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Review Article

Unveiling the Phytochemical Profile and Therapeutic Benefits of *Solanum xanthocarpum*: A Systematic Review

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ABSTRACT

Solanum xanthocarpum, a significant medicinal plant in traditional systems of medicine, possesses a rich phytochemical profile that contributes to its diverse therapeutic applications. This review explores the bioactive compounds such as alkaloids, flavonoids, and glycosides, which are responsible for the plant's pharmacological properties, including antioxidant, anti-inflammatory, antimicrobial, and antihyperglycemic activities. Recent studies have also highlighted its potential in treating respiratory disorders, liver dysfunction, and microbial infections. By consolidating traditional uses with modern pharmacological research, this paper aims to provide a comprehensive understanding of *Solanum xanthocarpum*, emphasizing its potential for future therapeutic developments.

Keywords: Anti-inflammatory effects, Anti-microbial activity, Antioxidant properties, Ethno-medicine of *Solanum xanthocarpum*, Phytochemical profile of *Solanum xanthocarpum*, Therapeutic benefits of *Solanum xanthocarpum*.

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INTRODUCTION

Natural products are very beneficial for medicinal purposes. Organic items acquire therapeutic properties from various plant sources. The World Health Organization (WHO) estimates that 80% of people on the planet use plant extracts in herbal medicine as their primary form of treatment. Herbal remedies are supported by a number of reasons, including acceptance, affordability, affordability, accessibility, and the lack of modern medical facilities. Ayurveda identifies the herb as a bitter, digestive, pungent, and alternate astringent in ancient times.[1]

Solanum xanthocarpum Schrad. and Wendl (Solanaceae) is an annual herb which grows as wild plant in many parts of India. In vernacular it is known as Kantakari or Bhatkatiya. According to "The Plant List Solanacae is a large family that contain 2300 species. Commonly *Solanum xanthocarpum* (SX) belongs to Solanacae family. India's indigenous population has been using medicine plants since the Neolithic period.[2] SX belongs to the Solanaceae family of plant families. It is a tiny, semi-prostatic plant with many, herbaceous branches that can be annual or perennial. Because of their accessibility in the original environment, ability to treat ailments, and smaller side products, medical stores were employed as a source of drugs by all mortal societies. Berries have an expanded calyx encircling them and might be yellow or green with white or green stripes. Fruits can be eaten, and the people of Manipur, India, use them as traditional medicine to treat a variety of illnesses. This plant belongs to the Ayurvedic group Dasamula, which meaning ten roots. This herb, which is a member of the panchmulas family that also includes solasodine and diosgenin, is the science of life, prevention, and longevity. It is also the most comprehensive medicinal system. Because the herb contains prickles, it is also called Duhsparsa; its significance is hard to pin down. Three species-violet-flowered, yellow-flowered, and white-flowered-have been listed in Ayurveda.[3]

Synonyms

Kantakari, Vyaghri, Dhavani, Kshudra, Kantakarika, Kantalika (Pharmacopoeias, 1999).

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Regional Names

English-Febrifuge Plant, Hindi-Katali, Bhatakataiya, Chhotikateri, Ringani, Telugu-Nelamulaka, Chinnamulaka, Mulaka, Pinnamulaka, Kannada-Kiragulla, Nelagulla, Tamil-Kandangatri, Kandan Katri, Kandanghathiri, Gujarati: Bhoringan (Pharmacopoeias, 1999).

The cooked, unripe fruits of *S. xanthocarpum* (Sx) have long been consumed as a vegetable by the Irula tribes of the Hasanur Hills (Tamil Nadu, India).[4] The Wayanad district of Kerala's Kattunaikka, Paniya, and Kuruma tribes eat fruits and seeds. In some regions of India, traditional healers view fruits as a beneficial herbal product that can be used to treat a variety of common ailments. Sexual medicine has a long history of use in Ayurveda. SX fruit has anti-HIV, anti-inflammatory, anti-cancer, anti-vomiting, and anti-oxidant qualities, according to a recent study. Sx contains phytoconstituents that are employed as possible fungicides, anti-allergic agents, and anti-fertility agents.[5] as well as antimicrobial and antifungal properties. All research on the plant *Solanum xanthocarpum*, including its taxonomy, cultivation, phytochemical components, medicinal qualities, and pharmacological activity, are included in this review.

Taxonomic Classification

Kingdom	Plantae
Subkingdom	*Tracheobionta*
Division	*Magnoliophyta*
Class	*Magnoliopsida*
Subclass	*Asteridae*
Order-	*Solanales*
Family	*Solanaceae*
Genus	*Solanum*
Species	*xanthocarpum*

METHODOLOGY

In order to present this review, we have gathered a massive amount of data from reliable and credible sources, including Google Scholar (http://scholar.google.com). Data bases that we used for our search terms include PubMed (http://www.ncbi.nlm.nih.gov/pubmed), Scopus (https://www.scopus.com), Research Gate (https://www.researchgate.net), Science Direct (https://www.sciencedirect.com), SciFinder (http://www.libnet.ulg.ac.be/en/eresources/ scifinder-scholar), and Web of Knowledge. We looked at research on the ethnomedical applications, phytochemistry, pharmacology of extracts, and identified chemicals of *Solanum xanthocarpum* that was published before June 2023. Books, journal articles, and websites like the "Kew Royal Botanic Gardens" (mpns.kew.org) were used to verify the names of the species, families, plant authorities, and synonyms. The Plant List" (www.theplantlist.org). The search key word *Solanum xanthocarpum* or *Solanum virginianum* were used with no specified time limit.

Botanical description and distribution

Solanum xanthocarpum is an annual or perennial herbaceous and tropical and subtropical areas are home to this thorny diffuse bright green perennial weed.[4]

The plant grows to a height of two to three meters and is primarily found in dry areas of India.[5] It's a green perennial herb with a zigzag stem and a base made of wood. It is a bright green herb that is quite spiky.[6]

It has several branches and compact, yellow, glabrous, shiny prickles that are 1.3 cm long.

The leaves are 2.5-5.7 cm long, oval in form (or possibly elliptic), and have stellate hairs on both surfaces.[7]

The petiole is hairy and is 1.3 to 2.5 cm. Its base is uneven and rounded, and it has long, pointed yellow prickles on its midrib. Berries of this plant are green and having white stripes at the juvenile stage, and yellow on aging. These have a diameter of 1.3 to 2 cm.[8] It is attached to a larger, hairy, thorny calyx that is 1.3 cm in length. The glabrous seeds have a diameter of 2.5 mm. The lobes are pointed, hairy, linear lanceolate, and 11 mm long on the outside.[9]

Corolla: The corolla is bell-shaped, white, gamopetalous, 1.9-2.2 cm long, and has sharp hair on the outside.

