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PHYTOCHEMICALS, BIOACTIVE COMPOUNDS, PHARMACOLOGICAL EFFECTS OF *LUFFA CYLINDRICA* AND THEIR MEDICINAL IMPORTANCE: A REVIEW

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ABSTRACT

In the context of contemporary healthcare, this review delves into the phytochemical composition, bioactive compounds and pharmacological effects of *Luffa cylindrica*, commonly known as sponge gourd. Against the backdrop of increasing interest in natural remedies, *Luffa cylindrica* emerges as a valuable botanical resource with diverse medicinal applications. Sponge guard is one of the important fibrous vegetable crops containing black seeds. The intertwined fibers found in the fruit of sponge guard is highly digestible and have numerous medicinal properties. The young fruit of the sponge guard contain group of the compounds like flavonoids, phenolics, ascorbic acid, oleanolic acid, ribosome-inactivating proteins, α -tocopherol, chlorophylls, carotenoids and triterpenoids. These phytochemicals and bioactive compounds found in sponge gourd contribute significantly to its medicinal uses, showcasing various pharmacological effects such as antioxidant, anti-inflammatory, analgesic, antimicrobial, hepatoprotective, wound healing and UV-protective properties. In the present review, it was discussed the beneficial aspects and potential medicinal applications of sponge gourd, particularly focusing on its rich phytochemical profile, bioactive compounds and pharmacological effects.

Key words : Fiber, Health benefits, Phenol, Phytochemicals, Sponge guard.

Introduction

The rising use of plant-based medications has sparked a growing interest in exploring the significance and utilization of medicinal plants. This has led to extensive research aimed at substantiating the therapeutic effectiveness claimed for these plants (Hall and Nazir, 2005; Haiyan *et al.*, 2009; Lawal *et al.*, 2010). Plants possess inherent substances that serve as a defense mechanism against microorganisms, and the concentrated active components of medicinal plants are commonly found in various organs such as leaves, stems, roots, seeds and fruits, among other plant parts (Kochar, 1981). The plant *Luffa cylindrica* commonly known as Sponge guard categorized under cucurbitaceae family. Sponge guard is the fast-growing plant of the tropical and sub-tropical region. Sponge guard is mostly cultivated in India, Brazil, USA, Nepal, Bangladesh and Pakistan. Brazil has large number of the local collection of the sponge guard. *Luffa*

is a genus with two species in Brazil such as *Luffa operculata* (L.) Cogn and *Luffa cylindrica* (L.) M. Roem (Gomes-Klein *et al.*, 2015). *Luffa cylindrica* is commonly referred as “Bucha” and its plant parts such as root, leaves, fruits and seeds has been utilized to treat diseases and gastrointestinal disorders (Coelho-Ferreira, 2009; Bolson *et al.*, 2015). In Guinea Bissau, the leaves are utilized for the treatment of fever, malaria and digestive disorders (Catarino *et al.*, 2016), in Bolivia to anuria (Bourdy *et al.*, 2004) in Cuba to parasitic infections (Cano and Volpato, 2004) in India to indigestion (Chander *et al.*, 2015) and in Pakistan as laxative (Ishtiaq *et al.*, 2015).

Luffa cylindrica bear bell-shaped flowers that are monoecious and have five petals. The sponge guard's 2-celled ovary, slender style with 3 stigmas and the anthers are clustered tightly. Pollination occurs by the bees on both ♂ and ♀ flowers of the identical plants. The immature fruit is either raw or cooked as a vegetable,



Fig. 1 : *Luffa cylindrica* leaves and flowers.

but it should be harvested before the purging of compounds develop and fibrous vascular bundles harden. The leaves of sponge gourd are eatable as a vegetable. Sponge guard is used by the peoples as traditional medicine. Sponge guard is recognised as high quality source of vital nutrients for the human health. Sponge guard is the richest source of phytochemical and bioactive compounds with medicinal importance.

