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Chapter - 2

Amorphophallus paeoniifolius: A Vital Medicinal Tuber

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Abstract

Amorphophallus paeoniifolius (Dennst.) Nicolson, also known as elephant foot yam, is a perennial herb in the Araceae family. In Southeast Asian countries, it grows wild and is cultivated as a vegetable. In many parts of the world, the rounded tuberous rootstock or corm is an important source of food. Additionally, the plant, particularly the corm, has traditionally been used to treat tumours, inflammations, rheumatism, haemorrhoids, arthralgia, elephantiasis, bronchitis, asthma, dyspepsia, colic, constipation, splenopathy, hepatopathy, amenorrhea, dysmenorrhea, seminal weakness, fatigue, general weakness, and other ailments. The corm has antioxidant, antibacterial, hepatoprotective, apoptotic, anticancer, antidiabetic, hypolipidemic, immunomodulatory, analgesic, anti-inflammatory, nephroprotective, neuroprotective, anthelmintic, anticonvulsant, CNS-depressant, anti-colitic, anxiolytic, and anti-osteoporotic properties, according to reports. Many phytochemicals have been reported in the tuber of *A. paeoniifolius*, including diterpenoids, triterpenoids triacontane, saponin, rutin, lupeol, betulinic acid, gallic acid, resveratrol, quercetin, stigmasterol, β sitosterol, and its palmitate. Additionally, the elephant foot yam has been found to contain thiamine, riboflavin, niacin, carotene, glucose, galactose, rhamnose, and xylose as major nutritional constituents. The presence of various active phytochemicals in the plant is thought to be responsible for the plant's diverse pharmacological properties, lending credence to the traditional claim of medicinal properties for a wide range of disorders. As *A. paeoniifolius* is a promising plant for human health, steps should be taken to encourage its cultivation as well as the development of products for improved nutritional and therapeutic use.

Keywords: *Amorphophallus paeoniifolius*, *Amorphophallus campanulatus*, elephant foot yam, corm, tuber, medicinal plants, pharmacological activities.

Introduction

Dietary habits have a significant impact on health and disease. While some foods can aggravate chronic illnesses, others have powerful medicinal and protective properties. Medicinal food plants are those plants whose consumed parts have been identified as therapeutic in traditional medicine, ethnomedicine, or biomedicine. Medicinal foods are considered to possess the potential to improve health, and general well-being, and reduce the risk of certain diseases [1]. *Amorphophallus paeoniifolius* (Dennst.) Nicolson (Elephant foot yam), is a highly promising tropical tuber crop in the Araceae family. It's a common vegetable in Indian cuisine and a good source of macro and micronutrients. Ayurveda, India's oldest medical system, mentions this tuberous vegetable in various forms. *Amorphophallus paeoniifolius* root extract has traditionally been used to treat piles, dysentery, and acute rheumatism. In addition, the elephant foot yam is used in Ayurvedic medicine to treat tumours, inflammations, haemorrhoids, arthralgia, elephantiasis, bronchitis, asthma, dyspepsia, colic, constipation, splenopathy, hepatopathy, amenorrhea, dysmenorrhea, seminal weakness, fatigue, general weakness, etc. The culinary and medicinal value of this tuber has made it popular in many parts of the world. *Amorphophallus paeoniifolius* tuber is grown and consumed widely in Southeast Asian countries such as India, the Philippines, Malaysia, and Indonesia. It has also gained the status of a cash crop in India due to its high production potential, market acceptability, and profitable economic returns, with a production potential of 50-80 t/ha [2–4]. Phytochemical and pharmacological activities of elephant foot yam have been researched extensively. The nutritional and therapeutic potentials of *A. paeoniifolius* tuber are the main focus of this chapter.

Chapter content

Taxonomic Classification [5]

Kingdom	Plantae
Subkingdom	Viridiplantae
Infrakingdom	Streptophyta
Superdivision	Embryophyta
Division	Tracheophyta
Subdivision	Spermatophytina
Class	Liliopsida
Order	Alismatales
Family	Araceae

Subfamily	Aroideae
Genus	*Amorphophallus*
Species	*paeoniifolius*

Synonyms

Amorphophallus campanulatus Blume ex Decne., *Amorphophallus bangkokensis* Gagnep., *Amorphophallus campanulatus* Decne., *Amorphophallus gigantiflorus* Hayata, *Amorphophallus dubius* Blume, *Amorphophallus microappendiculatus* Engl., *Amorphophallus rex* Prain ex Hook. f., *Amorphophallus paeoniifolius* var. *campanulatus* (Decne.) Sivad., *Amorphophallus sativus* Blume, *Amorphophallus virosus* N.E. Br., *Arum campanulatum* Roxb., *Arum phalliferum* Oken, *Arum decurrens* Blanco, *Arum rumphii* Gaudich., *Conophallus sativus* (Blume) Schott, *Dracontium paeoniifolium* Dennst., *Hydrosme gigantiflora* (Hayata) S.S. Ying, *Candarum rumphii* (Gaudich.) Schott, *Hydrosme gigantiflorus* (Hayata) S.S. Ying, *Plesmonium nobile* Schott

Common names

Elephant foot yam, Sweet yam, Elephant yam, Leopard palm, Stanley's washtub, Telinga-potato, White-spot giant arum, Cheeky yam, Corpse plant, Stink lily, and Voodoo lily [6, 7].

Distribution

Amorphophallus is primarily found on Pacific islands and throughout Asia. The species is indigenous to Asia's tropical regions. It grows wild in Sri Lanka, Philippines, Malaysia, Indonesia, and other Southeast Asian countries. It can also be found in India, China's south, New Guinea, Australia's north, and Polynesia. Elephant foot yam is widely available throughout India. Kerala, Tamil Nadu, Maharashtra, Uttar Pradesh, Odisha, Punjab, Bihar, Assam, Bengal, and Sikkim are among the states where they are widely grown [6, 8].