The oblong-lanceolate, 8 mm long anthers are punctured by tiny holes. Filaments are 1.5 mm long and glabrous. The style is glabrous and the ovary is ovoid.[10]

Flower: Flowering normally appears around November to May. Flowers are mostly White color, bisexual, regular, covered with stellate hairs (Figure 1 Flower).

Fruits: 1.1 cm diameter, Berry-pale fruits, in young fruits are green (Figure 1), and ripe fruit red color (Figure 2).

Seed: Seeds glabrous, smooth, and yellowish brown, Seeds with copious endosperm and straight or curved embryo.

This plant is extensively distributed throughout India, including Punjab, Assam, Uttar Pradesh, West Bengal, and Bihar. additionally found in Polynesia, tropical Australia, South-East Asia, and Ceylon and Malacca. March through April is when it is cultivated, and May through June is when it bears fruit. The majority of its locations are hot and dry (Pol *et al.*, 2016; Watt, 1893; Ara, 1988).

Cultivation

Rich loamy soil with a pH range of 7 to 8 that drains well is needed for the growing of this plant. This plant can also thrive

in saline soil. The temperature necessary for this cultivation is 21 to 27°C. This crop was seriously harmed by the frost and it recovered during April. The seeds have a diameter of roughly 2.5 mm and are raised from the crop. There is no latency period for these seeds. Its germination range is between 60 to 70% and the germination period is roughly 10 to 16 days.[9]

Ethnobotany

One of the key ingredients of the Ayurvedic medicine dashmularishta, which is used as a tonic for nursing women, is *S. xanthocarpum* roots. The heated aqueous extract of the mature fruits is used as a traditional medicine by the Kondh tribes of Orissa, India's Dhenkanal area to treat diabetes mellitus.[13] The people of Manipur, India, use fruits as a traditional medication to heal throat infections and inflammatory issues. According to folklore, the entire plant is used to treat leprosy, dropsy, and cough. Mukunda tribes of Rajasthan, India employed the root paste for the treatment of hernia.[14] Root poultice used to cure the piles are practicing as a traditional medicine in several areas in South India. seeds and mustard oil fumigation are a great combination for treating dental caries, tooth pain, pus formation, and associated gum swelling. Fruits, flowers, and stems are utilized to treat burning feet.[10]

PHYTOCHEMICAL STUDIES OF *SOLANUM XANTHOCARPUM*

Solanum xanthocarpum, commonly known as Yellow-berried Nightshade or Kantakari, is a vital medicinal plant in the Ayurvedic system of medicine. It belongs to the Solanaceae family and is found in various regions across India. *Solanum xanthocarpum*, known for its medicinal properties, contains a diverse range of phytochemicals that contribute to its therapeutic effects.[11] Phytochemical constituents in *Solanum xanthocarpum* leaves and stems are listed in Tables 1 and 2.

Alkaloids

Alkaloids are a significant group of nitrogen-containing compounds found in *Solanum xanthocarpum*. They are known for their potent biological activities and are often the basis for many medicinal applications.

Solasodine

This steroidal alkaloid is one of the major bioactive compounds in the plant. Solasodine serves as a precursor for the synthesis of steroidal drugs, including contraceptives and anti-inflammatory agents. It exhibits antifungal and anticancer properties and is being studied for its potential in cancer therapy.[12]

Solanine and Solamargine

These glycoalkaloids are toxic in high concentrations but have significant therapeutic potential at controlled levels. They possess antimicrobial properties, particularly against gram-positive bacteria. Solamargine, in particular, has shown promising results in cancer research due to its ability to induce apoptosis in cancer cells.[13]

Flavonoids

Flavonoids are a group of polyphenolic compounds widely recognized for their antioxidant properties. They play a crucial role in the plant's ability to scavenge free radicals, thereby protecting cells from oxidative damage.

Quercetin

This flavonoid is known for its strong antioxidant, anti-inflammatory, and antiviral properties. Quercetin contributes to cardiovascular health by reducing blood pressure, preventing platelet aggregation, and lowering the risk of atherosclerosis.

Kaempferol

Kapferol, a significant flavonoid found in *Solanum xanthocarpum*, has anti-inflammatory, antibacterial, and anticancer properties. It has been demonstrated to lower the risk of chronic illnesses and stop the formation of some cancer cells.[14]

Steroidal Saponins

Steroidal saponins are a class of compounds that have a wide range of pharmacological activities, including anti-inflammatory, anticancer, and immune-modulating effects.

Solasodine Saponins

These compounds are responsible for many of the plant's medicinal properties. They have been found to have cytotoxic effects on cancer cells and are being explored for their potential in cancer therapy. Additionally, they contribute to the plant's anti-inflammatory and anti-arthritic effects.[15]

Glycosides

Glycosides are compounds in which a sugar molecule is bound to a non-carbohydrate moiety. These compounds in *Solanum xanthocarpum* are primarily responsible for its cardioprotective and antidiabetic effects.

Solasodine Glycosides

These glycosides have shown potential in treating various cardiovascular conditions. They work by modulating the heart's electrical activity, reducing the risk of arrhythmias, and providing protective effects against myocardial infarction.[16]

Solasonine

This glycoside, similar to solamargine, is also involved in inducing apoptosis in cancer cells. It contributes to the plant's anticancer potential and is a subject of ongoing research.[17]

Table 1: Phytochemical Studies of *Solanum xanthocarpum*.

