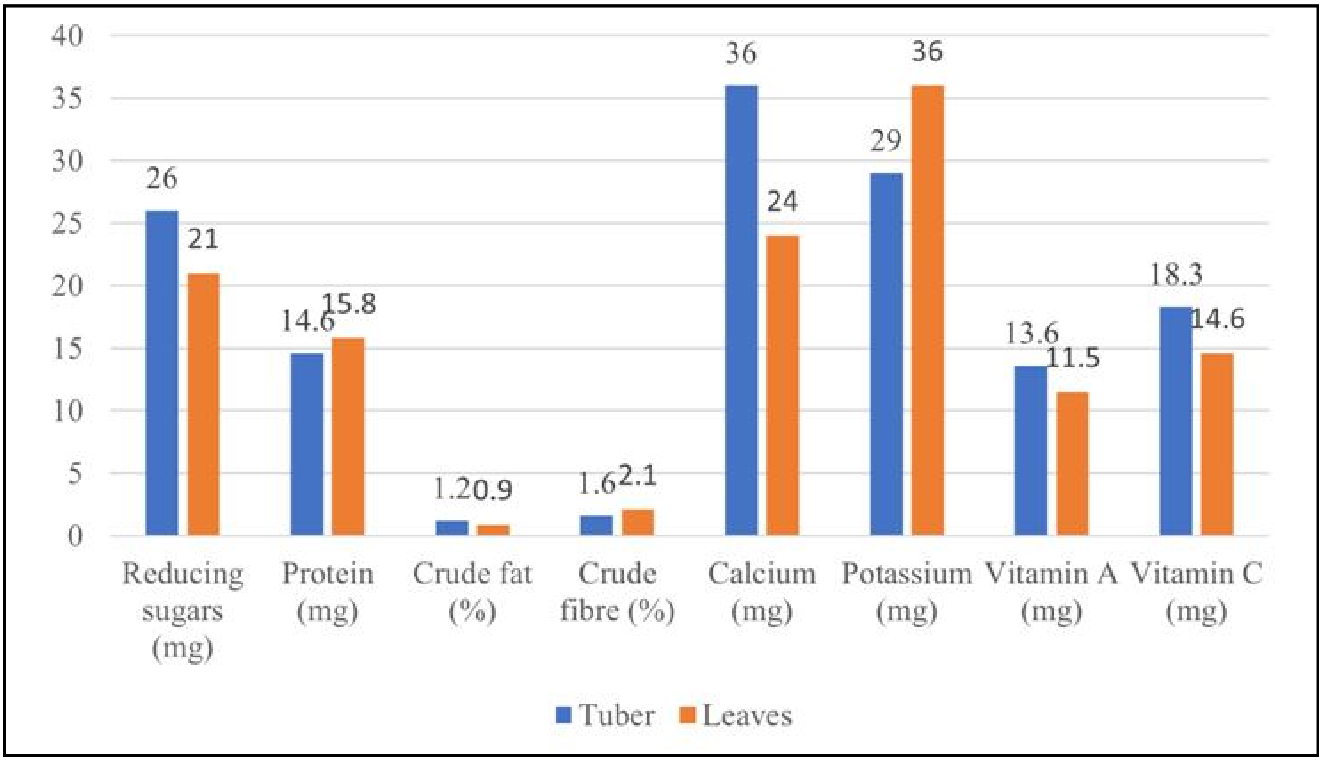

Figure 5: The Nutritional content of *P. rotundifolius* leaves and tubers.
Source: Anbuselvi and Balamurugan (2013).

Despite the rich nutrient content, the levels of antinutritional factors including oxalates and phytates are low and thus not a major concern. However, cyanogenic glycosides have been detected which indicates that need for proper processing of tubers before consumption to remove possible toxins (Nyirenda, 2020).

