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Review Article

Phytochemical compounds and pharmacological activities of *Ipomoea batatas* L.: An updated review

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Abstract

This article provides an overview of *Ipomoea batatas* L., the *Ipomoea* genus. The review covers traditional uses, nutritional value, phytochemical compounds, pharmacological activities, and toxicity studies. Data were collected from scientific databases and search engines. Sweet potatoes are used in various countries for traditional uses such as dietary fiber sources, treating allergies, and providing energy in diabetes mellitus treatment. The primary phytochemical compounds in *Ipomoea batatas* are phenolic compounds, flavonoids, anthocyanins, and carotenoids. Sweet potato contains several nutritional constituents: vitamin C, protein, fiber, carbohydrates, β-carotene, and minerals. Sweet potato exhibits various pharmacological activities, such as antioxidant, aphrodisiac, anticancer, and anti-inflammatory. The types of phytochemical compounds in each part of the plant are different. Each pharmacological activity and mechanism of action depends on the phytochemical compounds, part and variety of the plant, and extraction solvent. However, further study is required to investigate the chronic toxicity of *Ipomoea batatas*.

Keywords

Ipomoea batatas, pharmacological, phytochemical, traditional use, updated review

Introduction

Ipomoea batatas (L.) Lam. belongs to the *Ipomoea* genus, the largest species within the Convolvulaceae family (Srisuwan et al. 2018). There are several varieties of *I. batatas*, which differ based on the color of the peel and flesh of the tuber, including purple-purple, purple-orange, yellow-yellow purple, and yellow-yellow orange (YYO) (Fidrianny et al. 2018). It is a tuberous-rooted perennial plant that is usually grown as an annual. The stems form a running vine up to 4 m long and are typically prostrate and slender, with milky juice and short unbranched stems. The leaves are ovate cordate and borne on long petioles. Depending on the variety, they are palmately veined, angular, or lobed and can be green or purplish. The flowers are rare, with a funnel-shaped corolla that is white or pale purple, and are borne in cymes. The pods are round, containing 1–4 flattened, hard-coated seeds. This species is native to tropical America, India, China, the Philippines, and the South Sea Islands (Srivastava and Rauniyar 2020). Sweet potato is an economically important crop in many countries. It is the eighth most important food crop in the tropics and the sixth most important globally, following sugar cane, maize, rice, wheat, and raw milk in annual production. Although sweet potatoes originated in the Americas-Central America and the western coast of South America today, the largest cultivated areas for sweet potatoes are in China, Malawi, Tanzania, Nigeria, and Indonesia (FAO 2021).

Sweet potatoes contain various phytochemical compounds such as phenolic compounds, flavonoids, anthocyanins, carotenoids, and tannins in their roots, tubers, leaves, and stems (Vishnu et al. 2019; Abong et al. 2020). Additionally, they also contain essential nutrients like vitamin C, protein, fiber, carbohydrates, β-carotene, amylose, amylopectin, fat, and minerals (Senthilkumar et al. 2019; Obomeghei et al. 2020; Dinu et al. 2021).

Sweet potatoes have traditional uses in Malaysia, Pakistan, Philippines, Indonesia, and Tanzania, including as a source of dietary fiber, for treating allergies and anemia, and providing energy for people with diabetes mellitus (Abe and Ohtani 2013; Khan et al. 2013; Peter et al. 2014; Tan 2015; Akhter et al. 2016; Roué and Molnar 2017; Silalahi et al. 2021). Moreover, several studies have shown that the bioactive compounds in sweet potatoes have pharmacological activities such as antioxidant, aphrodisiac, genoprotective activity, anticancer, antibacterial, anti-inflammatory, antihypertensive, hypolipidemic, antidiabetic, inhibition of xanthine oxidation and hypouricemic effect, antidepressant, wound healing, prebiotic properties, anti-obesity, anti-sickling, immunostimulant, anti-fatigue, diuretic effect, and hepatoprotective.

Previous studies have indicated that sweet potatoes possess a rich medicinal history. The plant encompasses various phytochemical compounds, each harboring distinct pharmacological properties (Panda and Sonkamble 2012). Building upon these findings, the present research endeavors to provide an updated and comprehensive overview encompassing traditional uses, nutritional value, phytochemical compounds, pharmacological activities, and toxicity studies conducted between 2013 and 2022. Furthermore, this study compares the phytochemical composition and pharmacological activities across different parts of various sweet potato cultivars.

Material and methods

The information presented in this article was gathered by searching various search engines and scientific databases, including PubMed, Elsevier, Springer, Frontiers, Google Scholar, Scopus, Science Direct, and MDPI. The search terms used were related to *Ipomoea batatas*, focusing on its traditional uses, ethnomedicine, ethnobotany, nutritional composition, phytochemical compounds, pharmacological activities, toxicity, and other properties such as antioxidant, aphrodisiac, genoprotective activity, and many more. The articles selected for this review were published in the last ten years, with at least 30 published in the past two years. The report also includes a digital object identifier (DOI) for easy access and citation purposes.