The major phytochemicals found in the sponge guard are amino acids, inorganic acids, carboxylic acids, terpenes, phenol, tannins, and flavonoids (Mankilik *et al.*, 2014). Other than phytochemicals and bioactive compounds, sponge guard also contain large numbers of vitamins, mineral nutrients required for the good human health (Lee *et al.*, 2012). Fruits, leaves and entire plants of the sponge guard have wide range of application in the Ayurveda system for the preparation of various kinds of the medicine (Azeez *et al.*, 2013). Several kinds of extracts have been made from the fresh fruit of the sponge guard. The phytochemical and bioactive compounds found in the sponge guards are useful and have clinical importance for the medical care of an assortment of ailments, including inflammatory, cardiovascular, cancerous, and aging-related diseases (Wang *et al.*, 2012). Additionally, the seed of sponge guard noticed to be beneficial at preventing the spread of microorganisms like HIV, fungus, parasites and protozoa (Ng *et al.*, 2011). It also has been reported that the particularly effective in preventing NO production *i.e.*, is generated by LPS using sponge guard (Bor *et al.*, 2006).

Phytochemical and bioactive compound extraction standard

A diverse range of standard have been employed for obtaining the phytochemicals and biologically active compounds from *Luffa cylindrica*. Various treatment has been made by the researchers to extract the



Fig. 2 : *Luffa cylindrica* fruits and seeds.

phytochemicals and biologically active substances from *Luffa cylindrica*, this treatment includes extracts made from ethanol, ethyl acetate and water. In several studies, it has been found that the diverse range of extract procedure having the diverse quantity of the phytochemicals and bioactive compounds. However, the estimation analysis carried by Kao and chen, (2006) reveal that *Luffa cylindrica* peel water extract have maximum amount of the total phenolic compounds, whereas ethanol extract contains high degree of total flavonoids. In other estimation analysis using ethyl acetate extract, *Luffa cylindrica* peel contains more oleanolic acid, carotenoid concentration, and chlorophyll content than the competing extract (Kao *et al.*, 2012). In addition to the functional components extracted form *Luffa cylindrica*, in comparison with Luffa pulp, the extract from Luffa peel contains a large number of essential constituents.

Phytochemicals and bioactive compounds in the sponge guard

Phytochemicals and bioactive compounds are the secondary plant products produced by the plants and have several medicinal properties. These Phytochemicals identified in different parts of *Luffa cylindrica* include p-coumaric acid, chlorogenic acid, caffeic acid, luteolin-7-O-D-glucuronide, lutein A, luycoside, maslinic acid, ginsenosides, luffin P1, luffin S, luffacylin and apigenin-7-O-D-glucuronidemethyl ester (Singh and Vellapandian, 2022). Chromatic graphic is one of the best options to estimate the phytochemical and bioactive compounds present in the plants (Agubosi *et al.*, 2021). Most of the biological activities with therapeutical importance like antibacterial, antifungal, antiviral, hepatoprotective, hypolipidemic, analgesic, antioxidant, immune-stimulatory & modulatory and anticancerous effects can be detect using various chromatographic methods and mass spectrometry (Shittu *et al.*, 2021).

However, sponge guard have long history of the medicinal use. The several studies, it has been found that the sponge guard leaves have alkaloids with high concentration (14.9 mg/g) with low concentration of glycosides (11.60 mg/g). Therefore, the extract can have a bitter taste and perform a wide range of pharmacological actions, including antimalarial, antiarrhythmic, analgesic and stimulant activities, as indicated by the elevated concentration in alkaloid values (Alagbe, 2021). Other secondary metabolites like Tannins, flavonoids, terpenoids, steroids, saponins and oxalates have also been isolated from sponge guard. The analysis of a *Luffa* species extract using gas chromatography and mass spectrometry states that more than 35 phytochemicals and bioactive compounds are present and most of the bioactive compounds have curative impact on both human and animal health.

