



Unveiling the Therapeutic Potential of *Ipomoea Batatas* Lam: A Journey From Preclinical Research to Clinical Applications

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Abstract

Ipomoea batatas Lam, commonly known as sweet potato, has garnered recognition for its significant therapeutic potential, which can be largely ascribed to its abundant array of bioactive secondary metabolites. Among these phytoconstituents, flavonoids, anthocyanins, carotenoids and terpenoids have been shown to possess notable pharmacological properties through preclinical investigations. Evidence from *in vitro* studies utilising cell culture models indicates that these compounds exhibit robust antioxidant and anticancer activities, with anthocyanins in particular being reported to inhibit the proliferation of cancer cells. Furthermore, *in vivo* experiments substantiate the diverse therapeutic efficacy of *Ipomoea batatas*, revealing its anti-obesity, hypoglycaemic, hepatoprotective and anti-arthritic properties. Advancements in the understanding of these therapeutic attributes have facilitated the progression of extracts from *Ipomoea batatas* to clinical evaluation with subsequent assessment of safety, toxicity, pharmacokinetics and benefit-risk ratios. The transition from preclinical research to clinical validation accentuates its relevance in the realm of metabolic health, especially in combating obesity, liver dysfunction and diabetes. The successful completion of Phase III clinical trials has resulted in the introduction of plant-based antidiabetic formulations into the market, thereby reinforcing the pharmacological significance of this plant. Nevertheless, despite these promising developments, the complex interactions between the phytoconstituents and their corresponding therapeutic effects warrant further investigation. Continued research in this domain is essential, as it promises not only to enrich the understanding of the medicinal properties of *Ipomoea batatas* but also to reveal innovative therapeutic applications. Such endeavours will likely establish *Ipomoea batatas* as an esteemed natural resource within contemporary medicine.

Key words: *Ipomoea batatas*; Research; Research design; Research protocols; Therapeutics; Convolvulaceae; Sweet potatoes.

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Introduction

Ipomoea batatas Lam (mainly known as sweet potato), family *Convolvulaceae*, is a renowned perennial plant with edible properties, native to the tropical and subtropical regions of Cen-

tral and South America.¹ where it is cultivated since last 5000 years for its nutritional benefits.² This beautiful plant with diverse colours, including white, orange, purple and yellow (Figure 1)