Traditional use

In Malaysia, sweet potato is commonly used for making desserts and snacks, but it has the potential to be a supplementary staple to rice. Nutritionally, sweet potato is comparable to rice in terms of protein content, but it is superior in dietary fiber, certain minerals, and vitamins. Dietary fiber positively impacts diabetes, constipation, and possibly colorectal cancer. Potassium is effective against hypertension and protects against cardiovascular disease. Calcium helps build strong bones, while iron is essential for women during their childbearing years. Vitamins A, C, and E have powerful antioxidants against defects in unborn fetuses, certain cancers, and the effects of aging. Vitamin E also reduces the risk of cardiovascular disease and stroke, among other things (Tan 2015).

In Pakistan, *I. batatas* are known as "Shakarqandi" and are used to treat infertility, allergies, arthritis, cardiovascular problems, cancer, HIV, and aging, according to folklore (Khan et al. 2013; Akhter et al. 2016; Roué and Molnar 2017). In Batan Island, Philippines, *I. batatas* treats anemia and diarrhea (Abe and Ohtani 2013).

In Bulumario Village, North Sumatra, Indonesia, *I. batatas* is a carbohydrate resource that provides the energy needed and is considered safer for people with diabetes mellitus (Silalahi et al. 2021). In the northern region of the Benin Republic, sweet potato flour is regarded as a nutritional supplement for children in the fight against food insecurity and malnutrition, mainly vitamin A deficiency (Adjatin et al. 2018). Additionally, sweet potato is used by farmers in this region to cure headaches and sexual weakness, with the leaves used to treat headaches and the raw tuber used for sexual weakness.

In Southern and central Benin, the storage roots and leaves of sweet potatoes are used for the treatment or prevention of certain diseases, with suspected aphrodisiac, anti-anemic, abortifacient, wounds and burns healing, anti-microbial, purgative, analgesic, blood pressure regulator, and anti-malarial effects (Sanoussi et al. 2016).

In Mkuranga, Tanzania, *I. batatas* treat anemia, containing iron and ascorbic acid. Ascorbic acid helps to absorb non-heme iron present in these plants into the body, which justifies their potential as anti-anemics in ethnomedicine (Peter et al. 2014)

Nutritional values

Sweet potato is a plant commonly used by people for its nutritional benefits. The plant's tubers, roots, and leaves are all used as sources of nutrition due to their high content of proteins, carbohydrates, minerals, and vitamins. These plant parts contain different types of nutrients. Not much research has been conducted on the nutritional composition of stems. The nutritional constituents of different parts of *Ipomoea batatas* are presented in Table 1.

Table 1. Parts of sweet potato with nutritional constituents.

Plant part	Nutritional constituents	References
Tubers and roots	Vitamin C, Protein, fiber, carbohydrates, β-carotene, amylose, amylopectin, fat, mineral (potassium, magnesium, zinc, iron, manganese, sodium)	Senthilkumar 2019; Obomeghei et al. 2020; Dinu et al. 2021
Leaves	Protein, crude fiber, crude fat, carbohydrates, mineral (calcium, calcium, magnesium, sodium, manganese, cuprum, iron, zinc, potassium, phosphorus), vitamin C, β-carotene	Sun et al. 2014; Chirwa-Moonga, et al. 2020

Phytochemical compounds

Phytochemical compounds are bioactive compounds in various parts of sweet potatoes (*I. batatas*) that benefit human health. These include phenolic compounds, flavonoids, anthocyanins, carotenoids, and tannins (Amagloh et al. 2022). Some of these phytoconstituents give sweet potatoes a high antioxidant potential, as they possess properties such as hydrogen donating, singlet oxygen quenching, and potent reducing ability (Ali et al. 2018). The classes of secondary metabolites and phytochemical compounds in different parts of *Ipomoea batatas* are presented in Table 2.

Table 2. Parts of sweet potato with class and phytochemical compounds.