Vernacular names [3, 6]

Vernacular names in foreign languages	
Arabic	Batata El-Feel
Brazil	Inhame Gigante
Burmese	Wa
Chinese	Bai Ban Mo, Bai Ban Mo Yu
Czech	Zmijovec Zvonovitý
Danish	Elefantyams

Fijian	Daiga, Vaaga, Via Gaga, Viamiloa
French	Kouniak D’annam, Pomme De Terre De Télinga
Greek	Elephantini Dioscorea
Japanese	Koniaku, Konjac, Konnyaku
Laos	Duk Düa, Houo Ka Bouk, Kabuki
Malaysia	Hakai
Nepali	Wol
Philippines	Alu Pahi, Bagong
Sri Lanka	Kidaran
Thai	Buk Khang
Vietnam	Khoai Nưa, Nưa Chuông
Vernacular names in Indian languages	
Assamese	Ol, Ol-kochu
Bengali	Ole, Shuran
Gujarati	Suran
Hindi	Suranakand, Zaminkand, Alu, Jangli Suran, Kanda, Madana Masta, Gandira
Kannada	Suvarna gedde, Choorna Gedde, Kanda Gedde
Malayalam	Chena, Kattuchena, Kattuchenai, Cena Karana.
Manipuri	Haopan
Marathi	Suran
Oriya	Oluo, Owa, Samba, Farasi
Panjabi	Jimikand, Zimikand
Sanskrit	Suurana, Kanduula, Arshoghna, Kand-ayak, Vajrakanda.
Tamil	Senai Kizhangu, Sallaraikilangu, Karnai Kilangu
Telugu	Kanda gadda, Manchi- Kindaguddae, Thiya-Kandha
Urdu	Zamin-qand, Zamikand, Suran

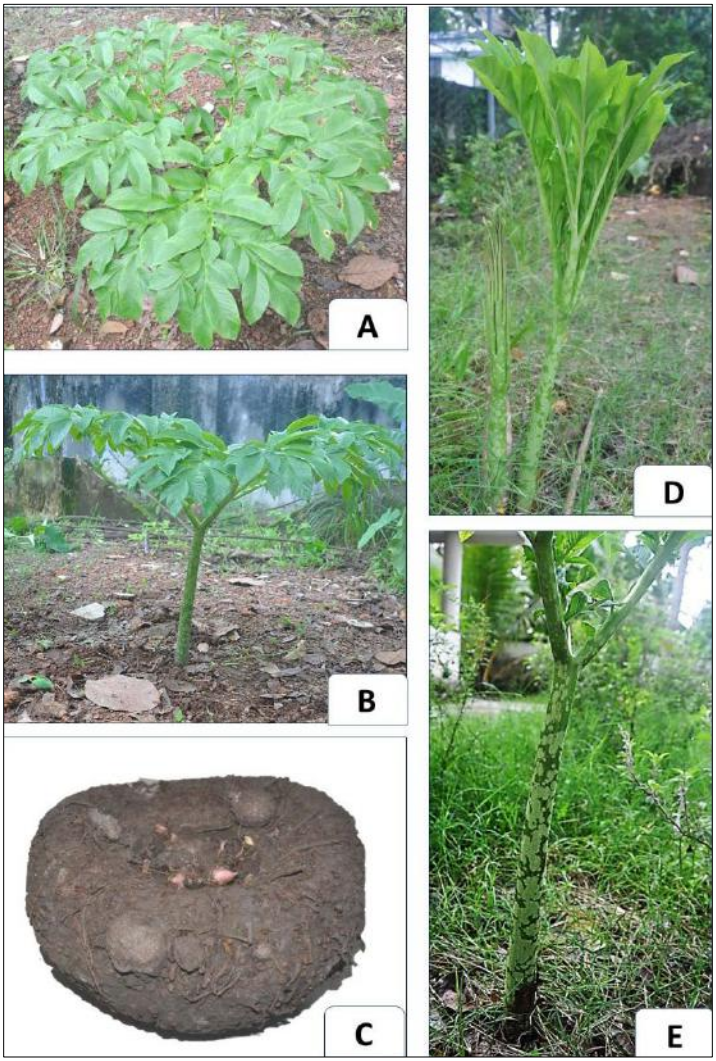

Fig 1: *Amorphophallus paeoniifolius* A). Leaf B). Plant C). Corm (tuber) D). Young Plant E). Petiole

Botanical description

Amorphophallus paeoniifolius is an annual herbaceous plant that grows to a height of 2.5 m from a perennial subterranean corm.

Corm: Its underground stem produces hemispherical depressed dark brown edible tubers with a diameter of around 30 cm and a height of about 20 cm at the base of the single compound leaf. If left unharvested, it will continue

to grow in size each year. By the end of the first year, corms can weigh up to 7 kg. Planting material for the next crop is corm sections weighing up to 0.5 kg.

Leaf: The genus *Amorphophallus* produces only one petiole with a single umbrella-like compound leaf at the top, making it unique among food crops. The leaf blade is divided into hundreds of leaflets and can grow to be over 1 m wide. This blade is attached to a thick fleshy stem with a diameter of up to 13 cm and a height of up to 2 m. The stem's pustular surface is attractively blotched with paler green shades. The leaves are compound, 3-partite, large, solitary, 60-90 cm long, with 5-12.5 cm long leaflets, variable in width, and heavily nerved. The blade bifurcates and eventually divides into obovate or oblong, acuminate, and decurrent lobes. The petiole is stout, long, and variegated.

Inflorescence: A single inflorescence is produced by this plant, which is followed by a solitary leaf. The entire inflorescence is 40-50 cm tall and 30-40 cm wide. Flowers are small, yellowish, and crowded into a very stout column (spadix). Female flowers are found on the lower part of the spadix, while male flowers are found on the top, with a transitional zone in between. The large spadix consists of a bulbous purple knob atop it, surrounded by a fleshy purple and green-blotched spathe up to 50 cm in diameter. The fresh inflorescence emits a rotting flesh-like odour to attract pollinating carrion flies and beetles.

Fruit: The fruiting zone features numerous 2 cm long cylindrical berries that mature from green to bright red, attracting birds and squirrels [6, 7, 9, 10].

Nutritional Importance

A foodstuff's nutrient and anti-nutrient composition influence its value as a source of food for human consumption. The nutrient content of *A. campanulatus* tubers varies depending on where they're grown, the soil, the season, the water, and the climate. The presence of oxalate, phytate, tannin, and hydrogen cyanide in a food limits its use and harms consumers. Koni *et al*., [11] evaluated the nutrient value, mineral content, and anti-nutrient content of *A. campanulatus* tubers collected in Indonesia. Crude protein (1.126±0.101%), crude fat (1.173±0%), and crude fibre (3.447±0.142%) were among the nutrients found in *A. campanulatus* flour. Phosphorus (1443.33±34.185 mg kg^{-1}), Calcium (8535.76±543.75 mg kg^{-1}), and Magnesium (1512.39±89.28 mg kg^{-1}) were among the minerals found. Oxalates (318.51±3.2 mg kg^{-1}) tannins (0.46±0.04%), cyanide (35878±0.402 ppm), and phytates (0.165±0.015%) were found in the anti-nutrient analysis.