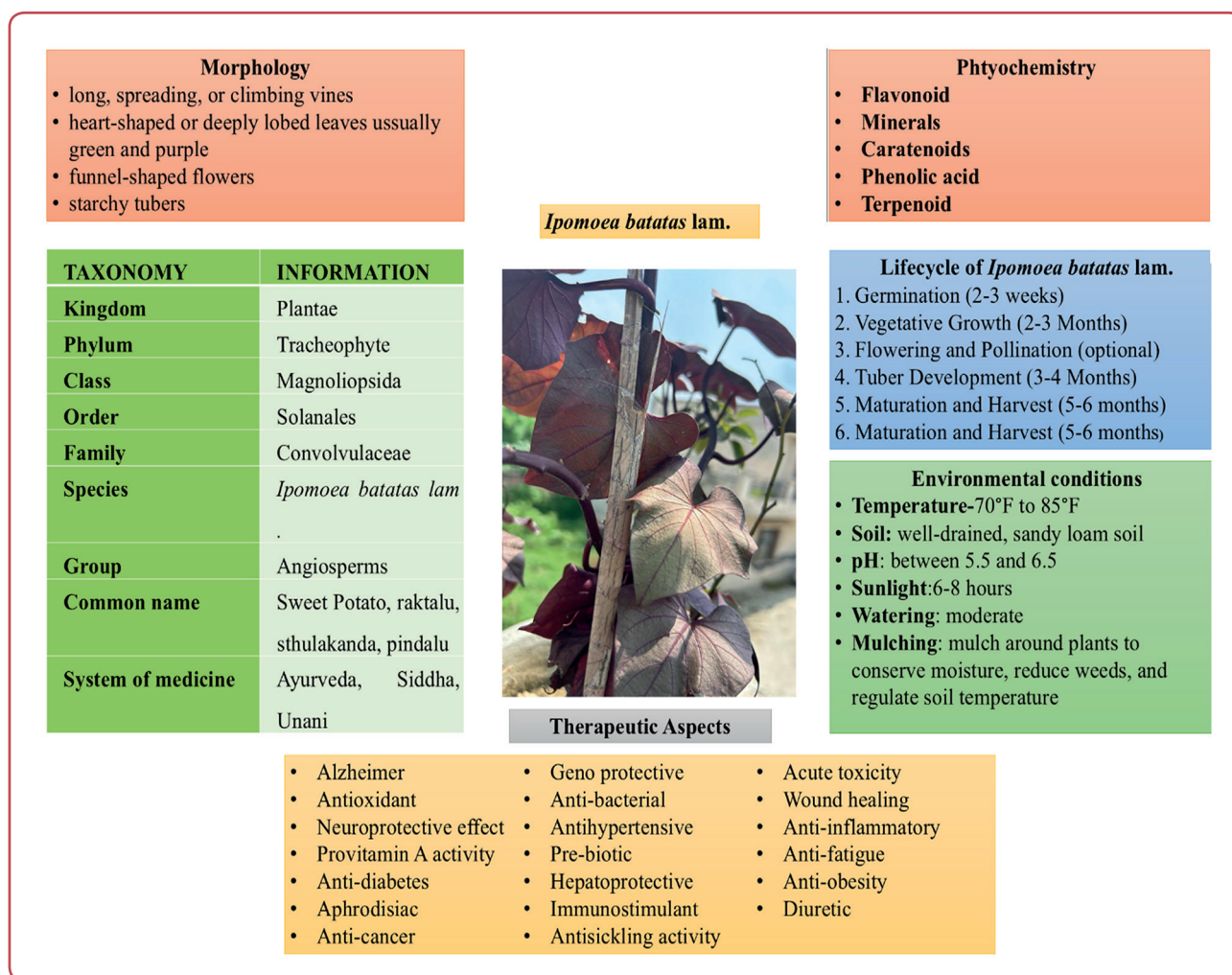


Figure 1: Pharmacognostical and therapeutic significance of *Ipomoea batatas Lam*

is a sprawling vine with elongated and creeping stems capable of extending 6 to 10 feet long and is characterised by trumpet-shaped flowers, predominantly purple or white and lobed leaves with a heart-shaped morphology.³ Under favourable growth conditions *vis* warm temperature and well-drained soil (predominantly sandy or loamy), enriched with organic matter, the sweet potatoes flourish well.^{4, 5} Although the plant is originally adapted to lowland ecosystems, it exhibits remarkable versatility, allowing it to thrive in various elevations and frequently colonise disturbed habitats, such as forest edges and clearings. This adaptability has facilitated their emergence as a significant agricultural crop worldwide with varied distribution in Europe, Asia, Africa and the Pacific.^{6, 7} Some of the significant characteristics including taxonomical classification is depicted in Figure 1.

The sweet potato holds significant cultural impor-

tance across various global communities. In Japan, the tuber has emerged as a symbol of perseverance and survival, commonly associated with period marked by economic hardship or natural disasters. Its introduction to African societies, particularly within Sub-Saharan Africa, occurred during the transatlantic slave trade, where it was embraced for its resilience to drought conditions.^{8, 9} Consequently, the sweet potato became a vital dietary staple in these regions.¹⁰ In the Southern United States, the sweet potato is especially valued, often serving as a key ingredient in celebratory dishes such as sweet potato pie and casserole. Beyond its role in everyday nutrition, the sweet potato has found its place in numerous rites and ceremonies, representing nourishment, resilience and the intrinsic relationship between humanity and the earth.^{11, 12} Thus, the sweet potato is not only a fundamental food source but also a potent cultural symbol, reflecting the diverse historical and social contexts in which it is situated.¹³