Plant part	Classes of secondary metabolites	Phytochemical compounds	References
Tubers and roots	Flavonoids	Rutin, apigenin, myricetin, and quercetin	Zhao et al. 2014; Drapal and Fraser 2019; Majid et al. 2019; Vishnu et al. 2019; Muhammad et al. 2022; Parveen et al. 2020; Shamsudin et al. 2022
	Phenolic	Gallic acid, catechin, caffeic acid	
	Anthocyanins	Cyanidin-3-O-(6”-p-hydroxybenzoylsophoroside)-5-O-glucoside and cy-3-O-(6”,6”-dicaffeoylsoph)-5-O-glc	
	Sesquiterpen	Trifostigmanoside I	
	Carotenoids	β-carotene isomer, β-cryptoxanthin, β-carotene mono-epoxides and di-epoxides, lutein epoxide, lutein, violaxanthin isomers, β-zeaxanthin isomers	
	Chlorogenic acid	5-caffeoylquinic acid, 6-O-caffeoyl-b-D-fructofuranosyl-(2-1)-a-D-glucopyranoside, trans-4,5-dicaffeoylquinic acid, 3,5-dicaffeoylquinic acid, and 4,5-dicaffeoylquinic acid	
Leaves	Carotenoids	Lutein, zeaxanthin, β-xanthine, 13 cis β-carotene, All-trans β-carotene, and β-9 cis β-carotene)	Islam 2014; Vishnu et al. 2019; Abong et al. 2020; Ameamsri et al. 2021
	Anthocyanins	cyanidin-3-O-(6”-p-hydroxybenzoylsophoroside)-5-O-glucoside [cy-3-O-(6”-p-hydroxybenzoylsoph)-5-O-glc], peo-3-O-(6”-p-hydroxybenzoylsoph)-5-O-glc, cy-3-O-(6”,6”-dicaffeoylsoph)-5-O-glc, cy-3-O-(6”-caffeoyl-6”-p-hydroxybenzoylsoph)-5-O-glc, cy-3-O-(6”-caffeoyl-6”-feruolylsoph)-5-O-glc, peo-3-O-(6”,6”-dicaffeoylsoph)-5-O-glc, peo-3-O-(6”-caffeoylsoph)-5-O-glc, peo-3-O-(6”-caffeoyl-6”-p-hydroxybenzoylsoph)-5-O-glc, and peo-3-(6”-caffeoyl-6”-feruolylsoph)-5-glc)	
	Diterpene	Phytol	
	Fatty acid	(Z)-9-Octadecenamide	
Stem	Phenolic	1,4-benzenediol (hydroquinone) and benzenesulfonic acid	Kurniasih and Saputri 2019; Obum-Nnadi et al. 2022

Pharmacological activities

Antioxidant activity

I. batatas tubers and roots exhibited antioxidant capacity in various *in vitro* antioxidant assays, with varying antioxidant capacity values for each extract. Ethyl acetate extract showed the highest antioxidant capacity compared to the ethanolic extract. The biologically proficient polyphenols in the plant extracts were attributed to their antioxidant potential (Majid et al. 2019). Furthermore, there was a high positive correlation between the concentration of phenolic content and 2,2-diphenyl-1-picrylhydrazyl (DPPH) inhibitory activity, indicating that antioxidant activity increases as the phenolic compound concentration increases (Trifonova et al. 2021). *An in silico* study showed the antioxidant capabilities of the aqueous extract of *I. batatas* tubers. The extract was found to normalize the altered levels of marker enzymes, lipid peroxidation, reactive oxygen species, mitochondrial tricarboxylic acid (TCA) cycle, and antioxidant enzymes, as well as histopathological changes caused by bisphenol A (BPA) (Revathy et al. 2017). The antioxidant activity of *I. batatas* has been attributed to the presence of flavonoids, such as anthocyanin (Savych et al. 2022). Anthocyanin purple sweet potato (APSP) could be a potential therapeutic agent for preventing Pb-caused reproductive toxicity by modulating the JNK signaling pathway and exhibiting antioxidant properties (Zhou et al. 2021). Additionally, the high-soluble dietary fiber (HSDF) of *I. batatas* inhibited oxidative stress and prevented Pb-induced renal injury (Zhang et al. 2018).

The ethyl acetate extract of purple, orange *I. batatas* tubers (PO2) exhibited the highest antioxidant activity, with the lowest IC_{50} DPPH (10.54 µg/mL) and the lowest EC_{50} FRAP (11.14 µg/mL). This was similar to another study where the ethyl acetate solvent resulted in the best activity (Dirgantara et al. 2022; Kumar et al. 2022). Moreover, PO2 demonstrated the highest total phenolic content (11.91 g GAE/100 g) and total flavonoid content (17.83 g QE/100 g) (Fidrianny et al. 2018). Another study showed that red sweet potato (SP) species have high levels of antioxidants in both the peel and pulp. The DPPH free radical scavenging potential varies among different extracts. The ethanolic extract of the peels of the red species (PERS) and the methanol extract of the pulp of the red species (PUWS) exhibited the highest antioxidant potential, with values of 90.26% and 88.59%, respectively (Naz et al. 2016). Peels of the red SP variety showed promising contents of phenolic and flavonoids. Flavonoids exhibit antioxidant properties through various mechanisms, including inhibiting the formation of reactive oxygen species (ROS) by enzyme inhibition, scavenging free radicals, and regulating antioxidant defenses (Mishra et al. 2013). Radical scavenging via hydrogen atom donation is believed to be the main antioxidant mechanism of phenolic compounds (Kumar and Goel 2019)

Sweet potato leaves' recovery and antioxidant activities are not only influenced by the part of the plant used but also by the types of extracting solvents utilized. The highest DPPH scavenging activity was found in the 50% acetone extract (36.6 mgVcE/g DM), followed by the 70% acetone extract (35.1 mgVcE/g DM), and the 50% ethanol extract (33.4 mgVcE/g DM) (Fu et al. 2016).