According to the findings of this study, *A. campanulatus* tuber has a high nutritive value and mineral content, making it suitable for human consumption. It must, however, be processed before consumption due to its low anti-nutrient content.

Almost all essential macro and micronutrients can be found in the tuber of *Amorphophallus campanulatus*. It also has low-fat content and a high fibre and carbohydrate content. Thus, the tuber can help to alleviate micronutrient and macronutrient deficiencies as well as increase food security. Basu *et al*., [4] conducted a study in India and reported the nutritional composition of the tuber as follows: (Table 1).

Table 1: Nutritional Composition of *Amorphophallus paeoniifolius* tuber

Proximate composition of the tuber (g/100g dry weight)	
Moisture	66.08 ± 1.98
Total carbohydrate	25.54 ± 6.52
Protein	9.81 ± 2.5
Soluble carbohydrate	6.67 ± 1.65
Fibre	5.7 ± 1.2
Ash	4.83 ± 0.54
Fat	1.414 ± 0.79
Vitamin content (mg/100g dry weight)	
Ascorbic Acid	76.65 ± 10.5
Alpha-Tocopherol	900.00 ± 15.54
Beta Carotene	0.19 ± 0.05
Lycopene	2.03 ± 0.58
Mineral content (mg/100g dry tissue)	
Sodium (Na)	14.2 ± 0.59
Potassium (K)	1208 ± 5.66
Calcium (Ca)	19.524 ± 2.66
Magnesium (Mg)	81.98 ± 6.54
Manganese (Mn)	0.394 ± 0.25
Iron (Fe)	1.794 ± 0.57
Chromium (Cr)	0.012 ± 0.05
Zinc (Zn)	2.058 ± 0.48
Copper (Cu)	0.332 ± 0.09
Boron (B)	0.37 ± 0.06

According to another Indonesian study, the tuber of A. *paeoniifolius* had a high content of dietary fibre (13.71%) and protein (7.20%) but a low-fat content (0.28%). Furthermore, the corm had a low glycaemic index (GI) of 42, as well as low starch in-vitro digestibility (61.75%), indicating that this tuber is a low GI (<55) food [12].

Traditional medicinal uses

In China, Japan, and Southeast Asia, the corm of *A. campanulatus* has long been used as a food source and traditional medicine. The tuber of *A. campanulatus* has been used to treat enlarged spleens, rheumatism, and tumours for hundreds of years. In Indian traditional medicine, the tubers are used as an appetizer, expectorant, aphrodisiac, irritant, and anti-catarrhal. The corm of *A. campanulatus* is also used to treat liver complaints, inflammation, vomiting, cough, bronchitis, asthma, arthralgia, and dyspepsia. Carminative, restorative, stomachic, and tonic properties are all attributed to the tuber [6, 13]. In addition, the tuber is used to treat anaemia, fatigue, intercostal neuralgia, pimples, seminal weakness, amenorrhea, dysmenorrhoea, throat swelling, and general debility [3, 8]. The dried corm is used to treat piles and dysentery. In ethnomedicinal practices, it is consumed by various Indian tribes for the relief of constipation, haemorrhoids, and colic [14]. The tuber is widely used in South India as a folk remedy for acute rheumatism, lung swelling, asthma, vomiting, tumours, and abdominal pain [6]. Traditional healers in the Palakkad district of Kerala, India, used *Amorphophallus paeoniifolius* as one of the most important plant species for dermatological infections/diseases and gastrointestinal disorders [15]. Dropsy, toothache, dyspepsia, urinary diseases, rheumatism, boils, fistula, haemorrhoids, colitis, diuretic, piles, elephantiasis, and glandular swellings are all treated with Elephant Foot Yam in Sri Lanka [16]. The tubers of *A. campanulatus* are used in the Philippines to treat boils and haemorrhoids, as well as to make antirheumatic poultices [6].

Pharmacological properties

In the development of current therapeutic systems, drug discovery from natural sources in light of ethnopharmacological studies plays an important role. Ethnopharmacology is defined as "the interdisciplinary scientific exploration of biologically active agents that have traditionally been used." Pharmacognostic, phytochemical, and pharmacological studies of traditional medicinal plants have recently received a lot of attention. Furthermore, many preclinical and clinical studies have looked into the biological activity potential of natural medicines, revealing a wide range of biological effects of

plant-derived compounds in various chemical groups [17]. Thus, pharmacological studies on *A. paeoniifolius* are reviewed here in order to learn more about its potential as a therapeutic candidate in the drug development process. Its tuber has been touted as a promising dietary and medicinal source, with the following benefits.

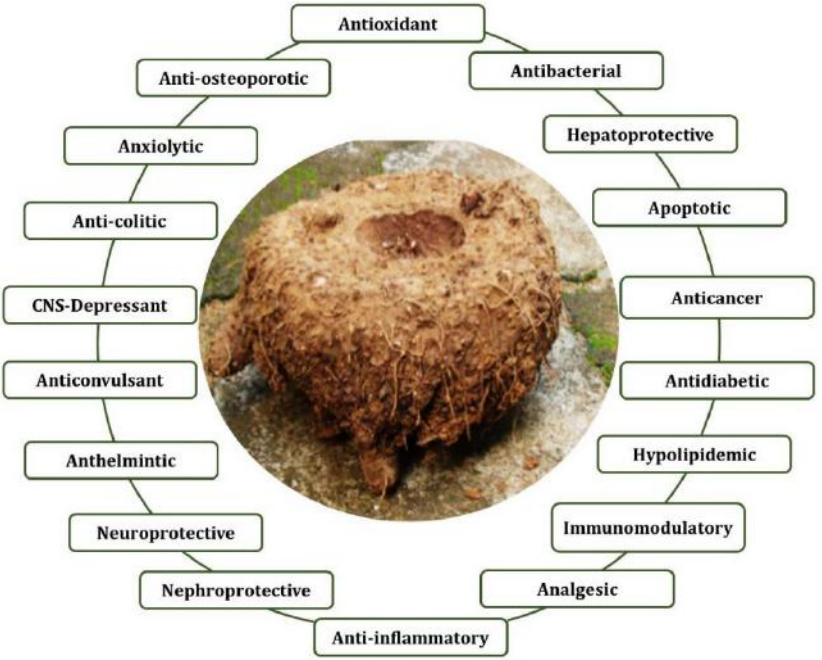

Fig 2: Important pharmacological properties of *A. paeoniifolius* tuber

1. Antioxidant

In vitro and *in vivo* studies have shown that the methanolic extract of *A. campanulatus* tuber has significant antioxidant activity. In response to thioacetamide (TAA)-induced oxidative stress, methanolic extract of the tuber at a dose of 250 mg/kg significantly lowered the levels of hepatic and renal oxidative stress markers such as catalase (CAT), glutathione peroxidase (GPx), glutathione reductase (GR), glutathione-S-transferase (GST), reduced glutathione (GSH), and lipid peroxidation (Thiobarbituric acid reactive substances). The phenolic and flavonoid content of the methanolic extract of *A. campanulatus* tuber may explain its antioxidant effect [13]. Another study showed that the ethanolic extracts of *A. campanulatus* tubers have higher antioxidant activity than their aqueous extracts [18].