Pre-clinical applications of *Ipomea batata*

Investigation of sweet potatoes has gained significant insight in contemporary research due to the unique nutritional and functional attributes they exhibit.^{14,15} A diverse array of bioactive compounds found in sweet potato leaves and roots, includes carbohydrates, proteins, carotenoids (lutein, β -xanthin, carotene), flavonoids (hyperoside, quercetin, kaempferol), anthocyanin (cyaniding), diterpenes (phytol), phenolic acids (caffeic acid), fatty acids, saponins, tannins and minerals which have also been screened for their diversified pharmacological properties.¹⁶ Accordingly, presence of flavonoids and phenolic compounds impart antioxidant and antidiabetic efficacy,¹⁷ anthocyanins demonstrated efficacy in altering the morphology of sickle cell anaemic blood and many more. Being rich in provitamin A, it also recovers vitamin A deficit as it will be then converted into vitamin A.¹⁸ A study indicating the prebiotic action of flour of 4 varied varieties of *Ipomea batata* roots in Brazil has also been examined. The probiotic efficacy was co-related with their high fibre content.¹⁹

The hypoglycaemic effect of *Ipomea batata* has also been established owing to its potential to increase insulin secretion and tissue glucose uptake, improved insulin sensitivity and pancreatic functioning, inhibit glucose transport in intestine and inhibition of inflammatory pathways (Figure 2).²⁰ The flavonoids present in the *Ipomea batatas* L like flavones, flavonol etc provide it anti-diabetic efficiency and thus it acts as a complementary therapy for management of diabetes. Flavonoids form complex with $AlCl_3$ and Ca^{2+} which leads to glucagon-like peptide-1 (GLP-1) release. In addition, various flavonoids interact with DPP-IV strongly, thereby inhibiting GLP-1 degradation.^{17,20}

A multitude of other bioactive components have been methodically assessed by *in vivo* and *in vitro* studies, the results of which are summarised in Table 1. Additionally, clinical studies involving human subjects are further documented. This review contributes to a broader understanding of the health benefits associated with the consumption of sweet potatoes, highlighting their roles in nutrition and therapeutic applications.