Aphrodisiac and gonadoprotective activities

In vivo studies have demonstrated that extracts of *I. batatas* tubers and veins possess aphrodisiac and gonadoprotective activities. These extracts have been shown to enhance sexual vigor/libido and sustain penile erections in rats, with improved sexual potency. The activity level varies depending on the type of extract used, with ethyl acetate extract being the most effective for all aphrodisiac parameters. The extracts' Polyphenols, vitamins, proteins, and iron enhance blood circulation within reproductive organs, resulting in persistent erections. In addition, polyphenols, terpenoids, tannins, anthocyanin, and zinc significantly enhance spermatogenic capacity. Furthermore, these extracts have demonstrated gonadoprotective activity, as evidenced by decreased mounting and intromission frequency and increased hesitation time of induced BPA rats (Majid et al. 2019). Specific secondary metabolites, such as rutin, quercetin, and gallic acid, have been identified and are thought to play a significant role in gonadoprotection and improve the quality of sperm. Gallic acid, a phenolic compound, can mitigate male reproductive toxicity. It achieves this by inhibiting lipid peroxidation, enhancing antioxidant status, and regulating reproductive hormone levels (Oyagbemi et al. 2016; Abarikwu et al. 2017).

Genoprotective activity

Several extracts of *I. batatas* tubers and veins have been shown to possess genoprotective activities. Polyphenols, tannins, and terpenoids in these plant extracts have been reported to scavenge free radicals and irreversibly bind to the active sites of Fe^{+2}, thus rendering it inert and preventing the Fenton reaction from completing. This protective effect has been observed against H_2O_2-induced oxidative damage to pBR322 DNA. As the generation of reactive oxygen species (ROS) was considered involved in oxidative DNA damage, polyphenol-rich *I. batatas* extracts provide a solid defense line by decreasing ROS levels and DNA fragmentation while increasing cell viability (Majid et al. 2019).

Provitamin A activity

Sweet potatoes can help alleviate vitamin A deficiency in humans by providing ample provitamin A carotenoids. These carotenoids can be converted into vitamin A. The levels of β-carotene in tuber flours from white to orange cultivars ranged from 0.19±0.08 to 22.71±0.67 µg/g dry matter (DM). The orange-fleshed varieties can potentially alleviate vitamin A deficiencies in children in rural areas of Côte d'Ivoire (Koua et al. 2018). Approximately 6 g of dry weight (DW) of orange sweet potato or 25 g of DW of other types of sweet potato can provide an appropriate and sufficient quantity of vitamin A in daily food (Kammona et al. 2015). Enriching white maize meal with 80% orange-fleshed sweet potato was estimated to increase pro-vitamin A carotenoid intake in children aged 6 to 59 months, reducing vitamin A deficiency in rural households (Mutuku et al. 2019).

Anticancer activity

Daucosterol linolenate (DLA) ($C_{53}H_{88}O_7$), daucosterol linoleate DL ($C_{53}H_{90}O_7$), and daucosterol palmitate DP ($C_{51}H_{90}O_7$) found in *I. batatas* tubers have inhibitory effects on breast cancer cell proliferation. *In vitro* studies demonstrated that all three compounds showed a more potent inhibitory effect on the MCF-7 breast cancer cell line, with DL exhibiting the strongest inhibition. Moreover, *in vivo*, studies have shown that DLA, DL, and DP can counteract the development of MCF-7 breast cancer in nude mice xenograft models (Jiang et al. 2019). As one of the phytosterols, Daucosterol induced a dose-dependent cell growth inhibition through cell cycle arrest and cell death. It also caused the depolarization of mitochondrial membrane potential and increased the ratio between Bax and Bcl-2 proteins (Vundru et al. 2013).

The anthocyanins of *I. batatas* leaves, and tubers showed a relatively stronger ability to induce apoptosis in MCF-7 breast cancer cell lines. However, leaf anthocyanins have shown a slightly higher apoptotic effect on HCT-116 and HeLa cell lines (Vishnu et al. 2019). Diets containing 10% purple sweet potato flesh, 10% purple sweet potato skin, or 0.12% anthocyanin-rich extract for 18 weeks reduced adenoma number in APCMIN mice. This reduction was attributed to the inhibition of tumor cell proliferation (Asadi et al. 2017). Anthocyanins are flavonoid compound that exhibits anticancer activity (Juwitaningsih et al. 2022) in various types of cancer, including breast cancer, anthocyanins, as one of the flavonoids class, can upregulate miR-27a. This upregulation of miR-27a reduces carcinogenesis, providing a potential therapeutic benefit in cancer treatment and prevention (Mirzaei et al. 2018).

Antibacterial activity

Methanolic extract of *I. batatas* tubers had antibacterial activities against *Staphylococcus aureus*, *Escherichia coli*, *Streptococcus pyogenes*, and *Serratia marcescens*, indicating that it can be utilized as an antibacterial. Cold extracts gave better activities than hot extracts. Antibacterial action has been demonstrated for flavonoids (Obum-Nnadi et al. 2022). Flavonoids are related to antibacterial activity by preventing bacterial cell division (Mincheva et al. 2019; Angelina et al. 2021; Satria et al. 2021).