A. campanulatus tuber extracts were also tested for their ability to protect human erythrocytes and leucocytes from H_2O_2-induced oxidative damage. Methanol, ethanol, acetone (70%), and hydro-alcohol (1:1) extracts of *A. campanulatus* tuber were tested for antioxidant effects. On human erythrocytes and leucocytes, *A. campanulatus* treated groups showed effective reductions of CAT, superoxide dismutase (SOD), GPx, and increased GSH and lipid peroxidation (LPO) levels when compared to the H_2O_2 alone treated group. In comparison to the other extracts tested, the methanolic extract of the tuber of *A. campanulatus* appears to have the best protective effect against H_2O_2-induced oxidative damage. In addition to their use as a potential source of natural antioxidants for the treatment and prevention of disease involving lipid peroxidation, tuber extracts may appear to be beneficial in preventing H_2O_2-induced oxidative RBC damage and can improve RBC membrane permanence [19]. These findings suggest that the tubers of *A. campanulatus* could be used as a natural antioxidant source.

2. Antibacterial

The disc diffusion method was used to evaluate the bactericidal efficiency of ethyl acetate, ethanol, acetone, chloroform, and petroleum ether extracts of *Amorphophallus campaulatus* dried tuber. The study included six gram-negative bacteria, including *Escherichia coli, Serratia marcescens, Enterobacter amnigenus, Klebsiella pneumoniae, Klebsiella oxytoca,* and *Brevibacterium paucivorans,* as well as four gram-positive bacteria, *Staphylococcus haemolyticus, Staphylococcus lentus, Staphylococcus aureus, and Bacillus cereus*. Ethanol, acetone, and chloroform tuber extracts had the highest antibacterial activity, followed by ethyl acetate and petroleum ether, among the various solvent extracts examined [20]. Antimicrobial screening of *Amorphophallus campanulatus* corm was also carried out in another investigation. Antibacterial activity against four harmful bacteria was found to be significant. *Staphylococcus aureus, Pseudomonas aeruginosa, Vibrio cholerae,* and *Proteus mirabilis* were among the bacteria used. To determine the zone of inhibition, methanolic and petroleum ether extracts were used. A relatively little amount of petroleum ether extracts has a strong inhibitory effect on the organism described [21].

3. Hepatoprotective

Many studies have shown that various extracts of the *A. campanulatus* tuber have hepatoprotective properties in different experimental models. The hepatoprotective activity of ethanolic extracts of *A. campanulatus* tubers against carbon tetrachloride (CCl4)-induced hepatic damage in rats was

investigated in a study. The daily oral administration of the extract at a dose of 500 mg/kg significantly reduced the markedly increased serum enzymatic levels toward normalization. Histopathological examination of rat liver sections supplemented the biochemical observations. The presence of flavonoids in *A. campanulatus tuber* extracts could confer a free radical scavenging potential, explaining its potent hepatoprotective activity [18]. Singh *et al*., [22] also reported that the methanolic extract of *A. campanulatus* tuber had hepatoprotective activity against acetaminophen-induced hepatic injury in albino rats. Another study found that a methanolic and aqueous extract of *A. campanulatus* tuber had a hepatoprotective effect in rats against paracetamol-induced liver damage that was nearly identical to that of the standard drugs silymarin and Liv-52 [23]. The ethanolic extract of the tuber showed potent hepatoprotective action in adult male albino Wistar rats in another experimental model of ethanol-induced hepatic damage, particularly by scavenging free radicals and combating oxidative stress [24].

Furthermore, the protective and curative potential of two different doses of methanolic extract of *A. campanulatus* tuber (125 and 250 mg/kg; p.o.) against thioacetamide-induced liver damage and oxidative stress in male Wistar rats was assessed. The extract's dose-dependent hepatoprotective and curative activity was supported by serum biochemical parameters, levels of hepatic and renal lipid peroxides, glutathione antioxidant systems, catalase, and histopathological studies. These findings suggest that *A. campanulatus* tuber may reduce oxidative damage caused by free radicals and that it could be used as the main ingredient in medical foods and nutraceuticals to treat oxidative stress-related disorders. *A. campanulatus*' antioxidant and hepatoprotective activity also renders scientific support to its use in traditional medicine for the treatment of liver diseases [13, 25].

4. Apoptotic/Cytotoxic

i) Breast cancer cell lines - MCF-7 and MDA-MB-231

The hydroethanolic extract of *A. paeoniifolius* tuber (APTE) showed promising apoptotic/anticancer activity in breast cancer cell lines. APTE induces apoptosis in the less metastatic MCF-7 cell line in a caspase-7 dependent and p53 independent way. The extract, on the other hand, is extremely effective at preventing the aggressive breast cancer cell line MDA-MB-231 from metastasis. In these cells, APTE caused apoptosis in a caspase-7-dependent way. HR-LCMS analysis of the active fractions identified multiple anticancer chemicals that may work singly or in combination for the extract's apoptotic/anticancer/antimetastatic activity [2].

ii) Liver cancer cell line - PLC/PRF/5

On the human liver cancer cell line PLC/PRF/5, the dose-dependent cytotoxic and apoptosis-inducing effects of the subfractions of *A. campanulatus* tuber methanolic extract (ACME), namely petroleum ether fraction (PEF), chloroform fraction (CHF), ethyl acetate fraction (EAF), and a methanolic fraction (MeF) were studied. MTT assay was used to investigate the antiproliferative effects of the ACME subfractions. 4′,6'-diamidino-2-phenylindole (DAPI), annexin V-fluorescein isothiocyanate (FITC), and 5,5',6,6' tetrachloro-1,1',3,3'-tetraethylbenzimidazolylcarbocyanine iodide (JC-1) fluorescence staining were used to determine apoptosis. 5-flurouracil (5-FU), a chemotherapeutic drug, served as a positive drug control. The ACME subfractions were shown to cause significant cytotoxicity in the PLC/PRF/5 human liver cancer cell line. Furthermore, the extracts were proved to cause apoptosis, as evidenced by DAPI, annexin V-FITC, and JC-1 fluorescent staining. The cells treated with 5-FU and CHF showed the most marked cytotoxic and apoptotic activity, whilst EAF and MeF treated cells showed a moderate outcome, and PEF treated cells showed the least effect. Additionally, these data show that ACME sub fractions reduce PLC/PRF/5 cell proliferation by triggering apoptosis in a dose-dependent manner [26].