Phenolic compounds, flavonoids and terpenoids in sponge guard

Phenolic compounds are secondary plant products naturally synthesized in the plants. The fresh pulp of sponge guard exhibits 20.74 mg/g of the total phenol, 0.5 mg/g of the anthocyanin, 17.94 mg/g flavonoids, and 1.2 mg/g vitamin-C (Kao *et al.*, 2012). Most of the phenolic compounds and their derivatives synthesized in luffa pulps are polyphenols including -O-[4-hydroxybenzoyl]-1-O-feruloyl-b-D-glucose, 1-O-p-coumaroyl-b-D-glucose and 1-O-caffeoyl-b-D-glucose, Diosmetin-7-O-b-D-glucuronide methyl ester, p-coumetic acid, -glucose and luteolin-7-O-b-D-glucuronide methyl ester (Du *et al.*, 2006). In addition, other secondary metabolic substances like terpenoids, terpene acid have also been traced from the pulp of sponge guard. Major terpene acids in the sponge guard are oleanolic acid and echinocystic acid (Stirpe and Battelli, 2006). Other than phenolic compounds and flavonoids, sponge guard is the major source of anthocyanin, carotenoids and chlorophylls. Major carotenoids reported from *Luffa cylindrica* are trans-lutein, cis-Lutein, cis-b-Carotene and cis Neoxanthin using diverse group of extracts. These functional compounds found in the sponge guard play crucial role in the formation of other beneficial compounds (Nilsson *et al.*, 1986). Classes of chlorophyll including chlorophyll – a, chlorophyll – b, hydroxyl-chlorophyll – a and hydroxyl-chlorophyll – b have been reported from *Luffa cylindrica* using various extracts including extracts made from water, ethanol and ethyl acetate.

Saponins in sponge guard

Saponins are naturally occurring bioactive compounds of terpenoids group found the *Luffa*

cylindrica peel and pulp (Tang and Eisenbrand, 1992). They have defensive role in the plant system against insects, pests and diseases (Shibata, 1977). Plant saponins are have been identified as one of potent drug in pharmaceutical industries for curing various kind of human diseases (Augustin *et al.*, 2011). Saponins of the *Luffa cylindrica* have been investigated by the several researchers in the drug industry for the development of anti-inflammatory drugs of terpenoids category (Matsuda *et al.*, 1990). However, various kinds of basic pharmaceuticals with triterpenoids in the form of saponins are frequently utilized for their anti-inflammatory effects, both in conventional medical treatment and folk medicine (Behboudi *et al.*, 1997). Aesein, a combination of oleanane triterpene saponins, provides a yield of around 13% in relation to the weight of the crude medicine and is given orally for medicinal purposes (Shibata, 1977).

Functional proteins and enzymes

In HPLC and GC-assisted estimation, *Luffa cylindrica* contain Ribosome inactivating proteins (RIPs) (Reddy *et al.*, 2010). Ribosome inactivating proteins (RIPs) are renowned for their various biological functions, such as ribosome inactivation, antiviral, anti-tumour, and immunomodulatory functions (Ng *et al.*, 1992; Barbieri *et al.*, 1993). RIPs are the special class of high-profile enzyme, naturally synthesize in the *Luffa cylindrica* with ability to depurinate the rRNA (Khajuria *et al.*, 2007) such a change might inhibit the ribosome from binding elongation factor 2 [EF-2], which could hinder the synthesis of proteins (Shaw *et al.*, 2005). However, RIPs found in the plants are function as potent inhibitor in synthesis of proteins by removal of adenine remnants from eukaryotic ribosomal RNA before or during the process of transcription (Olsnes and Pihl, 1981). Ribosomal inactivating proteins are of 2 types *i.e.*, type – I and type – II. The type – I ribosomal inactivating proteins is the diverse group of protein family made up of single polypeptide chain (Puri *et al.*, 2012), while type–II ribosomal inactivating proteins are heterodimeric structure consists of long chain glycoproteins and their secondary or B chain is disulphide chain. Type–II ribosomal inactivating proteins are highly toxic in nature (Li *et al.*, 2010). Of these two types of the ribosomal inactivating proteins, only type–I is found in the *Luffa cylindrica* species.

Pharmacological action of *Luffa cylindrica*

Studies indicate that extracts derived from various components of *Luffa cylindrica* contain a range of secondary metabolites, including flavonoids, tannins,

phenolic acids, alkaloids, saponins, terpenoids, among others. These extracts exhibit diverse pharmacological effects based on their composition.

Anti inflammatory

The anti-inflammatory capability of sponge gourd extracts is linked to the existence of bioactive elements like flavonoids and phenolic acids. These compounds, when extracted and utilized, have the potential to mitigate inflammation by disrupting the series of events that trigger inflammation, thereby reducing pain, swelling, and other symptoms associated with inflammatory conditions. The water extract from *Luffa* peel had the highest concentration of overall phenolics, while, the extract from ethanol consists greater amounts of overall flavonoids, which contribute to its anti-inflammatory effects (Kao *et al.*, 2012; Kanwal *et al.*, 2013).