Class of Compound	Phytoconstituent	Plant Part
Alkaloids	Solasonine	Whole Plant
Alkaloids	Solamargine	Whole Plant
Alkaloids	Solasodine	Whole Plant
Flavonoids	Rutin	Leaves
Flavonoids	Quercetin	Leaves
Steroids	β-Sitosterol	Whole Plant
Steroids	Diosgenin	Whole Plant
Phenolic Compounds	Gallic acid	Leaves
Phenolic Compounds	Chlorogenic acid	Leaves
Saponins	Solasodine rhamnosyl glycosides	Whole Plant
Tannins	Tannic acid	Leaves
Glycosides	Solasodine glycosides	Whole Plant
Fatty Acids	Palmitic acid	Leaves
Fatty Acids	Oleic acid	Leaves
Fatty Acids	Stearic acid	Leaves
Terpenoids	Squalene	Whole Plant
Terpenoids	Betulin	Whole Plant
Terpenoids	3-Acetyloleanolic acid	Whole Plant
Terpenoids	Cholest-4-en-3-one	Whole Plant
Miscellaneous Compounds	1-Heptatriacotanol	Whole Plant
Miscellaneous Compounds	Cyclopropane dodecanoic acid	Whole Plant
Miscellaneous Compounds	2-octyl-, methyl ester	Whole Plant
Miscellaneous Compounds	Tricyclo[20.8.0.0(7,16)]triacontane	Whole Plant
Miscellaneous Compounds	9-Octadecene, 1,1′-[1,2-ethanediylbis(oxy)]bis	Whole Plant
Miscellaneous Compounds	9-Desoxy-9x-chloroingol 3,7,8,12-tetraacetate	Whole Plant
Miscellaneous Compounds	(10Z)-Tetradec-10-enoic acid-(2S)-2-carboxy-2-hydroxyethyl ester	Whole Plant
Miscellaneous Compounds	(2R)-2-Hydroxy-N-[(2S,3S,4R,15Z)-1,3,4-trihydroxy-15-triaconten-2-yl] octacosamide	Whole Plant
Miscellaneous Compounds	2-Hydroxyethyl oleate	Whole Plant
Miscellaneous Compounds	Henicosyl formate	Whole Plant
Miscellaneous Compounds	1,3-diacetyloxypropan-2-yl icosanoate	Whole Plant
Miscellaneous Compounds	Methyl acetyl ricinoleate	Whole Plant
Miscellaneous Compounds	Methyl linoleate	Whole Plant
Miscellaneous Compounds	Methyl elaidolinolenate	Whole Plant
Miscellaneous Compounds	1-Tetradecanol	Whole Plant
Miscellaneous Compounds	1-Hexadecanol	Whole Plant
Miscellaneous Compounds	Dimethyl undecanedioate	Whole Plant
Miscellaneous Compounds	Z,E-2,13-octadecadien-1-ol	Whole Plant
Miscellaneous Compounds	Methyl palmitate	Whole Plant
Miscellaneous Compounds	Ethyl palmitate	Whole Plant
Miscellaneous Compounds	1-Heptacosanol	Whole Plant

Tannins and Phenolic Compounds

Tannins and phenolic compounds are known for their astringent properties and play a significant role in the antimicrobial and antioxidant activities of *Solanum xanthocarpum*.

Tannins

These are polyphenolic compounds that bind to proteins and other organic compounds, which can inhibit the growth of bacteria and fungi. Tannins have been found effective against a range of pathogens and are used in traditional medicine to treat diarrhea and wounds.[18]

Phenolic Acids

Phenolic compounds like chlorogenic acid and caffeic acid contribute to the plant's antioxidant activity. They neutralize free radicals and reduce oxidative stress, which is linked to various chronic diseases such as cancer and cardiovascular disorders.[19]

Other Phytochemicals

Solanum xanthocarpum also contains other phytochemicals like ascorbic acid (Vitamin C), β-carotene, and essential oils. These contribute to the plant's overall therapeutic profile by enhancing its antioxidant capacity and providing additional health benefits such as immune system support and protection against respiratory ailments.[20] All Phytochemicals are listed in Figure 3-5 (1-15).

Pharmacological Activities

Solanum xanthocarpum is traditional medicine for its wide array of pharmacological activities. These therapeutic effects are primarily due to the bioactive compounds present in the plant, such as alkaloids, flavonoids, saponins, glycosides, and phenolic compounds. The bioactive compounds identified in *Solanum xanthocarpum* contribute to a wide range of pharmacological activities

Anti-inflammatory Activity

Solanum xanthocarpum is well-regarded in traditional medicine for its potent anti-inflammatory properties, which play a significant role in its therapeutic applications. The plant's effectiveness in reducing inflammation can be attributed to its rich content of bioactive compounds, including alkaloids, flavonoids, and saponins. When the body encounters a foreign substance-be it a pathogen, foreign object, or another irritant-it naturally tries to eliminate the threat. These intruders can include viruses, bacteria, or other harmful microorganisms that cause infections. The body's response to these threats often manifests as inflammation, which is its way of defending against potential harm.[21] Acute inflammation is the body's immediate response to such threats and is typically characterized by 5 key symptoms:

1. **Redness:** Due to increased blood flow to the affected area.
2. **Pain:** Triggered by the release of chemicals that stimulate nerve endings.
3. **Swelling:** Caused by the accumulation of fluid in the tissues.
4. **Heat:** Resulting from increased blood flow and metabolic activity in the affected area.
5. **Loss of Function:** Occurs when the inflammation is severe enough to impair normal function.

One significant group of natural compounds known as phenylpropanoids plays a crucial role in managing inflammation. These compounds are particularly important in the pharmaceutical and industrial sectors, where they are used to modify extracts aimed at reducing inflammation.[22]

Phenylpropanoids exert their anti-inflammatory effects by targeting and inhibiting key enzymes involved in the inflammatory process.[23]

These enzymes include:

Cyclooxygenase-1 (COX-1) and Cyclooxygenase-2 (COX-2)

Enzymes responsible for the formation of proteinoids, including prostaglandins, which are mediators of inflammation and pain.[24]

Lipoxygenase (15-LOX)

An enzyme that contributes to the production of leukotrienes, which are inflammatory molecules.[25]

Figure 1: Morphology of Flower.

Phospholipase A2 (sPLA2)

An enzyme involved in the release of arachidonic acid, a precursor to inflammatory mediators.

Antimicrobial Activity

Solanum xanthocarpum exhibits potent antimicrobial activity, which includes antibacterial, antifungal, and antiviral effects. Plants often produce antimicrobial compounds as a natural defence mechanism to protect themselves from microbial infections and deterioration. This self-protective trait has made plant-based extracts valuable for preserving and ensuring the safety of food products.[26]

One notable characteristic of *Solanum xanthocarpum (SX)* is its antibacterial activity. Studies have demonstrated the efficacy of SX leaf extract against a range of pathogenic bacteria, such as *Salmonella typhi*, Vibrio cholerae, *Escherichia coli*, and *Streptococcus species*. The extract showed a Minimum Inhibitory Concentration (MIC) of 12.5 mg/mL against *Escherichia coli*, 16 mg/mL against Pseudomonas aeruginosa-which showed the largest zone of inhibition-and 6.25 mg/mL against Staphylococcus aureus, according to one investigation.[27]

Figure 2: Fruits.