iii) Colon cancer cell line - HCT-15

On the colon cancer cell line HCT-15, the dose-dependent cytotoxic and apoptosis-inducing effects of the subfractions of *A. campanulatus* tuber methanolic extract (ACME) *viz*. petroleum ether fraction (PEF), chloroform fraction (CHF), ethyl acetate fraction (EAF), and a methanolic fraction (MEF) were evaluated. The antiproliferative activities of ACME subfractions were investigated using the MTT assay. DAPI, Annexin V-FITC, and JC-1 fluorescence staining were used to examine apoptosis activity. 5-flurouracil (5-FU), a chemotherapeutic medication, was utilized as a positive drug control. The ACME subfractions effectively reduced HCT-15 cell growth in a dose-dependent manner. Apoptosis was also induced by the extracts, as evidenced by DAPI, Annexin V-FITC, and JC-1 fluorescent staining. The cells treated with 5-FU and CHF showed the most marked cytotoxic and apoptotic activity, whilst EAF and MEF treated cells showed a moderate outcome, and PEF treated cells showed the least effect. The findings revealed that CHF, one of the ACME subfractions, has high cytotoxic and apoptotic activity, and so could be investigated as a new target for anticancer drug development. These results reveal that ACME subfractions inhibit the growth of HCT-15 cells by triggering apoptosis [27].

iv) Plant and animal cell cytotoxicity

The cytotoxicity of various solvent extracts of *Amorphophallus paeoniifolius* tuber was investigated using two *in vitro* systems: *Allium cepa* L. root tip cells and the HEp-2 cell line. When compared to other solvent extracts, the mitotic index and cytotoxic index of *A. campanulatus* tuber were found to be high in petroleum ether and ethanol fractions. On HEp-2 cells, these two solvent fractions showed dose-dependent antiproliferative activity [28].

v) Anticancer

a) Anti-colon cancer activity

In a long-term preclinical model of 1, 2-dimethylhydrazine (DMH) induced colon carcinogenesis in male Wistar rats, the effects of *Amorphophallus campanulatus* tuber methanolic extract (ACME) on aberrant crypt foci (ACF) formation, colonic cell proliferation, lipid peroxidative damage, and antioxidant status were investigated. Biochemical and histological tests were performed on the intestinal and colonic tissues at the end of the 30-week study period. Intestinal and colonic lipid peroxidation (MDA) and antioxidants like catalase, glutathione peroxidase, glutathione reductase, glutathione-S-transferase, and reduced glutathione were significantly reduced ($p \leq 0.05$) after DMH administration. In DMH-intoxicated rats, ACME supplementation significantly ($p \leq 0.05$) improved intestinal and colonic MDA and reduced glutathione levels and antioxidant enzyme activities. The formation and multiplicity of ACF were also significantly reduced when ACME was administered. Furthermore, DMH-treated rats had increased expression of PCNA in the colon, while the oral administration of ACME showed decreased expression of this proliferative marker in all the experimental groups, including initiation, post-initiation, and the entire period. These findings suggest that ACME may have a significant chemopreventive effect on DMH-induced colon carcinogenesis [29].

b) Anti-hepatic cancer activity

The researchers looked into the effect of *Amorphophallus campanulatus* tuber methanolic extract (ACME) on N-nitrosodiethylamine (NDEA)–induced hepatocellular carcinoma (HCC) in rats. In a dose-dependent manner, ACME significantly reduced the NDEA-induced increase in hepatic nodule incidence, nodule multiplicity, and serum biochemical markers, as well as improved the hepatocellular architecture. The biochemical analysis of hepatic tissues revealed that ACME mitigates NDEA-induced oxidative stress by restoring antioxidant enzymes. NDEA-treated rats had increased expression

of proliferating cell nuclear antigen in the liver, while ACME supplementation resulted in decreased expression of this proliferative marker. Notably, ACME supplementation with 250 mg/kg body weight outperformed the other treatment regimens [30].

c) Anti-mammary tumour activity

The anticancer activity of *Amorphophallus paeoniifolius* (Dennst.) extract (APTE) against oestrogen positive MCF-7 and triple-negative MDA-MB-231 breast cancer cell lines was investigated. In MCF-7 and MDA-MB-231 cells, APTE had a considerable cytotoxic activity that was dosage and time-dependent. Wound healing, collagen adhesion, and transwell matrigel invasion assays were used to investigate the influence of APTE on metastatic parameters such as migration, adhesion, and invasion in MCF-7 and MDA-MB-231 cells, respectively. In all cell lines, APTE inhibited migration; however, its effect on adhesion and invasion inhibition was greater in MDA-MB-231 cells. Annexin V-Cy3 staining indicated that APTE promoted apoptosis in these cells, which was confirmed by the reduction of antiapoptotic Bcl-2 and activation of pro-apoptotic Bax, Caspase-7 expression, and PARP cleavage. Several anticancer compounds were discovered using high-resolution liquid chromatography-mass spectroscopy with bioactive ethyl acetate and butanol fractions of APTE. The work added to a growing list of naturally occurring chemo-preventive techniques by describing the mechanism of anticancer action of the edible tuber, *A. paeoniifolius* [2].

Another *in vivo* study investigated the impact of an ethanolic extract of *Amorphophallus paeonifolius* (AP) tubers on DMBA-induced mammary cancers in rats. The ethanolic extract of *A. paeonifolius* tubers was found to significantly reduce DMBA-induced oxidative stress, as evidenced by the normalization of antioxidant status in AP-supplemented animals. The effects of AP-extract on tumor latency and tumor burden were found to be extremely significant, with a $P \leq 0.001$ significance level. The effectiveness of the AP extract treatment was also evidenced by a decrease in mammary tumor incidences. These findings demonstrate that the ethanolic extract of *A. paeonifolius* has potent antitumor and antioxidant properties in laboratory animals [31].