2.3 Consumption uses of country potato

The country potato serves multiple functions, ranging from ornamental and medicinal to culinary uses, and even extends to applications such as perfume and alcoholic beverage production (Enyiukwu *et al*., 2014). In Ghana, people brew an alcoholic beverage using *S. rotundifolius* tubers (Opoku Agyeman *et al*., 2007; Nkansah, 2004). This nutrient rich tuber, despite being underutilized, holds the potential to enhance sufficient and reliable access to food and nutrition (Sethuraman *et al*., 2020). The crop has the capacity to fulfill the energy requirements of consumers. These tubers possess a taste similar to that of Irish potato and trifoliate yam, making them suitable for consumption either as the primary starchy staple or as a component alongside legumes, vegetables and rice. Additionally, they can be integrated into African and Indian culinary traditions by boiling, baking, or frying them (Akhila *et al*., 2022). The Country potato tubers are processed into flour and utilized in variety of food items, such as breakfast porridge (Sethuraman *et al*., 2020). The leaves can occasionally be consumed as potherbs as well (Kwarteng *et al*., 2018). Country potato tubers and leaves are utilized in various ways in different countries are listed below in the table 1.

Table 1: Utilization of country potato in various countries

S. No.	Country	Method of utilization	References
1.	Southern Asia (Including India and Srilanka)	Tubers are commonly steamed, often served alongside rice, and prepared with palm sugar and coconut milk	Akhila *et al.* 2022; Enyiukwu *et al.* 2014a; CABI, 2018
2.	Ghana	Baked in their skins and eaten as a snack food	
3.	Indonesia	Used in the preparation of minced meat balls	
4.	Northern Ghana	Used to prepare porridge which is eaten for breakfast	
5.	Nigeria	Commonly eaten raw	
6.	Other areas	Used and cooked as a leafy vegetable Stems have been used as livestock bedding material	Jansen, 1996; Nkansah, 2004; Laxmi-narayana *et al.*, 2016; Nkansah, 2004

2.4 Medicinal properties and phytochemicals

Country potato holds significant medicinal value and exhibits numerous functional food properties. Tubers are used for the treatment of diarrhea, dysentery, stomach ache, ulcer, wound healing, skin infections, sore throat, cough, fever and malaria (Archana *et al*., 2015; Nkansah, 2004). Scientifically validated medicinal properties emanate from bioactive secondary metabolites that have been extracted and characterized from the tubers, leaves, stem and roots. Antibacterial activity has been shown by leaf (Athira sathyan *et al*., 2018) and tuber (Murthy *et al*., 2018) extracts. The plant possesses saponins, anthraquinones, flavonoids and the saponins help to lower blood cholesterol levels and protect against fungal and viral infections affecting human beings (Kwarteng *et al*., 2018). Additionally, it shows significant antioxidant properties (Abraham and Radhakrishnan, 2005; Horvath *et al*., 2004).

The plant harbours diterpenes, sesquiterpenes and several volatile oils (Lukhoba *et al*., 2006). The leaves of the plant have also been used as healing agents and as antiseptic (Alleman, 2002). Bioactive compounds are extracted from the leaves, stems and tubers of country potato. These includes γ-muurolene, α-humolene, E-caryophyllene, n-dodecane, and 1-octene-3-ol, along with epi-α-cardinol, sesquiceneole, cyperene, epi-α-bisabolol and α-santalene. These substances exhibited notable antibacterial effects against *Pseudomonas aeruginosa*, *Escherichia coli*, and *Staphylococcus aureus* (Phung panya *et al*., 2013).

Phytochemicals were identified in the methanolic extracts of *P. rotundifolius* using high-performance liquid chromatography. The presence of polyphenols such as rosmarinic acid, caffeic acid, gallic acid, p-coumaric acid, quercetin and rutin were reported. These compounds are likely to be responsible for the observed biological activities in the tuber extract. Flavonoids are the primary components responsible for the antioxidant activity, as the flavonoid content in the methanol extract was found to be higher compared to other extracts (Jayapal *et al*., 2015; Subramaniam, 2014; Murthy *et al*., 2018; Mishra *et al*., 2022).

Extracts and purified compounds from country potato have shown several pharmacological activities through antimicrobial, antioxidant, anticancer, immunomodulatory, anti-inflammatory, antidiabetic, antinociceptive and neuroprotective effects (Akhila *et al*., 2022; Kwarteng *et al*., 2018). Figure 6 summarizes some key bioactive phytochemicals isolated from the species and their medicinal properties determined experimentally.