When it comes to Gram-negative bacteria like *Salmonella typhi, Escherichia coli*, and *Pasteurella mulocida*, the plant has more potent antibacterial activity. Certain bacterial diseases may benefit from the use of SX fruit extracts as a natural medication source. Bioactive substances including glycosides, lignins, tannins, and alkaloids, which include sesquiterpenes, monoterpenes, and triterpenes, are probably what give SX its antimicrobial activity. It is thought that these substances pierce the cell membranes of bacteria and fungi, preventing their growth and multiplication.[28]

Interestingly, while the fruit of *Solanum xanthocarpum* did not show antibacterial activity against *Bacillus subtilis* and *Escherichia coli*, it was effective against *Salmonella typhi*. Further studies, such as those by Salar *et al.*, have demonstrated the plant's broad-spectrum antimicrobial effects against a variety of pathogens, including the fungus *Aspergillus Niger* and bacteria such as *Staphylococcus aureus, Escherichia coli*, and *Pseudomonas aeruginosa.*[29]

Antioxidant Activity

Solanum xanthocarpum's antioxidant qualities are essential for shielding the body from oxidative stress and associated illnesses. shielding our cells from the harm that free radicals-unstable molecules that can cause a number of chronic illnesses, including as cancer, heart disease, and neurological disorders-create. Beta-carotene, vitamin C, and vitamin E are some of the most significant antioxidants; they combine to scavenge free radicals and guard against cellular damage.[30]

In a study conducted by[31] the effects of a solvent-free extract of *Solanum xanthocarpum* (SX) seeds were investigated specifically on the oxidative stress of sperm cells in the caudal epididymis of male albino rats. The study aimed to explore how the antioxidant properties of SX might protect these sperm cells from oxidative damage, which is a common cause of infertility and other reproductive issues in males.

The findings suggested that the SX seed extract significantly mitigated oxidative stress in the spermatozoa, potentially by enhancing the antioxidant defence system within the cells. This effect could be attributed to the presence of bioactive compounds in the extract, which act similarly to Vitamins C and E, scavenging free radicals and reducing lipid peroxidation in the sperm cells. The study highlights the potential of *Solanum xanthocarpum* as a

Table 2: Phytochemical constituents in *Solanum xanthocarpum* leaves and stems (source: Yogananth *et al.*, 2016).

Phytochemical	Extract of Leaf (Ethanol)	Extract of Leaf (Acetone)	Extract of Stem (Ethanol)	Extract of Stem (Acetone)
Alkaloid	++	++	+	+
Phenol	-	-	-	+
Flavonoid	++	++	+	-
Steroid	+	+	++	++
Saponin	++	++	++	++

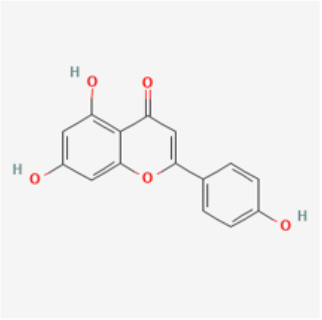
natural therapeutic agent for protecting reproductive health and possibly preventing oxidative stress-related diseases.[32]

Mechanism

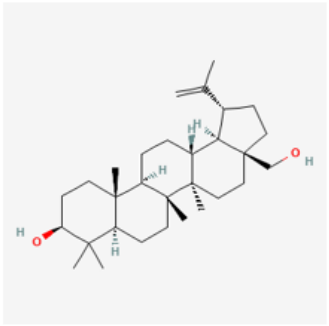
The antioxidant activity is largely due to the presence of flavonoids like quercetin and kaempferol, as well as phenolic compounds like chlorogenic acid. These compounds neutralize free radicals by donating electrons, thus preventing cellular damage caused by oxidative stress. They also enhance the activity of endogenous antioxidant enzymes like Superoxide Dismutase (SOD) and catalase.[33]

Antiasthmatic Activity

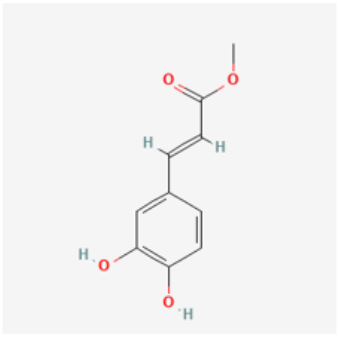
Solanum xanthocarpum has long been used in traditional medicine to manage asthma and other respiratory conditions. Chronic bronchitis is a significant health concern, affecting approximately 8-12% of the global population. Bronchial asthma, a chronic inflammatory condition of the airways, is characterized by symptoms such as bronchial hyperresponsiveness, eosinophilic inflammation, and restricted airflow. This condition is a major global health issue, arising from a complex interplay of genetic and environmental factors. Asthma's impact on the airways leads to symptoms including obstruction, eosinophilic inflammation, and heightened sensitivity to airborne triggers. The challenge