Antioxidant

The combined action of flavonoids, tannins, and phenolic acids in *Luffa cylindrica* extracts helps to combat oxidative stress by neutralizing free radicals (Addor, 2017). Oxidative stress arises from an unequal state between the generation of free radicals and the body's capacity to counteract or neutralize them. This imbalance may cause damage to the cells and is associated with various chronic diseases, including cardiovascular issues, neurodegenerative diseases and cancer. The antioxidant activity of *Luffa cylindrica* leaf extracts using Superoxide scavenging tests and DPPH (2,2-diphenyl-1-picrylhydrazyl) assays was studied with ethanol, methanol, and chloroform extracts. The leaf extracts in chloroform and methanol exhibited antioxidant activity of in vitro similar to that of the typical antioxidant, such as ascorbic acid (Tripathi *et al.*, 2016). Bhavsar *et al.* (2023) also reported the plant extracts exhibited the highest antioxidant potential from methanol extracts by using of Ferric iron decreasing antioxidant power, or FRAP assay.

Antimicrobial

The existence of bioactive substances like flavonoids, phenolic compounds, alkaloids, terpenoids and saponins in different components of *Luffa cylindrica*, including leaves, fruits, and seeds, contributes to its antimicrobial potential. These compounds have capability to impede microbial growth and impact a wide range of microorganisms. Extracts from *Luffa cylindrica* exhibited antimicrobial activity against *Candida albicans* and *Staphylococcus aureus*, indicating larger inhibitory zones, especially against *Candida albicans*. Fresh extracts exhibited superior activity than dried extracts from plants (Aboh *et al.*, 2012). The triterpenoid saponin Echinocystic acid, *i.e.*, derived from *Luffa*

cylindrica, showed antimicrobial activity against *Bacillus subtilis*, *Candida albicans*, *Listeria monocytogenes* and *Salmonella typhimurium* with a minimum inhibitory concentration (MIC) of 62.2 µg/ml (Garai *et al.*, 2018).

Antibacterial

Luffa cylindrica extracts have been studied for their impact on various bacteria, including pathogens like *Salmonella typhi*, *Bacillus subtilis*, *Escherichia coli*, *Staphylococcus aureus* and similar strains. Extracts sourced from different plant components, like leaves, fruits, or seeds, were assessed for their potential to hinder bacterial growth or induce bacterial demise. The methanol extracts obtained from dried leaves and ash-dried leaves of *Luffa cylindrica* demonstrated both inhibitory effects on bacterial growth and the ability to kill bacteria (Sirisa *et al.*, 2023). Devi *et al.* (2009) reported the antibacterial effects of ethanol extracts against various bacteria, showing 40-80 mm inhibition zones.

Antifungal

The antifungal action of *Luffa cylindrica* extracts may involve disrupting cell membranes or walls of fungi, interfering with essential fungal processes, or inhibiting enzymes critical for the fungal survival. *Luffa cylindrica* fruit ethanol extract (50-150 mg/ml) exhibited antifungal activity (45-92.5 mm inhibition zone) against *Aspergillus fumigatus*, *Aspergillus niger* and *Candida albicans* (Devi *et al.*, 2009). *Luffa cylindrica*'s butanol fraction exhibits antifungal effects (85% on *Fusarium solani*, 80% on *Trichophyton longifusus*), while crude extract of methanol and fraction of ethyl acetate inhibited *Microsporum canis* growth by 70% (Ahmad and Khan, 2013).

Antiviral

Luffa cylindrica contains various phytochemical compounds exhibits antiviral potential in other plants by interfering with viral replication, inhibiting viral entry into host cells, or affecting various stages of the viral life cycle. Luffin P1, extracted from *Luffa cylindrica* seeds, is the tiniest ribosome-inactivating peptide. However, its effectiveness against viral C8166 T-cell lines infected with HIV-1, demonstrating an ability to attach to the HIV reverse response component. Its unique inactivation mechanism is likely achieved through complementary charge interaction with proteins either from the virus or within cells (Ng *et al.*, 2011).