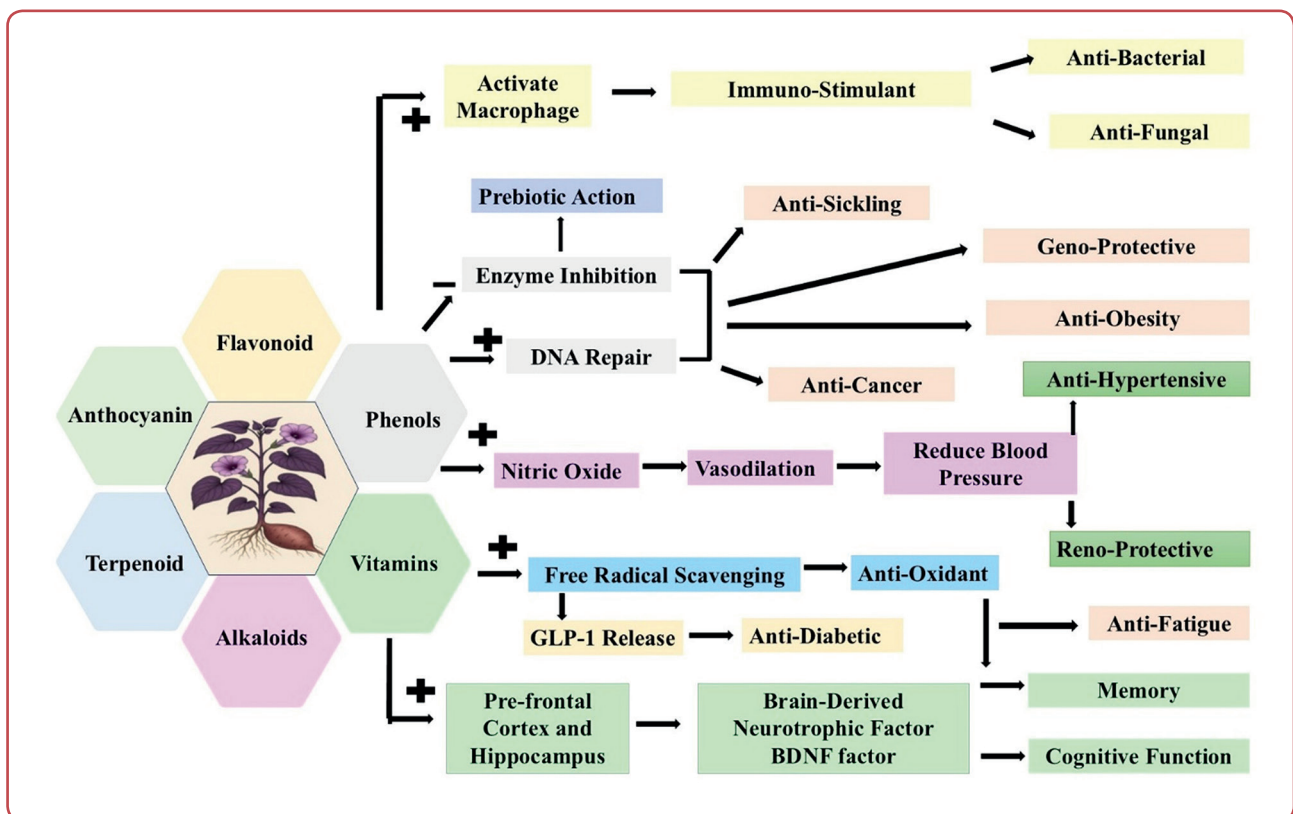


Figure 2: Therapeutic significance of *Ipomea batatas* Lam

Table 1: Pre-clinical investigation studies in *Ipomoea batatas* Lam extracts

Pharmacological activities	Plant part used	Methodology	Inference	Ref.
Alzheimer	Leaves	Amyloid-beta-peptide induce neuronal injury	Anthocyanins impeding oxidative damage, intracellular calcium influx, mitochondria dysfunction and cell apoptosis.	[21, 22]
Neuroprotective effect	Leaves	LPS-induced BV-2 microglial cells	Neuro-inflammation induced was attenuated due to antioxidant efficacy; release of pro-inflammatory mediators.	[23]
	Anthocyanins	Induced ischemic stroke	Neuroprotective effect marked by improved Bcl-2 expression and caspase-3 levels, resulting in reduced apoptotic rate.	[24]
Hypoglycaemic	Roots (methanolic extract)	Alloxan-induced diabetes	Carotenoids present decrease blood glucose and insulin resistance; Act as insulin secretagogues.	[25]
	Leaves	Alloxan-induced diabetes	Ameliorate hepatic enzyme functions	[26]
	Leaves	Streptozotocin-induced diabetes	Act as ROS scavenger and regenerate β -cells damage.	[27]
	Tubers and leaves	Streptozotocin/nicotinamide induced diabetes	Enhance pancreatic cell regeneration and ameliorate insulin resistance.	[28]
	Peel off (aqueous extract)	Alloxan-induced diabetes	Reduced oxidative stress.	[29]
	Leaves (methanolic extract)	<i>In vitro</i> test	Alpha-glucosidase, lipase and amylase inhibition.	[30]
	Leaves	<i>In vitro</i> enzymatic assays	Alpha-glucosidase and amylase inhibition.	[31]
Aphrodisiac	Tubers and veins	300 mg/kg male Sprague Dawley rats were used for aphrodisiac model BPA-induced gonadotoxicity	Stimulate testosterone secretion causing better libido and potency. Owing to antioxidant efficacy, gallic acid, rutin of <i>I. batatas</i> inhibits lipid peroxidation, thereby regulating reproductive hormone levels.	[30, 31]
Anti-arthritic and anti-inflammatory	Tuber and roots	Carrageenan-induced paw oedema (inflammation) and complete Freund's adjuvant-induced arthritis	Polyphenolic constituents ameliorate inflammation and improve oxidative stress.	[32]
Antiulcer		Aspirin-induced gastric ulcer (Rabbits)	Polyphenols present improved ulcer score, gastric volume and acid output.	[33]
	Tubers (methanolic extract)	Ethanol induced ulcer (Wistar rats)	Suppressed formation of oedema and protects gastric mucosa wrinkles.	[34]
		Cold stress and aspirin-induced gastric ulcer (Wistar rats)	Gastroprotective effect as indicated by better mean ulcer score, ulcer index with marked increase in antioxidant enzymes like GSH, SOD, CAT etc.	[35]