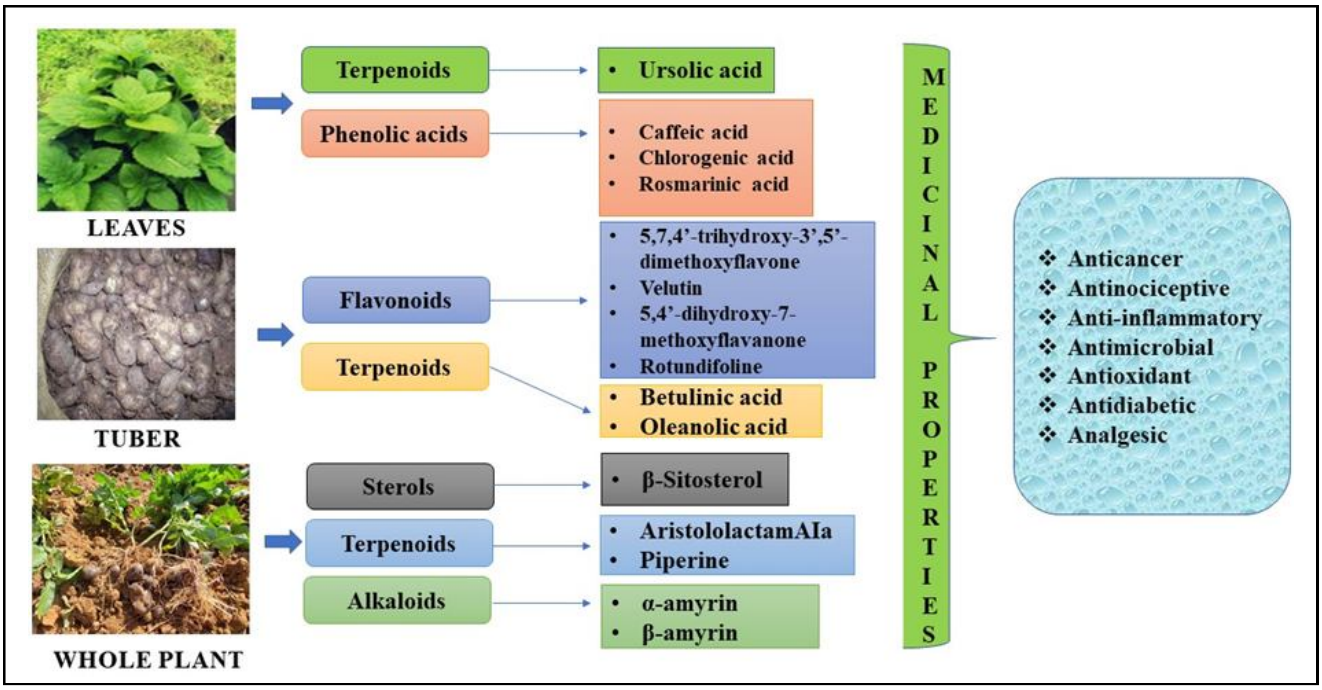

Figure 6: Medicinal phytochemicals properties in Country potato and their pharmacological activities.
Source : Enyiukwu *et al*. (2014); Kwarteng *et al*. (2018); Chandrasekara, (2018) and Pidigam *et al*. (2022)

In *in vitro,* the antibacterial, antifungal and antiviral activities were studied in country potato and it may be useful for the development of new antimicrobial drugs to combat drug resistant pathogens. The immune-boosting effects can enhance the body's defence systems (Kwarteng *et al*., 2018).

Anbuselvi and Hema Priya (2019) conducted a quantitative assessment of *P. rotundifolius* for biochemical contents. Tubers possess higher content of the protein (15.6 mg) and crude fat (1.2%) than peel. Apart from this, the nutrients present in the tubers and peel are compared and presented in Table 2.

The antinutrient component present in tuber are given in table 4. This table also includes the method of extract used in estimation of antinutritional compound.

3. Research gap

The key areas that need enhancement through research and extension efforts are highlighted in Table 4. Despite this, achieving these improvements can significantly boost the production and utilization of Country potato. Implementing these investigation and outreach strategies will demand significant time and resources (Sugri *et al*., 2013).