Anticancer

Extracts derived from *Luffa cylindrica* have exhibited cytotoxic effects against certain cancer cells, involving their capability to prevent the growth and viability

of these cancerous cells. Koledoye (2021) reported the medicinal potential of *Luffa cylindrica* methanol leaf extract as a promising agent against colorectal cancer, exhibiting potency against both human colon cancer cell lines of HT-29 and HCT 116, as well as in preventing colon cancer *i.e.*, was induced by DMH (1, 2 dimethylhydrazine). *In vitro* studies revealed the *Luffa cylindrica* hot water extract effectively targeted circulating cancerous cells, notably the CD133+/CD44+ subpopulation in hepatocellular carcinoma, potentially reducing cancer stem cell ratios, aiding in recurrence and metastasis prevention (Abdel-Salam *et al.*, 2019). While, leaf ethanol extract in varied breast cancer cell lines revealed anticancer effects attributed to phenolic compounds and saponin constituents (Abdel-Salam *et al.*, 2018).

Antidiabetic

Luffa cylindrica seed and leaf extracts effectively lowered blood glucose, improved lipid profile and regulated serum enzymes in alloxan-induced diabetic Wistar rats, affirming its potential for managing diabetes complications and enhancing treatment (Abigail and Metuaghan, 2019). The *in-vitro* test evaluating alpha-glucosidase and amylase activity revealed higher concentrations of antidiabetic constituents in *Luffa cylindrica* stem compared to its leaf (Sola *et al.*, 2022).

Anthelmintic

Luffa cylindrica leaves consists of crude ethanol and methanol extracts involved anthelmintic effects against Indian earthworm of *Pheretima posthuma* (Pratap *et al.*, 2012; Tripathi *et al.*, 2016). While, the ethanol extract exhibited potent anthelmintic activity against *Pheretima posthuma*, comparable to standard drug of mebendazole (Tripathi *et al.*, 2016).

Analgesic and anti-pyretic

The methanolic leaf extract from *Luffa cylindrica* reduces abdominal constriction in mice and decreased rat rectal temperature. Its analgesic and antipyretic effects align with ethnobotanical uses for pain and fever relief (Saliu *et al.*, 2019). The pain-relieving effects from fruits of the *Luffa cylindrica* plant, extracted with alcohol and ethanol (100 mg/kg) were assessed utilizing tail immersion and acetic acid-induced writhing techniques in mice and revealed the extracts of ethanol exhibited substantial analgesic activity at 60 and 90 minutes in the tail immersion test (Velmurugan *et al.*, 2011).

Antiemetic

The extracts of ethanol and hexane from leaves of *Luffa cylindrica* and male flowers exhibited the anti-

emetic effects against chick emesis simulation. The male flower's hexane extract exhibited inhibition of retches of 71.5% and 43.5%, while the leaf's ethanol extract showed 68.66% and 68.46% inhibition of retches (Kanwal *et al.*, 2013).

Hepatoprotective effect

The *Luffa cylindrica* methanol extract exhibited hepatoprotective effects in rats intoxicated with CCl₄ and showed as enhanced liver function, reduced oxidative stress and improvement in liver health (Oyeyemi *et al.*, 2022). While, the hydroalcoholic extract also exhibited the comparable hepatoprotective qualities in a liver damage model induced by erythromycin estolate (Pawashe *et al.*, 2011).

Wound healing activity

The entire plant of *Luffa cylindrica* extracted in chloroform exhibited wound healing properties by reducing both the wound area and the time taken for epithelization (Abirami *et al.*, 2011).

Skin protection

Flavonoids found in *Luffa cylindrica* act as secondary metabolites and serve as UV protectants, offering defense against mutagenic UV rays (Helfrich *et al.*, 2008). Ascorbic acid and carotenoids, constituents within *Luffa cylindrica*, function as photoprotective agents when topically applied to the skin prior to exposure to ultraviolet (UV) radiation (Rojas *et al.*, 2016). Umehara *et al.* (2018) reported the *Luffa cylindrica* plant extract prevented trans epidermal water loss in UVB-irradiated hairless mice.