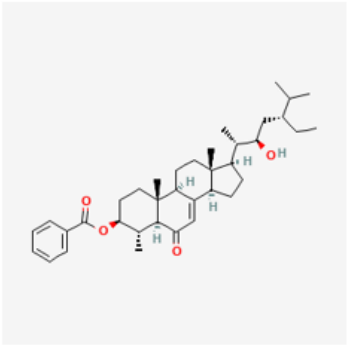
1.Apigenin



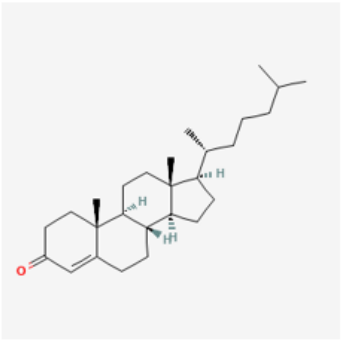
2. Betulin



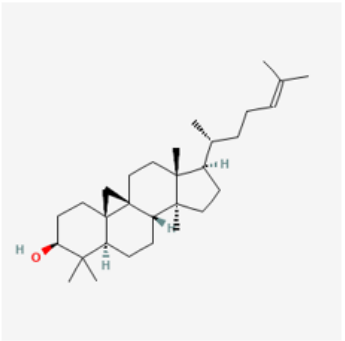
3. Caffeic acid methyl ester



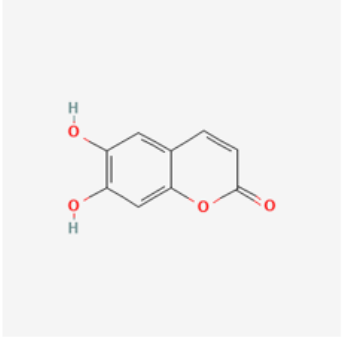
4. Carpesterol



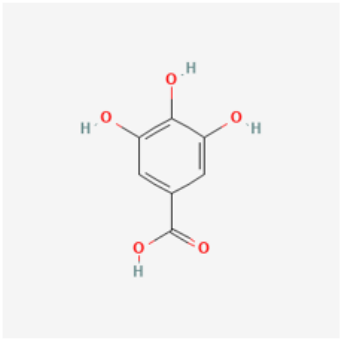
5. Cholest-4-en-3-one



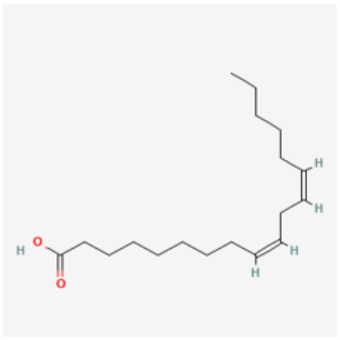
6. Cycloartenol



7. Esculetin



8. Gallic Acid



9. Linoleic Acid

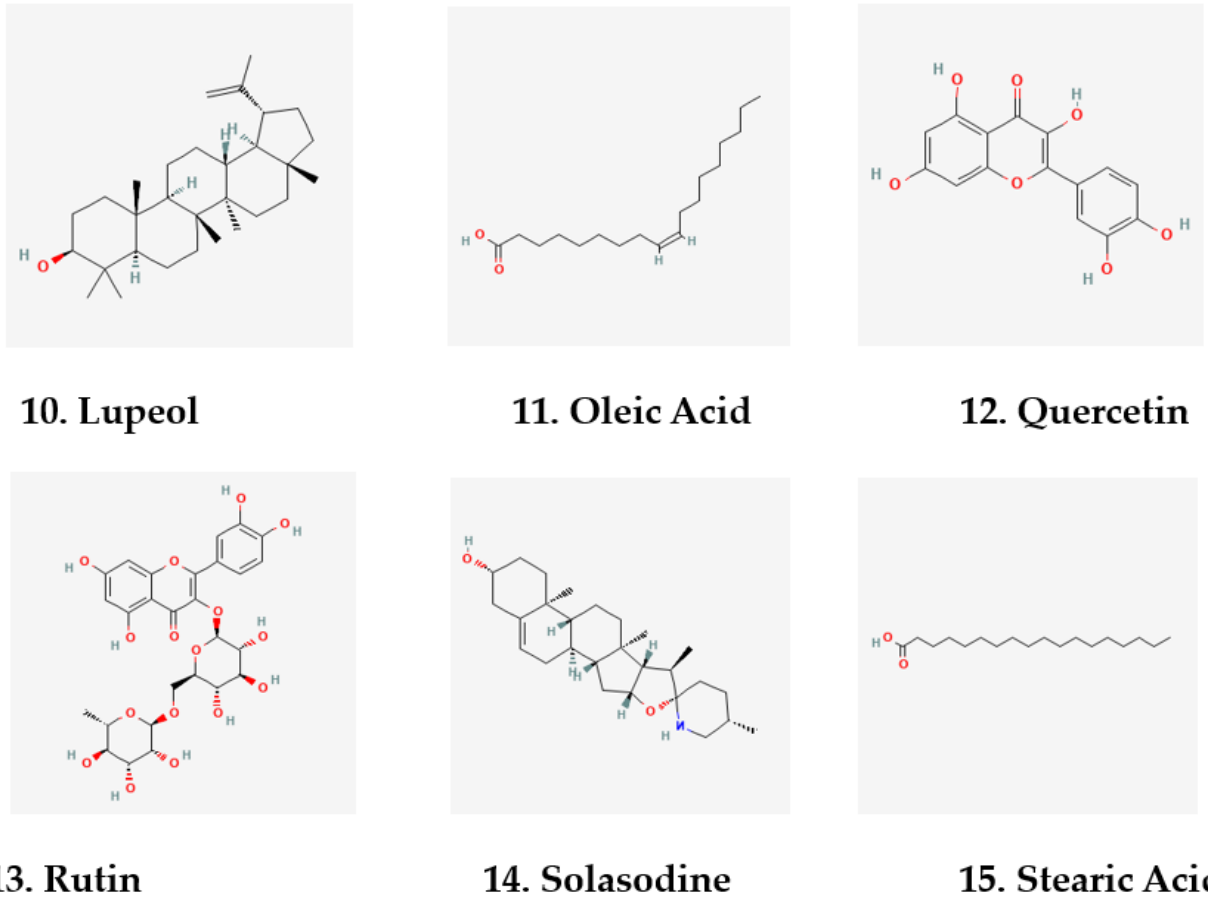


Figure 3: Various Chemical structure of *Solanum xanthocarpum*.

in managing this condition lies in the intricate relationship between inherited predispositions and environmental exposures. Globally, approximately 7-10% of people are affected by bronchial asthma.[34] While a variety of medications offer relief, the effects are often temporary and may not address the underlying issue. In Southern India, practitioners of the Siddha system of medicine frequently use *Solanum xanthocarpum* (SX) to treat respiratory conditions. Traditional preparations, such as dried whole plants or decoctions, are commonly used for this purpose. In clinical observations, *Solanum xanthocarpum* has shown significant improvement in pulmonary function in patients with mild to moderate asthma, typically within 6-8 hr of administration. The relief from asthma symptoms provided by SX may be attributed to its bronchodilator effects, reduction of bronchial mucosal edema, and decrease in airway obstruction.[35]

Cardioprotective Activity

The cardioprotective effects of *Solanum xanthocarpum* are particularly important in the context of modern medicine, where cardiovascular diseases are a leading cause of mortality. The cardioprotective activity is attributed to the glycosides and flavonoids in the plant. These compounds help regulate blood pressure, reduce cholesterol levels, and prevent the formation of atherosclerotic plaques. They also possess antioxidant properties, which protect the heart muscle from oxidative stress, thus preventing conditions like myocardial infarction.[36]

Solanum xanthocarpum is used in traditional medicine to manage hypertension, reduce the risk of heart attacks, and improve overall cardiovascular health. Its ability to lower blood pressure and protect against heart disease makes it a potential candidate for developing new cardioprotective drugs.[37]

Antidiabetic Activity

The plant has shown potential in managing diabetes and its complications. The antidiabetic activity of *Solanum xanthocarpum* is primarily due to its ability to enhance insulin sensitivity, improve glucose metabolism, and inhibit the absorption of glucose in the intestines. Flavonoids like quercetin and saponins play a key role in these mechanisms. The plant also has antioxidant properties that help protect against oxidative stress, which is a major factor in the development of diabetic complications.[38]