		Act on different cell lines like MCF- 7 (breast cancer) HeLa and ATCC-CCL-2 (uterine cancer) NB4 (leukaemia)	Blocks CdK4 and cyclin D1 protein expression and induce apoptosis, thereby, helps in treating various cancers like breast, uterine, pancreas, prostate cancer and in leukaemia.	[36, 37]
Anti-cancer	Leaves	ATCC-CCL-185	Inhibits tumour proliferation and prevents lung cancer.	
		CCK-8 and Hoechst 33342 assays and flow cytometry	SPG-56, a glycoprotein inhibited metastasis of breast cancer in MCF-7.	[38]
		MTT assay	Induce apoptosis in MCF-7 and SNU-1 cancer cells.	[39]
Genoprotective	Tubers and veins	H ₂ O ₂ -induced oxidative damage	Polyphenols reduced ROS levels and DNA fragmentation and enhance cell viability.	[29]
Antibacterial	Leaves	Gram positive and Gram negative	Polysaccharides and proteins prevent food-poisoning bacteria.	[40, 41]
Antifungal	Peel (ethanolic extract)	<i>Aspergillus niger</i> fungal strain	Polyphenols and flavonoids present are found responsible for antifungal effect.	[42, 43]
Antihypertensive	Tuber (aqueous extract)	NaCl administered hypertensive Wistar rats	Cardiovascular effects as evidenced by reduction in systolic blood pressure.	[44]
Vasorelaxation	Leaf extract		Vasodilation effect in isolated rat aorta and mesenteric vascular bed.	[45]
Anti-inflammatory and wound healing	Peel (methanolic extract)	Excision and incision wound model in Wistar rats	Antioxidative effect found responsible for the wound healing effect.	[46]
Anti-fatigue	Leaves	Weight loaded swimming test in rats	Extended exhaustive swimming time, Inhibited BLA increase; reduced SUN levels.	[47]
Anti-obesity	Plant	3T3-L1 adipocytes <i>In vitro</i>	Reduced leptin secretion, indicating suppressed fat droplets growth; enhanced lipolysis.	[48]
	Aerial parts	<i>In vitro</i> evaluation	Lipase inhibition caused by resin glycosides in aerial parts.	[49]
Diuretic	Roots (aqueous extract)	Diuretic activity using flame photometry	Carbohydrate, flavonoids, tannins in roots were found responsible.	[50]
Hepatoprotective	Leaves	CCl ₄ induced hepatotoxicity	Anthocyanins present were found responsible	[51]
		Alcohol induced liver damage	Serum ALT and AST levels got reduced.	[52]
Immuno-stimulant	Tuber	Assay of pro-inflammatory biomarkers	Inhibit production of inflammatory mediators (NO, TNF-alpha IL-6, MCP-1 and PGE-2)	[53]
	Roots	Immune function	D-glucan, a polysaccharide presents in roots act as immunostimulant.	[54]
Anti-sickling activity	Leaves	Emmel test	Anthocyanin present are found responsible for anti-sickling activity.	[55]
Renoprotective	Tuber	Uric acid induced inflammation and injury	Anthocyanins especially peonidin provide renoprotection via its antioxidant, anti-inflammatory, anti-fibrotic, anti-apoptotic mechanism. It also causes restoration of gut dysbiosis.	[56]
Anti-lithiatic	Leaves and roots	Ethylene glycol induced lithiasis in male Wistar rats	Improved diuretic index with increased diuresis	[57]