Table 2: Chemical components found in the tuber and peel of *P. rotundifolius*

Parameter	Tuber	Peel
Reducing sugar	26 mg	21 mg
Protein	13.6 mg	15.6 mg
Crude fat	1.20%	0.90%
Crude fibre	1.60%	4.80%
Citric acid	0.35%	0.36%

Source: Anbuselvi and Hema Priya (2019)

Table 3: Antinutritional components of country potato

Phytochemicals	Ethanolic extract	Methanolic extract	Ethyl acetate extract
Alkaloids	***	***	**
Tannins	-	-	**
Steroids	-	-	*
Anthocyanines	-	***	**
Ascorbic acid	-	**	*
Flavonoids	-	**	-
Phenolic flavonoids	-	**	-
Cardiac glycosides	-	-	*
Tri-terpenoids	-	***	**
Phlobatannins	-	-	*

Note: (i) * - Present; (ii) - : Absent: Anbuselvi and Hema Priya (2019)

Table 4: Research and extension interventions aimed at enhancing crop improvement goals for country potato

S. No.	Areas in need of enhancement	Areas of focus	Enhancements needed
1.	Crop improvement	Varieties	Substitute the current landraces
2.	Genetic conservation	Research	Collection, characterization, and conservation of germplasm
3.	Crop Agronomic practices	Extension	Selection of cultivars, planting time, planting distance and manures application ratio
4.	Propagation and molecular work	Research	Molecular, budding, approach, cleft and splice grafting methods
5.	Size	Varieties	Genetic methods to increase tuber size
6.	Duration	Varieties	Shorten the maturity period from 4-5 months to 3 months
7.	Ease of peeling	Varieties	The peel should be easy to remove
8.	Fibrousness	Varieties	Adjust the natural dormancy period by either eliminating it or extending it
9.	Shelf life	Varieties	Implement enhanced storage and processing techniques
10.	Nutritional	Research	Enrichment with vitamins and development of orange-flesh color through bio-fortification
11.	Taste	Varieties	Enhance the sweetness, aroma, and starch content while reducing the moisture content
12.	Utilization	Extension	Raise awareness about the health advantages and usage among consumers residing in urban areas
13.	Value enhancement	Processing	Assess options for parboiling, blanching, dehydration, roasting, and frying, as well as packing techniques
14.	Training	Extension	Good Agricultural Practices (GAP) (soil fertility, pest control and postharvest handling methods)

The research institutes should aim to close the gaps between research and extension as outlined in Table 4. Achieving meaningful outcome requires active participation from both research institutes and growers. It is necessary to deploy and scale up improved technologies to boost the production and utilization of country potatoes. This initiative should encompass farmer field schools, as well as training sessions covering good agronomic practices (GAP), integrated soil fertility management, integrated pest management (IPM), and integrated disease management (IDM) strategies and postharvest management.

The primary limitations, including low yield, absence of improved varieties, shortages of planting materials, early dormancy, declining soil nutrient status, labor-intensive cultivation, reduced soil quality, insect infestations, and significant postharvest spoilage.

4. Limitations and improvement prospects in future

Country potato stands as a significant minor tuber among other tuber crops. However, it faces challenges such as low yield, susceptibility to photosensitivity, absence of improved varieties, shortages of planting materials, early dormancy, declining soil fertility, labor-intensive cultivation, poor soil quality, insect infestations and significant postharvest losses (Murugesan *et al*., 2020). Because of its sterile nature and non-setting of true seeds, tubers showed low variability in size with small tubers accounting for 75% of the total production (Nanema *et al*., 2009). The prevalence of small tubers has been identified as a significant limitation for the promotion of country potatoes (Nkansah, 2004; Prematilake, 2005). The tuberization of country potato is subjected to seasonal variations. It is essential to explore strategies for altering these seasonal effects, either by developing new varieties or employing alternative methods, to enable year round cultivation. There remains a limited focus on genetic enhancement and the development of varieties for various minor tuber crops (Nkansah, 2004; Murugesan *et al*., 2020). These crops have been overlooked for an extended period (Enyiukwu *et al*., 2014). A renewed and coordinated initiative is required for the collection, conservation, evaluation and cataloging of genetic stocks pertaining to underutilized tuber crops (Olojede *et al*., 2005).