d) Antidiabetic

The effect of 0.1 and 0.25% acetone extract of elephant-foot yam in the diet of streptozotocin-induced male Wistar diabetic rats was investigated. Water intake, diet intake, urine output, body weight gain, urine sugar, fasting blood sugar (FBS), and glomerular filtration rate (GFR) were all measured in

the rats. About all of the above-mentioned parameters, a concentration-dependent improvement in diabetic status was observed. The findings clearly show that an acetone extract of elephant foot yam is an effective anti-diabetic agent in streptozotocin-induced diabetic rats [32]. Another study used Swiss albino mice to test the antihyperglycemic potential of a methanol extract of *Amorphophallus campanulatus* corms. In glucose-loaded mice, oral glucose tolerance tests were used to determine the antihyperglycemic activity. When mice were given the extract at doses of 50, 100, 200, and 400 mg per kg body weight, blood glucose levels in glucose-loaded mice were reduced by 28.8, 29.1, 35.3, and 37.4%, respectively. Glibenclamide, a common antihyperglycemic drug, reduced blood glucose levels by 40.7% when given at a dose of 10 mg per kg of body weight. Thus, at the highest dose tested, the extract had nearly the same antihyperglycemic potency as glibenclamide [33]. According to these findings, *A. campanulatus* tuber could be used as a therapeutic dietary source to reduce diabetes complications.

e) Hypolipidemic

The combined effects of Mung bean (*Vigna radiata*) and Elephant foot yam (*Amorphophallus paeoniifolius*) on serum lipids and atherogenic indices in albino rats were evaluated, and the results were compared to a standard drug Cholestyramine. In rats, the Drug powder at 1080 mg/kg bw and 2160 mg/kg bw significantly ($p \leq 0.01$) reduced total cholesterol, triglycerides, low-density lipoprotein, and very-low-density lipoprotein levels, and increased high-density lipoproteins (HDL). Atherogenic indices such as Castelli Risk Index I, Non-HDL C/HDL, Castelli Risk Index II, TG/HDL, Atherogenic coefficient, and Atherogenic Index of Plasma all improved significantly ($p \leq 0.01$). When compared to the bile acid sequestering agent Cholestyramine, the combination of mung bean and yam significantly lowered serum lipid levels as well as atherogenic indices in albino rats. Mung bean and yam have long been staples in Asian cuisine. By becoming a mainstay of non-pharmacological medicines against dyslipidemia, the combination offers hope for lowering the high coronary artery disease risk among Asians [34].

f) Immunomodulatory

Using charcoal clearance, spleen index, and delayed-type hypersensitivity (DTH) response models, the effect of a methanol extract of *Amorphophallus campanulatus* tuber on immunological function in mice was investigated. Orally, the extract was given in doses of 250 and 500 mg/kg. The methanolic extract of the tuber had immunomodulatory activity, lowering charcoal clearance, spleen index, and DTH response significantly. By facilitating the

footpad thickness response to sheep red blood cells (RBC), methanolic extract of the tuber reduced the charcoal clearance rate and cellular immunity in sensitized mice [35].

g) Antinociceptive/Analgesic

In Swiss albino mice, the antinociceptive potential of a methanol extract of *A. campanulatus* corms was investigated. An intraperitoneally administered acetic acid-induced pain model in mice was used to determine antinociceptive activity. The extract reduced the number of abdominal constrictions induced by intraperitoneal administration of acetic acid by 30.4, 33.3, 42.4, and 45.5%, respectively, when given to mice at doses of 50, 100, 200, and 400 mg per kg body weight. In comparison, when given at doses of 200 and 400 mg per kg body weight, aspirin, a standard antinociceptive drug, reduced the number of abdominal constrictions in mice by 27.3 and 36.4%, respectively. It shows that even at the lowest dose, the methanol extract of elephant foot yam outperformed aspirin. The findings suggest that *A. campanulatus* tubers contain phytoconstituents with antinociceptive properties [33].

Shilpi *et al*., [36] reported that *A. campanulatus* tuber has analgesic properties. In Swiss albino mice, oral administration of the tuber's methanol extract at doses of 250 and 500 mg/kg suppressed the frequency of acetic acid-induced writhing in a dose-dependent manner. Another study investigated the *in vivo* analgesic activity of a methanol extract of *Amorphophallus paeoniifolius* tuber. In male Swiss albino mice, intraperitoneal administration of a methanol extract of the corm (250–500 mg/kg body weight) had dose-dependent analgesic activity in the tail-flick and acetic acid-induced writhing response tests. The plant may contain phytoconstituents that inhibit the cyclooxygenase enzyme, resulting in peripheral analgesia, or act on central opioid receptors, resulting in central analgesia [37]. Aqueous extract of *Amorphophallus paeoniifolius* has also been reported to have analgesic activity due to peripheral and central inhibition of prostaglandin synthesis [38].

h) Anti-inflammatory

Amorphophallus paeoniifolius tubers are anti-inflammatory and have traditionally been used to treat inflammation. Petroleum ether, chloroform, methanol, and water were used to extract the tubers in that order. The extracts were tested in a carrageenan-induced paw edema model in rats at doses of 200 and 400 mg/kg for anti-inflammatory activity. For comparison, the standard drug diclofenac sodium was given at doses of 5 and 10 mg/kg. The triple responses in guinea pigs were measured for antihistaminic effect, and isolated guinea pig ileum preparation was used for bioassay. The results show that only

the methanol extracts have significant anti-inflammatory activity. The anti-histaminic activity of the methanol extract is also demonstrated by the bioassay and triple response results [37].

i) Nephroprotective

Amorphophallus campanulatus was studied for its nephroprotective properties against chronic alcohol-induced oxidative stress and tissue damage. For 30 days, rats were given an ethanolic extract of *A. campanulatus* as well as ethanol [(40 percent w/v)^2 g/kg body weight/day] to see if it had any nephroprotective effects against alcohol toxicity. Renal antioxidant enzymes, serum urea, creatinine, and proinflammatory cytokines were all measured biochemically. Hematoxylin and Eosin, periodic acid Schiff, Feulgen and Picrosirius stain were used to detect histomorphological and histochemical changes. The terminal deoxynucleotidyl transferase dUTP nick end labelling (TUNEL) assay technique was used to determine the degree of apoptotic cell death. In the EtOH group, serum urea, creatinine, pro-inflammatory cytokines, tissue TBARS, and glutathione metabolising enzyme activity were significantly ($p \leq 0.01$) elevated, whereas cytosolic and mitochondrial superoxide dismutase, catalase, and levels of reduced glutathione were significantly ($p \leq 0.001$) decreased. Supplementing the EtOH group rats with ethanolic extract of *A. campanulatus* (ACE) reversed these effects to normal levels. Furthermore, ACE supplementation reduced degenerative changes in renal cells caused by alcohol treatment. ACE supplementation also reduced glycogen and deoxyribonucleic acid depletion, excess fibrosis due to collagen deposition, and increased apoptotic cell number, with the higher dose showing the most prospect. Thus, ACE treatment reduced ethanol-induced nephrotoxicity due to the extract's antioxidative and antiapoptotic properties. The presence of various bioactive components in the tuber could explain the extract's reported nephroprotective effects. According to the findings, *A. campanulatus* tuber can be used as a regular nutrient or as a therapeutic agent to protect renal cells [39].