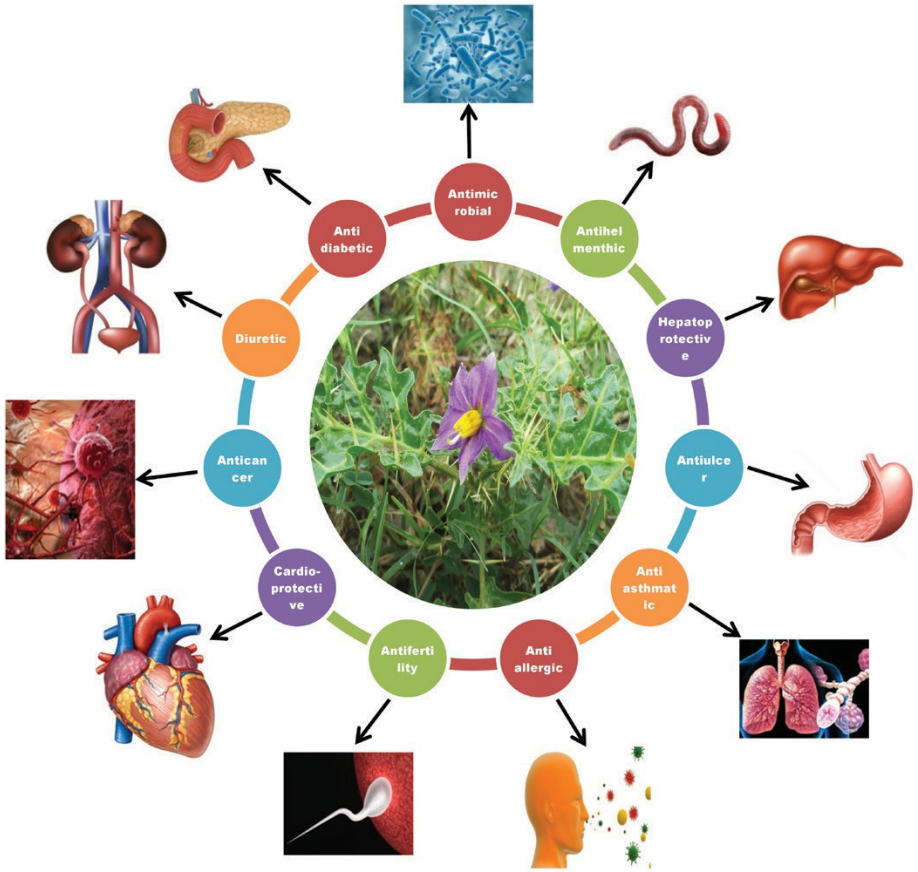


Figure 4: Graphical representation of pharmacological activities reports in *S. xanthocarpum*.

Anticancer Activity

Solanum xanthocarpum has shown promising anticancer activity in various studies, making it a subject of interest in cancer research.

The anticancer activity is largely attributed to the glycoalkaloids like solamargine and solanine, as well as the flavonoids present in the plant. These compounds induce apoptosis (programmed cell death) in cancer cells, inhibit cell proliferation, and disrupt the cancer cell cycle. They also possess antiangiogenic properties, preventing the formation of new blood vessels that tumours need to grow.[39]

The anticancer potential of *Solanum xanthocarpum* is being explored in various types of cancers, including breast, lung, and liver cancers. While more research is needed, the plant offers a potential source of new anticancer agents that could complement existing treatments.[40]

Hepatoprotective Activity

Solanum xanthocarpum is also known for its ability to protect the liver from damage. The hepatoprotective activity is due to the plant's antioxidant and anti-inflammatory properties. Flavonoids and saponins in the plant help detoxify the liver, reduce inflammation, and protect liver cells from oxidative stress. These compounds also aid in the regeneration of damaged liver tissue. Traditionally, *Solanum xanthocarpum* has been used to treat liver disorders, including jaundice, hepatitis, and cirrhosis. It is also being studied for its potential to protect against drug-induced liver damage and other liver-related diseases.[41]

Anthelmintic Activity

Anthelmintics are drugs used to treat parasitic worm infestations, which are prevalent in both humans and animals. The World Health Organization (WHO) has identified helminthiasis as a widespread global health issue, affecting people of all ages, particularly in regions with limited access to sanitation and healthcare.

Solanum xanthocarpum (SX), a plant long utilized in traditional medicine, has shown promising anthelmintic properties. Among tribal communities, SX has been used effectively to combat helminthic infections. Scientific studies have confirmed the anthelmintic potential of SX, particularly through the use of methanolic and aqueous extracts of the plant.[42]

In various research publications, it has been observed that these extracts exhibit significant anthelmintic activity against parasitic worms. The active compounds present in SX, such as alkaloids, flavonoids, and glycosides, are believed to disrupt the normal

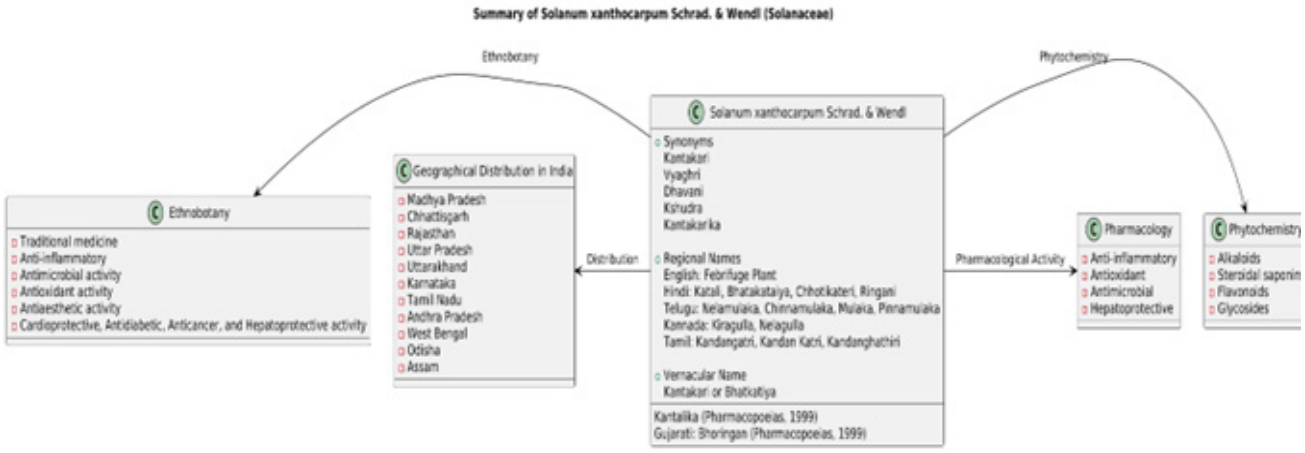


Figure 5: Summary of synonyms geographical distribution, phytochemical, ethnobotany and pharmacology of *Solanum xanthocarpum*.