The antibacterial activity of the extract from the peels and pulp of red and white sweet potato varieties varies based on differences in plant parts and extraction solvents. The red variety was effective against *S. aureus* and *Bacillus subtilis*, while the white variety was effective against *Pasteurella multocida* (Naz et al. 2016).

Sweet potato leaf ethanol extracts contain flavonoids, tannin, steroid, and polyphenolic compounds that show promise as an antibacterial agent for inhibiting *Bacillary dysentery*. The extract showed a significant zone of inhibition in a dose-dependent manner against *Shigella* dysenteriae ATCC 13313, with a minimum inhibitory concentration (MIC) of 10–20% w/v (Kusuma et al. 2017). Flavonoid glycosides, such as chrysoeriol-7-O-α-L-rhamnopyranosyl-(1→ 6)-β-D-(4”-hydrogenosulfate) glucopyranoside, exhibit antibacterial activity by causing cell lysis and disrupting the cytoplasmic membrane. Their action alters the membrane permeability, which leads to the leakage of cellular components and ultimately results in the death of the bacterial cells (Tagousop et al. 2018).

Antiinflamatory activity

I. batatas, both its tubers and roots, possessed anti-inflammatory properties and could alleviate oxidative stress and inflammation of acute and chronic nature. Various experimental models, such as the inhibition of heat-induced albumin denaturation assay, carrageenan-induced rat paw edema model, and croton oil-induced ear edema and anal edema model, have demonstrated the significant anti-inflammatory activity of *I. batatas* compared to control groups. Specifically, the IPR-EA extract exhibited the highest edema inhibition in models of carrageenan-induced paw edema (79.11 ± 5.47%) and croton oil-induced ear and anal edema (72.01 ± 7.80% and 70.80 ± 4.94%, respectively) (Majid 2018). Moreover, a study discovered that the ethanol extract derived from the purple sweet potato tuber, which contains anthocyanins, exhibited a capacity to decrease the levels of TNF-α and IL-6 in the liver. This suggests a beneficial effect of the extract in suppressing inflammation, potentially contributing to its anti-inflammatory properties (Artini et al. 2022).

The extract of sweet potato leaves phenolic acid compounds (SPLPA), such as caffeic acid, at a concentration of 0.2 mg/mL exhibited a significant reduction in the release of Nitric oxide (NO) and its contribution to the expression of inflammation-related factors, such as nitric oxide synthase (iNOS), tumor necrosis factor-alpha (TNF-α), interleukin 6 (IL-6), and nuclear factor kappa B (NF-kB). This extract showed a beneficial effect on the integrity of Caco-2 monolayers, indicating its potential as an anti-inflammatory agent (Zhang et al. 2022).

Antihypertension activity

The aqueous extract of purple sweet potato tuber has shown significant decreases ($p<0.05$) in systolic blood pressure (SBP) across all treatment groups. A dose of 100 mg of this extract effectively prevented the increase in SBP until the 10th day. Multiple peptic hydrolysates derived from sweet potato tuber proteins have been found to possess antihypertensive activity. This activity is achieved through the inhibition of angiotensin-converting enzyme (ACE). By inhibiting ACE, these hydrolysates help to regulate blood pressure and may have potential therapeutic benefits for individuals with hypertension. The hydrolysate with a molecular weight ranging from 1 to 5 kDa exhibited the highest activity, with an IC_{50} value of approximately 0.396 mg/mL (Wu and Lin 2017).

A clinical study showed that systolic blood pressure was significantly lower after four weeks of consuming a purple-fleshed sweet potato beverage than before ($p=0.0125$) in Caucasian individuals. Systolic blood pressure was significantly lower on day 29 compared with day 1 ($p=0.0125$) and significantly higher on day 43 compared with day 29 ($p=0.0496$). Acylated anthocyanins found in purple-fleshed sweet potatoes have been suggested to play a role in reducing blood pressure by promoting vasodilation (Oki et al. 2016).

Hypolipidemic and anti-artherosclerogenic activities

Sweet potato proteoglycans (SPG) derived from the root of sweet potato had a hypolipidemic effect. This effect was mediated through the elevation of serum HDL-C concentration via induction of lecithin-cholesterol-acyltransferase (LACT) activity, an increased ApoA-I concentration, and reduced serum lipid concentration by regulating LPL activity (Kan et al. 2014).