j) Neuroprotective

In Alzheimer's disease (AD) rats, the neuroprotective effect of *Amorphophallus campanulatus* (AC) tuber was investigated. AD was induced by giving streptozotocin (STZ) (3 mg/kg, ICV) on the 1st and 3rd days following surgery. A stereotaxic apparatus was used to perform surgery on anesthetized rats. For 14 days, STZ-induced AD rats were given petroleum ether extract of AC (100, 200, and 500 mg/kg, p.o.). The effect of AC tuber on AD rats was determined by measuring changes in behaviour (Y maze

apparatus and single trail passive avoidance), biochemical parameters in brain tissue (oxidative stress parameters (SOD, CAT, and LPO), amyloid β peptide (Aβ) and acetylcholinesterase (AchE), and histopathological examination of brain tissue. When compared to AD rats, AC treated rats demonstrated a substantial (p<0.01) increase in the percent of change in behaviour and step-through delay in the Y maze task and single-trial passive avoidance test. AC treatment considerably lowers A1-40, A1-42 peptides, and AchE in brain tissue when compared to AD rats (p<0.01). Furthermore, AC therapy significantly lowered oxidative stress in AD rats. Treatment with AC extract lowers the production of amyloid plaques in the brain tissue of AD rats, according to histopathological analysis. And the study suggests that AC extract has a neuroprotective effect in AD rats by lowering oxidative stress, Aβ, and AchE in brain tissue [40].

k) Anthelmintic

The antihelmintic effectiveness of methanolic extracts of the tuber of *Amorphophallus paeoniifolius* against *Pheretima posthuma* and *Tubifex tubifex* was examined. The extract was evaluated at doses of 25, 50, and 100 mg/ml for the time of paralysis and the time of death of the worms. At the highest dose of 100 mg/ml, the extract showed considerable anthelmintic action. The standard reference was piperazine citrate (10 mg/ml), while the control was pure water. The extracts were discovered to not only paralyze but also kill earthworms (vermicidal). The traditional use of *A. paeoniifolius* tubers as an anthelmintic has also been confirmed, as the tuber's methanolic extract showed significant activity against the worms used in study [41]. Another study looked at the phytochemical and anthelmintic properties of the corm of *A. campanulatus*. Petroleum ether, chloroform, and methanol were used to extract the corm. The methanol extract was used to isolate crude tannins. Anthelmintic activity was tested on all extracts and crude tannins. The anthelmintic activity was found in chloroform extracts, methanol extracts, and crude tannins. Crude tannins resembled Albendazole in terms of paralysis and death times [41].

l) Anticonvulsant

The anticonvulsant activity of the tuber of *A. paeoniifolius* was studied. The effects of petroleum ether extracts of *A. paeoniifolius* at doses of 200, 300, and 400 mg/kg on the onset of convulsion in the Isoniazid (INH) induced mice model were investigated. The standard drug was diazepam, at a dose of 4 mg/kg. In terms of the onset of convulsions, petroleum ether extracts of the tuber showed dose-dependent activity. The experiment revealed that *A. paeoniifolius* has anticonvulsant properties. [42].

m) CNS-Depressant

It was also claimed that the said tuber's petroleum ether extract had central nervous system depressant activity. The extracts significantly (P<0.05) reduced locomotor activity and grip of the rotating rod when given intraperitoneally at doses of 100, 300, and 1000 mg/kg body weight. The standard drug diazepam showed a significant reduction in activity when compared to the control group of animals. A dose of 1500 mg/kg of petroleum ether extract of *A. campanulatus* tuber has also been proven to be a safe dose. The extract caused sedation and a decrease in locomotor activity in mice, according to the findings. Furthermore, the observed activity of the petroleum ether extract of *A. campanulatus* tuber in decreasing central nervous system activity was dose-dependent [43]. Dey *et al* [44] also observed that the petroleum ether extract of *A. paeoniifolius* has CNS depressant activity. Phenobarbitone and diazepam, both well-known CNS depressants, also showed dose-dependent CNS depressant activity. The petroleum ether extract had a significant synergistic effect with diazepam, but only a minor synergistic effect with phenobarbitone. Both phenobarbitone and diazepam act on the $GABA_A$ receptor to depress the central nervous system. The $GABA_A$ receptor is made up of five subunits (α, 2β, γ, δ). The benzodiazepine-binding sites are on the α subunit, while the barbiturate-binding sites are on the β subunit. Phenobarbitone and diazepam bind to their specific binding sites and produce their effects. The CNS depression activity of petroleum ether extract with diazepam is more synergistic than phenobarbitone. Because the petroleum ether extract had a synergistic effect with diazepam but not with phenobarbitone, the components in the extract may bind to the subunit and facilitate GABA-mediated Cl- channel opening, hyperpolarizing the cell and causing CNS depressant effects. Diazepam is an agonist for the benzodiazepine receptor. As a result, the extract has agonistic activity with benzodiazepine receptors, possibly comparable to diazepam.

n) Anti-colitic

The corm of *A. paeoniifolius* is used ethnomedicinally to treat various gastrointestinal and inflammatory disorders. The effects of extracts of *A. paeoniifolius* tubers on acetic acid-induced ulcerative colitis (UC) in rats were investigated in a study. The methanol extract (APME) or aqueous extract (APAE) (250 and 500 mg/kg) or the standard drug, prednisolone (PRDS) (4 mg/kg) were given orally to Wistar rats for 7 days. On the sixth day of treatment, UC was induced by injecting 4 percent acetic acid (AA) transrectally, and colitis was assessed 48 hours later by measuring colitis parameters, biochemical estimations, and colon histology. Pretreatment with

APME or APAE significantly reduced AA-induced weight loss and increased colitis parameters such as stool consistency, colon weight/length ratio, and ulcer score, area, and index ($p < 0.05$ - 0.001). The use of extracts reduced the increase in alkaline phosphatase and lactate dehydrogenase in serum, as well as myeloperoxidase activity and cytokines in colon tissue, caused by the administration of AA ($p < 0.001$). Treatment with extracts prevented AA-induced lipid peroxidation, superoxide dismutase, and catalase activity decline reduced glutathione content ($p < 0.05$ - 0.001), as well as histopathological changes. PRDS had a similar anti-inflammatory effect on colitis. Inflammation and oxidative damage in the colon was reduced by APME and APAE, which had a preventive effect on UC. The presence of phytochemicals, betulinic acid, β-sitosterol, and glucomannan may be responsible for the effects. Therefore, the corm of *A. paeoniifolius* had anti-colitic properties due to its anti-inflammatory and antioxidant properties (Dey *et al*., 2017).