Clinical applications of *Ipomea batata*

Antidiabetic effect of *Ipomea batata*

- Effect of Caiapo (white sweet potato) in patients with type 2 diabetes

Caiapo, an extract of white sweet potatoes, is found beneficial in regulating plasma glucose and cholesterol levels in about 61 patients with type 2 diabetic patients. This was confirmed by investigating the results of different parameters like HbA(1c), cholesterol and triglycerides involved in its pathophysiology. A decrease in HbA(1c) levels along with improved cholesterol levels was observed with no significant changes in triglycerides.⁵⁸

In another study involving 18 male patients with type 2 diabetes, it was discovered that Caiapo extract reduced the insulin resistance with no effect on body weight.⁵⁹ The effect of white sweet potato in 54 elderly patients with type 2 diabetes was also found. An amelioration in all parameters including HbA(1c) levels, body mass index, the mini nutritional assessment (MNA) score and Geriatric Nutritional Risk Index (GNRI) was observed indicating the hypoglycaemic action of white sweet potato in elderly patients.⁶⁰

- Antioxidant and anti-inflammatory effect of purple sweet potato

Clinical studies involving administration of purple sweet potato leaves (200 g/day) for 14 days in 16 healthy individuals have also been conducted to observe their antioxidant efficacy. The antioxidant as well as anti-inflammatory effect was observed due to presence of enormous number of polyphenols (902 mg) present in the leaves. This antioxidant efficacy can be utilised in the management of various chronic diseases associated with oxidative stress.⁶¹

Health supplements

- Improved iron absorption in iron-deficient Malawian and Peruvian women

The impact of regular (0.55 mg Fe/100 mg) as well as biofortified (0.97 mg Fe/100 mg) sweet potato in iron-deficient Malawian and Peruvian woman has been studied in a randomised clinical trial involving about 25 women in each case for about two weeks. The cumulative erythrocyte assimilation was measured after 14 days to

determine iron absorption. The iron absorption from biofortified sweet potato was found about two folds high than regular.⁶²

- Increase in haemoglobin content in pregnant leaves

Sweet potato leaves (boiled) are used as a vegetable. Its efficacy (100 g leaves decoction for 10 days) in increasing haemoglobin content has been studied and compared with iron tablets in four pregnant females. However, more confirmation is still required in higher number of individuals.⁶³

- Impact of purple sweet potato juice on liver function and blood pressure

In Netherlands, TNO Quality of Life ran a six-month study with 40 older adults to explore how purple sweet potato (PSP) juice affects liver enzymes and blood pressure. Known for its rich anthocyanin content, PSP juice may offer various health benefits, like acting as an antioxidant and protecting the liver. Throughout the eight weeks, the researchers checked blood pressure and insulin resistance. Earlier studies in Japan also suggested improvement in liver health and blood pressure on administering PSP drinks and this research took a deeper look into those possibilities. The results shared helpful information about using PSP juice as a supplement for heart and metabolic health.