Genetic improvement is necessary to enhance commercial potentiality of country potato by developing cultivars with higher yields and resistance to stresses (Achigan-Dako *et al*., 2015). Conventional breeding methods have not been exploited due to limited research caused by the status as an underutilized orphan crop. While numerous underexploited root and stem tuber crops bear flower, but a significant portion of them fail to produce seeds, thus restricting opportunities for breeding and further enhancement (Prematilake *et al*., 2005). Genotyping studies showed variations within and between landraces signifying prospects for selecting superior types (Asha *et al*., 2023). Useful traits for introgression include enhanced tuber yields, early maturity, drought tolerance and resistance to pests and diseases. Tuber dormancy also needs to be reduced and more uniform tuber shape preferred by markets should be selected. Breeders must focus on creating high yielding cultivars that do not exhibit tuber branching and can withstand fluctuations in weather conditions (Enyiukwu *et al*., 2014 a,b).

Modern biotechnologies such as tissue culture, molecular markers and genetic engineering provide new opportunities for genetic enhancement of country potato as a climate resilient cash crop. Prematilake, (2005) documented callus culture regeneration in *S. rotundifolius* and this research led to the development of media for plant regeneration from leaf specimen (direct organogenesis process), to produce variants. The findings revealed discrepancies in vegetative structure, foliage color and tuber dimension among certain regenerants. The variation was predominantly observed in plants regenerated via indirect organogenesis.

Micropropagation technique has been utilized in the Division of Plant Genetic Resources, Indian Institute of Horticultural Research in Bangalore, India, was successful *in vitro* regeneration and subsequent establishment of *ex vitro*, with 85% survival rate was attained using young shoot tips and nodal portions of country potato. Additionally, nodal segments of Coleus species were identified as the most suitable ex-plant source for initiating cultures (Rajasekharan *et al*., 2010). Chemical mutagens and tissue culture technologies have been utilized to regenerate plantlets with desired variations, thereby broadening the genetic diversity of the crop. Experiments conducted by researchers using various cultivars of Country potato have revealed the production of small-sized tubers and occasionally 'branched' tubers. Future research programs need to be designed to address these issues (Murugesan *et al*., 2020).

Use of marker assisted breeding and genetic engineering approaches can accelerate development of improved varieties adapted to different agroecosystems. Target traits to enhance through biotechnology include higher nutrient content, bioactive phytochemicals, abiotic stress tolerance and yield-related factors. Realizing the breeding and biotechnology potentials requires increased investments in research focusing on Country potato and related neglected crops. Overall, the underutilized Country potato has promising untapped genetic potential to develop as a profitable food security crop if accorded research and policy priority (Yulita *et al*., 2014).

5. Conclusion

This review has highlighted the important traits of Country potato as a nutritious food crop, source of therapeutic phytochemicals, and high-value cash crop for income generation by smallholder farmers. Realizing these multifunctional potential country potato can contribute positively to achieving food and nutrition security, preventive health through dietary phytopharmaceuticals, rural income growth and ultimately, the sustainable development goals. However, the crop has remained underutilized and underexploited owing to the orphan crop status, limited awareness of its benefits among stakeholders, and inadequate scientific research to tap into the agronomic and genetic potentials. Therefore, increased investments are necessary to promote research focusing on genetic improvement, production agronomy, post-harvest handling, product development, value addition, and development of new varieties with large marketable tubers, among other priority areas. Public awareness campaigns and supportive policies are also required to create an enabling environment for mainstreaming country potato into agricultural and food systems. Implementing holistic and inclusive interventions can help overcome current limitations holding back this promising crop, thereby unlocking the full potentials for wealth and health creation. Assessing the marketing opportunities and challenges for country potato is essential. However, the primary constraints identified include photosensitivity, rapid tuber deterioration, insufficient storage methods, small tuber size, and limited availability in markets. Addressing these constraints should be a priority in future research programmes.

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Conflict of interest

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

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