o) Anxiolytic

Using various animal models of anxiety, a study was designed to investigate the anxiolytic activity of petroleum ether extract of *A. paeoniifolius* tuber in mice. The anxiolytic properties of a petroleum ether extract of the tuber were tested in mice at different doses (100, 150, 200 mg/kg p.o) using various animal models of anxiety, including the elevated plus maze, open field test, and light & dark test. For elevated plus maze and open field tests, the petroleum ether extract showed potent anxiolytic activity in a dose-dependent manner. In the light and dark tests, however, the extract failed to show any significant anxiolytic activity. According to the findings, a petroleum ether extract of *A. paeoniifolius* tuber could be a powerful anxiolytic agent in mice [46].

p) Anti-osteoporotic

In an ovariectomized rat model of osteoporosis, petroleum ether extract of *Amorphophallus paeoniifolius* (PEAP) and β-Sitosterol were tested for anti-osteoporotic activity. PEAP (100 and 300 mg/kg, p.o.) and β-sitosterol (120 mg/kg, p.o.) treatment of ovariectomized rats began on the 60th day after ovariectomy and lasted for 45 days. On the 1st and 45th days of treatment, serum biochemical parameters (alkaline phosphatase (ALP), calcium, and inorganic phosphorous) were measured. At the end of treatment, histopathology and biomechanical parameters (BMD, bone weight, length, and thickness, uterine weight, force at break, bone ash calcium content) were assessed. In ovariectomized rats, treatment with PEAP and β-sitosterol resulted in significant re-mineralization of bone, preventing a rise in serum

ALP, Calcium, and Phosphorous levels. The post-ovariectomy weight gain was prevented in the treatment groups. The anti-osteoporotic effect of PEAP and β-sitosterol, which is equivalent to standard Raloxifene, was supported by an increase in BMD and calcium content in bone ash. Increased trabecular thickness and decreased osteoclast formation were seen in histological results, indicating that PEAP and β-sitosterol have a protective effect by promoting bone formation and suppressing bone resorption. Because of its high content of phytoestrogen β-sitosterol, these findings suggest that PEAP has remarkable anti-osteoporotic activity. As a result, it could be a promising candidate for treating postmenopausal osteoporosis [47].

Pharmacological activities of the phytoconstituents of *A. campanulatus*

Many studies found phytoconstituents in *Amorphophallus paeoniifolius* tuber extracts using a qualitative assay. Petroleum ether, ethyl acetate, hexane, chloroform, methanol, and water extracts were tested for the presence of various phytoconstituents. Alkaloids, steroids, fats, and fixed oil are found in petroleum ether extract. Ethyl acetate and hexane extracts contain alkaloids, flavones, steroids, carbohydrates, and saponins. Alkaloids are present in the chloroform extract. The methanol extract, on the other hand, contains alkaloids, steroids, flavonoids, tannins, glycosides, phenols, saponins, and carbohydrates. The aqueous extract is tested for flavonoids, tannins, proteins, and carbohydrates [48-50].

In the corm, several bioactive compounds with potent pharmacological properties have been reported that belong to the above-mentioned major classes of phytoconstituents. The tubers of *Amorphophallus campanulatus* consist of a variety of phytochemicals with promising pharmacological properties (Table 2). It possesses betulinic acid, β- sitisterol palmitate, β-sitisterol, stigmasterol, lupeol, and triacotane. The tuber also contains saponin, rutin, thiamine, riboflavin, niacin, and carotene. Glucose, galactose, sharp calcium oxalate crystals, rhamnose, and xylose are also present. Because of the presence of a diterpenoid called salviasperanol, a triterpenoid called amblyone, and a flavonoid called 3,5 diacetyltambulin, the corms are said to have antibacterial, antifungal, and cytotoxic properties [51-55]. Furthermore, due to the presence of polyphenols such as gallic acid, resveratrol, and quercetin, Angayarkanni *et al.,* [56] reported antioxidant activity for the ethanolic extract of *A. paeoniifolius*. D-galactose, D-glucose, 4-O-acyl-Dmethyl galacturonate, and L-arabinose were found in a 2:1:1:1 molar ratio in a water-soluble polysaccharide isolated from the aqueous extract of *Amorphophallus campanulatus* corm. This molecule was found to activate splenocytes [57]. In another study, a polysaccharide konjac glucomannan with a molecular weight

of 1.115×10^6 daltons and moisture uptake of 8.37% was isolated from the tuber of *Amorphophallus paeoniifolius* and found to contain mannose and glucose units in a ratio of 1/0.1 [58].

Table 2: Pharmacological properties of the important phytochemicals of *Amorphophallus paeoniifolius* tuber

Bioactive compounds	Group of Compound	Pharmacological Activities
Amblyone	Triterpenoid	Antibacterial, Cytotoxic [55]
Salviasperanol	Diterpenoid	Antibacterial, Cytotoxic [54]
3,5-diacetyltambulin	Flavonoid	Antibacterial, Cytotoxic [53]
Quercetin	Flavonoid	Hepatoprotective [52], antiallergic, antioxidant, anti-inflammatory, antiviral, anticancer [59]
β - sitosterol	Phytosterol	Anticancer [60], Anti-osteoporotic [47]
Betulinic Acid	Triterpenoid	Laxative [14], Anti-hemorrhoidal [61]
Glucomannan	Heteroglycan	Laxative [14]

Conclusion

Herbal remedies were used exclusively to treat diseases prior to the introduction of modern medicines. Around 70-80% of the world's population lives in vast rural areas of developing and underdeveloped countries and relies primarily on medicinal plants for primary health care. *Amorphophallus paeoniifolius* has the potential to provide nutrition security as well as medicinal benefits to developing countries. A thorough examination of the literature on *A. paeoniifolius* revealed that it is a popular remedy among Ayurvedic and traditional practitioners for the treatment of a variety of ailments. The majority of pharmacological studies confirm the traditional claim of *A. paeoniifolius*' medicinal properties, which may be due to the presence of various bioactive molecules in the plant, according to the review's findings. Henceforth, the phytochemical constituents and isolated bioactive compounds of *A. paeoniifolius* tuber can be investigated further in order to identify lead molecules for the development of new herbal drugs. Likewise, steps should be taken to encourage the cultivation of *A. paeoniifolius* as well as the development of products for improved nutritional and therapeutic use.

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