Medicinal importance of *Luffa cylindrica*

Luffa cylindrica found to be one of the unique vegetable due to numbers of medicinal properties. As a traditional remedy for fever, gastro-intestinal diseases, seizures, infections of the skin, diabetes, rheumatoid arthritis, snake bite and back pain, the whole plant consists of seeds, leaves, roots and stem bark have been reported (Azeez *et al.*, 2013). Sponge guard is one of the potent plants of the cucurbitaceae family have been tested as immuno-modulatory, immune-stimulating, antiviral (Ng *et al.*, 2011), anti-inflammatory properties (Kao *et al.*, 2012), antifungal, hypoglycemic, cytotoxic and antioxidant effects due to the occurrence of several secondary metabolites (Smith *et al.*, 2006; Lawal *et al.*, 2010; Farag *et al.*, 2012). In other study it has been found that the leaves of sponge guard are capable of preventing the growth of Gram -ve and Gram +ve harmful bacteria (Wildman, 2001; Roy and Lingampeta, 2014). Gas chromatographic and mass spectrophotometric study states that the leaves

of sponge guard have wonderful phytochemicals useful in the production of novel drugs and its effectiveness towards a broad range of infectious diseases (Patel *et al.*, 2013; Ediriweera *et al.*, 2019). Furthermore, the stem bark and seeds of the sponge guard pharmacologically active compounds, which have been reported to exhibit antifungal and antimicrobial effects (Amin *et al.*, 2009; Kao *et al.*, 2012). Luffein is a type of protein isolated from the seed of sponge guard. In addition, luffein is ribosome-inactivating protein potentially effective against the development of microbes like insects, fungus, and some bacteria. The phenolic compounds of the sponge guard have been found to be most effective at preventing LPS-induced NO production (Bor *et al.*, 2006).

The ribosomal inactivating proteins found in the *Luffa cylindrica* have diverse range of medicinal properties, as they have been tested in the several immune-toxic reactions for the development of anti-HIV agents (Barbieri, 1982). Terpenoids including saponins available in sponge guard pulp and peel are defensive in nature against microbial infection but also produces infection in some cases (Ríos, 2010). In some cases, the hypersensitive reaction i.e., immune system reactions against may or may not be controlled by the organs. The reports exhibited by Caliset *et al.* (1997) revealed as promising immune-modulating action in an isolated test for stimulation of human lymphocytes. Additionally, it was reported that cyclocanthosides E and G, astragalosides I, II, IV, and VI and astrasieversianins II and X were all able to promote proliferation of lymphocytes in humans i.e., dosages ranging from 0.01 to 10 g/ml (Abbas *et al.*, 2011). Later, Khajuria *et al.* (2007) isolated active substances from sponge guard peel having immune-modulating action of oleanolic acid and echinocystic acid, in which both substances enhanced the phagocytic index and stimulated macrophages, enhancing immune responses that are humoral as well as cell-mediated (Saha *et al.*, 1961). Other than peel and pulp, sponge guard seed have potent medicinal and pharmaceutical importance as reported in the several studies (Ng *et al.*, 1992). The substances isolated from the seed of sponge guard have the property of abortifacient (Ríos, 2010). However, the evidences reported from ethno pharmacological studies reflecting that these substances are very useful in the childbirth but harmful when taken in larger quantities than required (Pamplona-Roger, 2000).

Later study of the HPLC-assisted chemical extract of *Luffa cylindrica* antiviral capabilities as immunosuppressive medications should be studied more in the future (Kamatenesi-Mugisha *et al.*, 2007).

However, such type of investigation should be pursued for their strategic effect of the several transcriptional activities and metabolic pathways inside the body as well as their response on the potent immune system of the body (Hashimoto *et al.*, 1985).

Conclusion

In conclusion, sponge gourd, a part of the cucurbitaceae family, stands out as a rich source of bioactive compounds and phytochemicals. The identification and extraction of functional chemicals from various parts of the plant offer promising potential for treating diverse diseases. Studies emphasize the higher concentration of phenolics in peel water extract and flavonoids in ethanol extract, underscoring its medicinal significance. Local cultivars exhibit a richer profile of beneficial compounds, presenting substantial opportunities for the pharmaceutical industry. The future lies in exploring these phytochemicals and metabolites for the development of effective drugs and medicines to combat a wide array of diseases and disorders.

Competing interests

Authors have declared that no competing interests exist.

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