The hypolipidemic and anti-atherosclerotic activities of the leaves of *I. batatas* suggested that they had therapeutic potential in traditional medicine. After four weeks of treatment with the *I. batatas* leaves extract (all doses tested), all parameters such as low-density lipoprotein cholesterol (LDL-c)/high-density lipoprotein cholesterol (HDL-c) and total cholesterol (TC)/HDL-c were significantly decreased ($p < 0.01$). Treatment with both extracts (all doses tested) and atorvastatin decreased aorta thickness and surface area. However, only 500 and 600 mg/kg extract doses significantly reduced aorta thickness and surface area ($p< 0.05$). Atherosclerotic plaques were more prominent and frequent in the hypercholesterolemic control (HC) animals than in the hypercholesterolemic animals treated with the extract (Ntchapda et al. 2021). Flavonoid compounds, such as Luteolin and luteoloside, have been found to have positive effects on blood lipids and hepatic steatosis. The underlying mechanisms for these benefits may be linked to their antioxidant properties and their ability to regulate enzymes involved in fatty acid, cholesterol, and triglyceride metabolism in the liver (Sun et al. 2021).

Antidiabetic/ hypoglycemic activity

The Simon No. 1 cultivar of *I. batatas* leaves extract has been shown to have anti-diabetic properties by protecting pancreatic beta-cells and suppressing insulitis in rats induced with STZ-induced diabetes (Novrial et al. 2020). Among the phenolic acid compounds found in sweet potato leaves, ethyl caffeate was found to be the most potent inhibitor of α-glucosidase, with an IC_{50} of 70 ± 1 μg/mL, which was 6.77 times lower than that of acarbose. The tested phenolic acid and flavonoid compounds also inhibited α-amylase activity, with ethyl caffeate being the most potent inhibitor, with an IC_{50} of 8.0 ± 0.3 μg/mL, which was 13.1 times lower than that of acarbose (Luo et al. 2020).

The primary anthocyanin in purple-fleshed sweet potato, cyanidin 3-caffeoyl-phydroxybenzoylsophoroside-5-glucoside, has been found to inhibit hepatic glucose secretion and reduce blood glucose levels effectively. *In vivo*, studies of this compound have demonstrated significant reductions in fasting blood glucose levels from their initial high levels at time 0, which ranged from 186–205 mg/dL, after oral administration (Jang et al. 2019). White skinned sweet potato (WSSP) *I. batatas* roots/peel-off resulted in significant reductions ($p<0.05$) in blood glucose levels, protein glycation levels, total cholesterol, triglycerides, and low-density lipoprotein (LDL)-cholesterol levels. Furthermore, there was a significant ($p<0.05$) increase in high-density lipoprotein (HDL)-cholesterol levels following the treatment. These findings suggest that WSSP could potentially benefit from managing diabetes and improving lipid profiles (Akhtar et al. 2018).

The ethanolic extract of *I. batatas* leaf (EIBL) exhibited antihyperglycemic activity in STZ-induced rats, attributed to flavonoids acting as antioxidants-a- a linear correlation between the dose of flavonoid antioxidant agents and the antihyperglycemic activity. In addition, the study showed a positive correlation between the antihyperglycemic activity of flavonoid antioxidants and glibenclamide. The anthocyanin compounds in EIBLhelp maintain blood sugar levels by inhibiting excess sugar absorption and protecting pancreatic beta cells. (Yustiantara et al. 2021).

Inhibition of xanthine oxidation and hypouricemic activities

Anthocyanin-rich purple sweet potato extract (APSPE) derived from dried purple sweet potato powder has a hypouricemic effect in hyperuricemic mice by inhibiting xanthine oxidase (XO) activity both *in vitro* and *in vivo*. *In vitro*, APSPE was found to significantly inhibit XO activity in a dose-dependent manner. *In vivo*, APSPE inhibited XO activity in mouse liver and reduced serum uric acid levels in hyperuricemic mice (Zhang et al. 2015a). APSPE also effectively inhibited XO activity with an IC_{50} value of $7.194 \pm 0.858 \times 10^{-5}$ mol cyanidin-3-glucoside (C3G) equivalent L. *In silico* studies showed that the most potent XO inhibitory compounds were found in fraction 3, including cyanidin 3-sophoroside-5-glucoside, cyanidin 3-(6”-caffeoyl-6”-feruloyl sophoroside)-5-glucoside, and peonidin 3-(6”-caffeoyl-6”-feruloyl sophoroside)-5-glucoside (Zhang et al. 2017). In addition, 25 mg/kg double acylated anthocyanins from purple sweet potato (HAA-PSP) were found to have a greater ability to reduce uric acid levels and inhibit key enzymes in the uric acid production pathway compared to APSPE (Yang et al. 2020).

Antidepressant activity

An *in silico* study has shown that cyanidin-3-O-glucoside and peonidin-3-O-glucoside, a major anthocyanin found in purple sweet potato tubers, have potential health benefits as an antidepressant candidate. The mechanism of action of these compounds involves their interaction with the D2 dopamine receptor (Kurnianingsih et al. 2021).