functioning of parasitic worms, leading to their immobilization and eventual death. These compounds interfere with the parasite's metabolism, potentially causing paralysis and expulsion from the host body.[43]

Studies published in reputed journals highlight the effectiveness of SX extracts in treating helminthic infestations. For instance, experimental results have demonstrated that SX extracts exhibit comparable or even superior efficacy to standard anthelmintic drugs in certain cases. This has led to increased interest in exploring SX as a natural alternative or complementary therapy for helminthic infections.

Given the global burden of helminthiasis, the exploration of SX's anthelmintic properties could contribute to developing new, plant-based treatments that are both effective and accessible, particularly in resource-limited settings.[44]

Anti-ulcer Activity of *Solanum xanthocarpum* (SX)

On the lining of the stomach, small intestine, or esophagus, ulcers are open sores that form. These excruciating lesions are usually divided into three categories according to where they are found: gastric ulcers in the stomach, oesophageal ulcers in the throat, and duodenal ulcers in the small intestine.

Research into the medicinal properties of *Solanum xanthocarpum* (SX) has revealed its potential in treating ulcers. Studies comparing the anti-ulcer activity of various extracts from SX leaves have shown promising results. Specifically, extracts obtained using petroleum ether and chloroform have been tested for their efficacy in healing ulcers.[45] The findings suggest that these extracts, particularly in the early stages of treatment, exhibit significant anti-ulcer activity, with chloroform extracts showing superior results compared to petroleum ether. The anti-ulcer effects of *Solanum xanthocarpum* are believed to be due to the presence of bioactive compounds such as alkaloids, flavonoids, and glycosides, which contribute to the plant's protective and healing properties. These compounds may work by enhancing the production of mucus in the stomach lining, reducing acid secretion, or acting directly on the ulcerated tissue to promote healin.[45]

The exploration of SX as a natural anti-ulcer agent offers a promising avenue for developing new treatments that are both effective and accessible. Given the prevalence of ulcer-related conditions worldwide, the potential of SX to provide relief through natural, plant-based remedies is of great interest to researchers and healthcare providers alike.

CONCLUSION

In conclusion, *Solanum xanthocarpum* presents a promising avenue for pharmacological exploration due to its rich phytochemical profile and traditional medicinal uses. Its diverse therapeutic effects warrant further investigation to elucidate the mechanisms of action of its bioactive compounds. This research could potentially lead to the development of new treatments for various health conditions, reinforcing the importance of integrating traditional knowledge with modern scientific inquiry. Future studies should focus on standardizing the extraction methods, determining optimal dosages, and conducting clinical trials to validate its efficacy and safety for broader medicinal applications.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

S. xanthocarpum: *Solanum xanthocarpum*; **WHO:** World Health Organization; **FDA:** Food and Drug Administration; **CNS:** Central Nervous System; **GI:** Gastrointestinal; **COX:**

Cyclooxygenase; **TNF-α:** Tumor Necrosis Factor Alpha; **IL-6:** Interleukin-6; **NF-κB:** Nuclear Factor Kappa B.

AUTHOR CONTRIBUTIONS

NKJ and SA spearheaded the conceptualization, framework, and structure of the review. PK, RR, and SK played a crucial role in drafting and refining the manuscript. AT, ML, and DD conducted an extensive literature survey and gathered relevant data. AS and SS provided critical insights and assisted in content validation. Figures and tables were meticulously designed by SA, and NKJ to enhance the manuscript's clarity and visual impact. All authors actively contributed to discussions, revisions, and final approval of the manuscript, ensuring its scientific integrity and coherence.

SUMMARY

Solanum xanthocarpum, a species known for its medicinal properties, has been the subject of increasing interest due to its diverse phytochemical constituents and therapeutic potential. This review comprehensively explores the bioactive compounds found in various parts of the plant, such as alkaloids, flavonoids, glycosides, and steroids, with a focus on their pharmacological significance. Studies have shown that the plant exhibits a wide range of pharmacological activities, including antioxidant, anti-inflammatory, hepatoprotective, antidiabetic, and antimicrobial properties, positioning it as a promising candidate for natural drug development.

Special emphasis is placed on the molecular mechanisms through which *Solanum xanthocarpum* exerts its biological effects. Alkaloids such as solasodine and flavonoids such as rutin have been highlighted for their role in reducing oxidative stress and modulating inflammatory pathways. Moreover, the plant's ability to inhibit microbial growth underscores its potential use as an alternative to synthetic antibiotics, especially in the wake of rising antibiotic resistance. The review also examines the therapeutic implications of the plant in traditional medicine, reinforcing its long-standing usage in the treatment of respiratory ailments, fever, and inflammatory conditions.