The effect of intake of purple-fleshed sweet potato beverage (125 mL in about 20 healthy adults (between 18 and 70 years of age) with high blood pressure and liver enzymes for four weeks has also been investigated in Caucasian subjects. A significant reduction in systolic blood pressure with no change in diastolic blood pressure was observed. However, the liver enzymes were found within normal range.⁶⁴

In another similar study performed in Kumamoto (Japan), the effect of purple sweet potato beverage rich in acylated anthocyanins was assessed on serum hepatic biomarkers in around 38 healthy Japanese adults (between 30 to 60 years of age), however with borderline hepatitis and higher level of liver enzymes like gamma-glutamyl transferase (GGT), aspartate transaminase (AST) or alanine aminotransferase (ALT). At the end of 8-week study, the level of hepatic biomarkers was found to be significantly reduced especially GGT.⁶⁵

Role of white sweet potatoes in weight management

In a randomised controlled trial involving 58 adults, the effect of consumption of white sweet potatoes (132 g daily for eight weeks) formula as meal replacement in regulating body weight has been assessed. From many decades, white sweet potato has been consumed as nutritious carbohydrate source in different countries like Japan, Taiwan, Brazil. After eight weeks, all the associated parameters including body weight, body fat, BMI, wrist, thigh, calf, mid-arm circumference etc were found to be significantly reduced with no adverse or side effects claiming the commercial utilisation of this weight loss formula in managing body weight.⁶⁶

Efficacy of sweet potato juice in controlling acid reflux and dyspepsia

A pilot study involving 12 male patients to assess the efficacy and tolerability of fresh sweet potato juice (100 mL twice a day for two weeks) in individuals suffering from dyspeptic symptoms like acid reflux and dyspepsia has been assessed. A significant improvement in gastrointestinal symptoms like nausea, abdominal cramps, heart burn and retrosternal discomfort was observed. In addition, vomiting, bloating, epigastric pain, loss of appetite etc were also significantly improved.⁶⁷

Pharmaceutical preparations

Hand and body lotion

The antioxidant action of formulated hand and body lotion containing *Ipomoea batatas* L peel extract has been established using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical inhibition method. In addition, the physical stability after four weeks storage at room temperature was assessed by measuring different characteristics including organoleptic properties, pH, homogeneity, phase separation, spreadability and viscosity. The results indicated very strong antioxidant activity with better physical stability.⁶⁸

Non-alcoholic beverages

The non-alcoholic beverages ie *Faara* and *Sauti* have also been prepared using sweet potato tubers with citrus lime and ginger flavour. Their pH,

total sugar content, vitamins C and A, total solids, brix, total titrable acidity were found within the ranges as specified by Ghana standard board for juices and beverages. Both preparations are however deprived of vitamin C because of heat treatment and vitamin A content is more in *Faara* than *Sauti* beverage. Sensory parameters evaluated for acceptance preference were also well accepted with ginger flavoured as most favoured.⁶⁹

As an excipient

Sweet potato starch has also been investigated as tablet excipient. To improve characteristics, it needs to be chemically modified using pentanol and glacial acetic acid. The hardness was found higher than normal starch and particle size distribution was also well accepted. Further studies to assess the capability of sweet potato starch as filler, binder and crushing agent was also suggested.⁷⁰

As protective sunscreen

The potential of its ethanolic leaves extract as active sunscreen due to high anthocyanin contents has been proven on seven adult females using patch test. Only two out of seven females observed irritation which might be assumed due to old leaves used which might vary in their phytoconstituents. Moreover, anthocyanins are in more amount in young leaves.⁷¹

As antidiabetic capsules using magnesium stearate

Due to high hypoglycaemic potential of *Ipomoea batata* L, its capsules using magnesium stearate as glidant and lubricant has been formulated. The prepared capsules were also evaluated to ensure its standards as specified per the regulations. All the parameters were found in the range specified.^{72,73}