Wound healing activity

A 1% gel formulated with ethanolic extract of *I. batatas* root peels showed the most significant wound-healing effect in mice within all treatment groups. The secondary metabolites in *I. batatas*, such as gallic acid, kaempferol, rutin, catechin, and quercetin, possess potent anti-inflammatory properties. They block neutrophil infiltration, reducing TNF-α, IL-1β, and NO levels. Anthocyanins complement this effect by inhibiting pro-inflammatory cytokines and NF-κB, further reducing inflammation (Jeong et al. 2013; Xu et al. 2013; Majid et al. 2018; Silva-Correa et al. 2021).

The ointment based on white sweet potato tuber at 2.5 effectively triggered the healing of a cutaneous wound, as evidenced by the increased number of cells undergoing metaphase and tissue re-epithelialization, regardless of the time of wound treatment (4.5-fold increase, $p< 0.01$). The re-epithelialization process was also significantly more intense in wounds treated with the *I. batatas* ointment than those treated solely with Beeler’s base. Specifically, it was 43% and 75% more intense in wounds treated with the ointment for 4 and 10 days, respectively. White sweet potato’s wound healing properties may be linked to the presence of carotenoids and (poly)phenols in its tubers. These compounds help control excessive free radicals produced during inflammation, facilitating and promoting healing (Hermes et al. 2013).

In vitro assay, they demonstrated that sweet potato tip and tuber extracts from the anthocyanin-high cultivar ‘Sinjami’ showed a 75% wound healing effect in the 100 μg/mL treatment group. In the 32 μg/mL treatment group, Sinjami tubers exhibited a 90% wound healing effect. These findings suggest that the anthocyanin compounds found in sweet potato extracts might serve as a natural wound healing agent, primarily due to their influence on the inflammatory response (Hong et al. 2022).

Prebiotic activity

Root sweet potato (RSP) flours from four different varieties, two with white peel (Rainha branca and Campina branca) and two with purple peel (Vitória and Lagoinha), have varying levels of fiber, resistant starch, fructooligosaccharides (FOS), phenolic compounds, and sugars. These flours showed to have positive prebiotic activity scores with probiotic strains, indicating their ability to selectively stimulate beneficial bacteria (*Lactobacillus acidophilus*, *Lactobacillus casei*, and *Bifidobacterium animalis*) while limiting enteric competitors (de Albuquerque et al. 2020).

Microbial cultivations showed that Peonidin (P1, P2, P3, P4, P5) and purple sweet potato anthocyanin (PSPAs) of purple sweet potato (PSP) could induce the proliferation of *Bifidobacterium bifidum*, *Bifidobacterium adolescentis*, *Bifidobacterium infantis*, *and Lactobacillus acidophilus* (Sun et al. 2018a).

Sweet potato fiber extract (SPFE) from Bestak has a prebiotic activity score similar to FOS but higher than inulin. The growth of Lactobacillus plantarum Mut7 was found to be significantly higher in the SPFE substrate (3.21 log CFU/ mL), while *Bifidobacterium longum* grew better in the FOS substrate (2.19 log CFU/mL). The highest prebiotic activity score was obtained for *L. plantarum* Mut7 grown on SPFE (1.62). SPFE exhibits high prebiotic activity due to its rich content of prebiotics like fructooligosaccharides (FOS), inulin, and raffinose. (Lestari et al. 2013).

Antiobesity activity

High-dose purple sweet potato color (PSPC) administration to high-fat diet (HFD) rats significantly ($p<0.01$) reduced obesity, compared with HFD-treated rats, with no significant difference between PSPC and control group rats. PSPC's anti-obesity effects are likely due to flavonoids like anthocyanins, which reduce oxidative stress and regulate leptin/AMPK signaling in the hypothalamus (Zhang et al. 2015b).

Consuming sweet potato leaves with a high-fat diet (HFD) can have an anti-obesity effect. The group that ingested a 5% freeze-dried powder of sweet potato leaves (SPLP) showed a significant decrease in weight gain and adipose tissue weight without reducing feed intake. Polyphenols in SPLP could affect the blood lipid composition and dietary fiber (Kurata et al. 2017).

The effects of fermented purple sweet potatoes (PSP) on obese mice showed that their administration suppressed body weight gain and abnormal expansion of white adipose tissues. Anti-obesity effects of PSP may be due to its ability to induce adipose browning and exert antioxidant action, thus protecting the mice from the adverse effects of a high-fat diet (Lee et al. 2021).

Antisicikling activity

Anthocyanin extract from sweet potato leaves reversed sickle-shaped erythrocytes in SS blood to a standard biconcave form. The extract has a practical anti-sickling effect, particularly in hypoxic conditions. The plant's antisickling activity is due to anthocyanins' ability to interact with proteins, competing with abnormal hemoglobin S polymerization and preventing sickling of sickle cells (Mpiana et al. 2014).