Discussion

The literature concerning *Ipomoea batatas* Lam reveals significant therapeutic properties substantiated by robust outcomes from both preclinical animal studies and clinical trials. The plant is characterised by the presence of bioactive secondary metabolites, including anthocyanins, flavonoids and carotenoids, which are associated

with various pharmacological activities. These phytochemicals interact with different molecular and cellular pathways, leading to effects such as antioxidant, anti-inflammatory, antidiabetic, antimicrobial, neuroprotective and even anticancer properties. The antioxidant is triggered by anthocyanins and phenolic compounds, which help in neutralising free radicals and combating oxidative stress. On the other side, the anti-inflammatory side, they work by inhibiting proinflammatory mediators like tumour necrosis factor alpha (TNF- α) and interleukin 6 (IL-6), while flavonoids play a role in regulating blood sugar by blocking carbohydrate-digesting enzymes such as amylase and α -glucosidase. Moreover, the bioactive components in sweet potatoes have been found to trigger apoptosis in cancer cells and shield neurons from oxidative and inflammatory damage. These findings highlight the plant potential as a natural, safe and easily accessible source of multi-targeted therapeutic agents. The progression of multi-targeted therapeutic from pre-clinical assessments to clinical investigations has established the safety and toxicity profiles of *Ipomoea batatas*, in addition to its pharmacokinetic and pharmacodynamic properties, this transition has facilitated the advancement of viable marketed formulations derived from the plant. Among the prevalent medicinal formulations of *Ipomoea batatas* are several notable preparations like sweet potato leaf extract capsules, which are standardised for flavonoids and polyphenols and are utilised primarily for blood sugar regulation, as well as exhibiting anti-inflammatory and antioxidant action. Additionally, the sweet potato starch gel or ointment gel, created through the combination of sweet potato starch and other bioactive agents, has demonstrated efficacy in skin regeneration and moisture retention, thereby promoting wound healing and providing skin protection.

Furthermore, *Ipomoea batatas* polysaccharide tablets, are preferred to enhance gastrointestinal health, support energy levels, modulate immune responses and bolster overall immunity, represent another significant formulation. The extract of sweet potato anthocyanins, available in both liquid and powdered forms, is rich in anthocyanins and is employed for its cardiovascular, anti-cancer and antioxidant benefits. Additionally, dried sweet potato flour, often fortified with vitamins and minerals, serves as a functional food ingredient, particularly beneficial for individuals with dietary restrictions, such as those experiencing digestive issues.

While *Ipomoea batatas* is not prominently featured in widely recognised traditional Chinese medicine (TCM) formulations, it is frequently incorporated as a dietary or supportive herb rather than as a primary active component in remedies aimed at enhancing digestion and tonifying the spleen. One such example is Gan Shu Tang, also referred to as sweet potato soup decoction, a simple formulation used in TCM that aims to support digestion, alleviate exhaustion and strengthen the spleen. It is commonly recommended for individuals suffering from poor appetite and compromised digestive function.

Conclusion

Ipomoea batatas Lam has an abundant array of bioactive secondary metabolites. Among these phytoconstituents, flavonoids, anthocyanins, carotenoids and terpenoids have been shown to possess notable pharmacological properties through preclinical investigations. Evidence from *in vitro* studies utilising cell culture models indicates that these compounds exhibit robust antioxidant and anticancer activities, with anthocyanins in particular being reported to inhibit the proliferation of cancer cells. Furthermore, *in vivo* experiments substantiate the diverse therapeutic efficacy of *Ipomoea batatas*, revealing its anti-obesity, hypoglycaemic, hepatoprotective and anti-arthritis properties. Therapeutic potential of *Ipomoea batatas* Lam opens avenues for further research to establish its potential in healthcare, creating its mechanistic highlights, clinical trials expansion and formulation development combined with a novel drug delivery approach.

Ethics

This study was a secondary analysis based on the currently existing data and did not directly involve with human participants or experimental animals. Therefore, the ethics approval was not required in this paper.

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Conflicts of interest

The authors declare that there is no conflict of interest.

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Data access

The data that support the findings of this study are available from the corresponding author upon reasonable individual request.

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