Immunostimulant activity

Sweet potato tubers' fiber extract (SFE) facilitated IgM production by HB4C5 cells with heat and dialysis treatments and positively affected immunostimulatory activity *in vitro* (Kumalasari et al. 2020). The 18.3 kDa homogeneous polysaccharide component of purple sweet potato tuber (PSPP-1) improved the RAW264.7 immune functions of phagocytic activity and nitric oxide, reactive oxygen species, and cytokine production. PSPP-1 was also shown to activate toll-like receptor 2 and toll-like receptor 4-mediated pathways, with significant improvements in the expressions of proteins in MyD88-dependent, mitogen-activated protein kinase (MAPK)-signaling, NF-κB-signaling, AP-1 signaling, and TRIF-dependent pathways (Ji et al. 2021). Sweet potato glycoprotein (SPG-1) increased immune activity with a dose-response effect, as indicated by the measurement of serum lysozyme activity and T cell immune response (Xia et al. 2015).

Anti-fatigue activity

The anti-fatigue effects of total flavonoids from sweet potato leaf (TFSL) were found to be significant. TFSL was able to extend the total swimming time of mice, effectively inhibit the increase of blood lactic acid (BLA), decrease the level of serum urea nitrogen (SUN), and increase the hepatic and muscle glycogen content (Li and Zhang 2013).

Diuretic activity

Aqueous extract of *I. batatas* root (AEIB) dose-II (400 mg/kg, p.o) significantly ($p<0.01$) increased the diuresis in total urine volume mL/100 g/h. The diuretic could be due to presence of Carbohydrate, flavonoids and Tannins. (Sucharitha et al. 2016). The diuretic mechanism of action of AEIB is currently unknown. However, previous studies suggest that flavonoid compounds, like quercetin, exert their diuretic activity by binding to the adenosine A1 receptor, which is associated with diuretic effects (Aswini et al. 2020).

Hepatoprotector activity

Administration of sweet potato leaf extract (SPLE) resulted in a significant reduction ($p<0.05$) in cholesterol and triglyceride levels compared to the negative control group. Among the different doses tested, 200 mg/kg body weight of SPLE exhibited the most effective outcome in decreasing serum glutamic pyruvic transaminase (SGPT) and serum glutamic oxaloacetic transaminase (SGOT). Quercetin in SPLE acts as an antioxidant, scavenging free radicals to protect the liver from oxidative damage. This leads to reduced SGOT and SGPT enzyme activity, demonstrating its liver-protective effect (Mahfudh et al. 2021).

Water-soluble polysaccharides (PSWP) derived from purple sweet potato tuberous roots exhibited a potential protective effect against acute liver damage induced by CCl l_4. Among the various polysaccharides tested, PSWP showed the strongest hepatoprotective effect. Purple sweet potato polysaccharides, especially PSWP, exhibit hepatoprotective effects through free radical scavenging by antioxidant enzymes, alleviation of lipid oxidative stress, and elevation of GSH and T-AOC levels (Sun et al. 2018b).

Purple sweet potato anthocyanins (APSPE) have shown good hepatoprotective activity against CCl_4-induced liver damage. APSPE inhibited the increase of liver weight effectively and protected the liver by decreasing the release of aspartate transaminase (AST) and alanine transaminase (ALT). Furthermore, APSPE increased the activity of superoxide dismutase (SOD) and the content of glutathione (GSH) while reducing the content of malondialdehyde (MDA) in mice livers, indicating a potential therapeutic effect against liver damage (CCl_4-induced). (Wang et al. 2016). Anthocyanins might be responsible for the observed anti cytolytic effects (Seniuk et al. 2021).

Toxicity

In vivo, the study showed that the plant extracts did not reveal any significant changes in behavioral patterns, toxicity, or mortality during the specified period during acute toxicity evaluation. The administered doses ranging from 100 to 2000 mg/kg in rats were considered safe as no deaths were recorded in the experimental groups, and no observable signs of toxicity were noted (Majid et al. 2019). The investigation also was performed at doses of 300–4000 mg/kg of rats. Some *I. batatas* extract, namely IPT-EA, IPT-M, IPR-EA, and IPR-M extracts, were found safe up to the highest 4000 mg/kg (Majid et al. 2018). The LD50 of purple sweet potato extract is greater than 5,000 mg/kg bw (Damayanti et al. 2022). While the aqueous leaves and stem extracts did not show mortality up to 10 mg/kg body weight, and the acute oral LD_{50} value was 12.0 ± 1.2 g/kg (Adeyemi et al. 2015). This latest toxicity information contradicts previous studies that indicated a potential for liver damage (Panda and Sonkamble 2012).

In vitro, cytotoxicity study by Hoechst 33342 Live Cell Staining showed that purple sweet potato root tuber and leaf anthocyanins had no cell toxicity at several concentrations (100–400 µg/mL) (Vishnu et l., 2019). *I. batatas* presented no IC_{50} values indicating high cell viability (59.67 ± 0.83–63.34 ± 0.85). This plant might be safely applied to treat diseases (Ameamsri et al. 2021).

Conclusions

The types of phytochemical compounds in each part of the plant are different. Each pharmacological activity and mechanism of action depends on the phytochemical compounds, part and variety of the plant, and extraction solvent.

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