REFERENCES

1. Guo BJ, Bian ZX, Qiu HC, Wang YT, Wang Y. Biological and clinical implications of herbal medicine and natural products for the treatment of inflammatory bowel disease. Ann N Y Acad Sci. 2017;1401(1):37-48. doi: 10.1111/nyas.13414, PMID 28891095.
2. Liu Y, Yang R, Zou HD, Xu ZP, Pan J, Wu JT, *et al.* Phenolic components from the fruits of *Solanum xanthocarpum* with anti-inflammatory activity. Nat Prod Res. 2024;38(6):1007-15. doi: 10.1080/14786419.2023.2211217, PMID 37165597.
3. Konar A, Chatterjee R. *Solanum xanthocarpum*-A critical approach to the lesser known aspects of the herb. Int J Sci Res Biol Sci. 2022.
4. Siddiqui S, Faizi S. Studies in the chemical constituents of the fresh berries of *S. xanthocarpum*. J Chem Soc Pak. 1983;5:99-101.,. Studies in the chemical constituents of the fresh berries of *S. xanthocarpum*. J Chem Soc Pak, 5. 1983; 732-740 (2010):99-101. J. Sci. Ind. ressearch 69.
5. Comparative antioxidant and hepatoprotective potential quercetin and corycavidine from *Hedyotis corymbosa* (L.) Lam. and *Solanum xanthocarpum* Schrad & Wendl. Indian J Exp Biol. 2022. doi: 10.56042/ijeb.v59i11.56831.
6. G., A. Wound healing potential of some medicinal plants. Int J Pharm Sci Rev Res at., S. 2011.
7. Dubey P, Gupta PC. A new flavonol glycoside from the flowers of *Solanum xanthocarpum*. Phytochemistry. 1978;17(12). doi: 10.1016/S0031-9422(00)89302-4.
8. Heble MR, Narayanaswami S, MSC. Diosgenin and b–sitosterol: isolation from *S. xanthocarpum* Tissue Cultures Sci. 1968;161:1145.
9. Lall BS, Ahmad SQ. The biology and control of brinjal (eggplant) fruit and shoot borer, Leucinodes orbonalis1. J Econ Entomol. 1965;58(3):448-51. doi: 10.1093/jee/58.3.448.
10. Bhat P, Ghane SG, Hegde HV, Jayagoudar S. A comprehensive review on traditional therapeutic uses, bioactive principles and pharmacological activities of Kantakari (*Solanum virginianum* L.): an important Ayurvedic herb. Plant Sci Today. 2023. doi: 10.14719/pst.2363.
11. Eranezhath S. Retraction: phytochemical and antimicrobial studies of extracts of *Solanum xanthocarpum*. Anc Sci Life. 2016;35(3):191. doi: 10.4103/0257-7941.179876, PMID 27143810.
12. Kumar P, Shakya R, Kumar V, Kumar D, Chauhan R, Singh H. Chemical constituents and strong larvicidal activity of *Solanum xanthocarpum* among selected plants extracts against the malaria, filaria, and dengue vectors. J Vector Borne Dis. 2023;60(1):18-31. doi: 10.4103/0972-9062.361177, PMID 37026216.
13. Imran M, Majid H, Ali M, Qadir A. Phytochemical screening of *Solanum xanthocarpum* and its xanthine oxidase inhibitory activity. Biol Sci. 2022;2(3). doi: 10.55006/biolsciences.2022.2308.
14. Kumar S, Sharma UK, Sharma AK, Pandey AK. Protective efficacy of *Solanum xanthocarpum* root extracts against free radical damage: phytochemical analysis and antioxidant effect. Cell Mol Biol (Noisy-le-grand). 2012 doi:10.1170/T938;58(1):174-81. PMID 23273209.
15. Parmar KM, Shende PR, Katare N, Dhobi M, Prasad SK. Wound healing potential of *Solanum xanthocarpum* in streptozotocin-induced diabetic rats. J Pharm Pharmacol. 2018;70(10):1389-400. doi: 10.1111/jphp.12975, PMID 29984407.
16. H, A.S. Phyto-Pharmacological Review of *Solanum xanthjocarpum* Schrad and Wendl. Int J Pharmacogn Phytochem Res. 2019.
17. Pathan AR, Vadnere GP. *Solanum xanthocarpum* (white variety): A phyto-pharmacological review. Int J Pharm Technol at. 2012.
18. Dewangan H, Bais M, Jaiswal V, Verma VK. Potential wound healing activity of the ethanolic extract of *Solanum xanthocarpum* schrad and wendl leaves. Pak J Pharm Sci. 2012;25(1):189-94. PMID 22186329.
19. Chhajed M, Jain A, Gupta S, Dubey I, Shrivastava AK. Phytochemical Investigation and Pharmacological Evaluation of *Solanum xanthocarpum* Endowed with their potential Activity. J Pharm Technol Res Manag. 2018;6(1):55-65. doi: 10.15415/jptrm.2018.61005.
20. Sundari GS, S R, A P. Phytochemical evaluation of three species of *solanum* L. Int J Res Ayurveda Pharm. 2013;4(3):420-5. doi: 10.7897/2277-4343.04323.
21. Anwikar S, Bhitre M. Study of the synergistic anti-inflammatory activity of *Solanum xanthocarpum* Schrad and Wendl and *Cassia fistula* Linn. Int J Ayurveda Res. 2010;1(3):167-71. doi: 10.4103/0974-7788.72489, PMID 21170209.
22. More SK, Lande AA, Jagdale PG, Adkar PP, Ambavade SD. Evaluation of anti-inflammatory activity of *Solanum xanthocarpum* Schrad and Wendl (Kaṇṭakāri) extract in laboratory animals. Anc Sci Life. 2013;32(4):222-6. doi: 10.4103/0257-7941.131976, PMID 24991071.
23. Xu Z, *et al.* Bioactive lipids from the fruits of *Solanum xanthocarpum* and their anti-inflammatory activities. SSRN Electron J. 2022. doi: 10.2139/ssrn.3996176.
24. Solapure P, Pradeep D, Mundugaru R, Hegde PL. Comparative anti-inflammatory activity of *Clerodendrum serratum* (Linn.) Moon and *Solanum xanthocarpum* Schrad and Wendl in Wistar ablino rats. J Phytopharmacol. 2016;5(2):38-44. doi: 10.31254/phyto.2016.5201.
25. Jalali Ghassam B, Ghaffari H, Prakash HS, Kini KR. Antioxidant and hepatoprotective effects of *Solanum xanthocarpum* leaf extracts against CCl4-induced liver injury in rats. Pharm Biol. 2014;52(8):1060-8. doi: 10.3109/13880209.2013.877490, PMID 24646306.
26. Abbas K, Niaz U, Hussain T, Saeed MA, Javaid Z, Idrees A, *et al.* Antimicrobial activity of fruits of *Solanum nigrum* and *Solanum xanthocarpum*. Acta Pol Pharm. 2014;71(3):415-21. PMID 25265821.
27. Pardhi P, Jain AP, Ganeshpurkar A, Rai G. Anti-microbial, anti-oxidant and anthelmintic activity of crude extract of *Solanum xanthocarpum*. Pharmacogn J. 2010;2(11):400-4. doi: 10.1016/S0975-3575(10)80022-7.
28. Kannabiran K. Evaluation of antimicrobial activity of saponin isolated from *Solanum xanthocarpum* and *Centella asiatica*. Int J Nat Eng Sci. 2009.
29. Hemashenpagam N, Growther, L., Sankar, Selvaraj, T. & Panneerselvam, A. Phytochemical analysis and antimicrobial activity of *Solanum xanthocarpum*. Biomed. (2009).
30. Usman H, Ullah MA, Jan H, Siddiquah A, Drouet S, Anjum S, *et al.* Interactive effects of wide-spectrum monochromatic lights on phytochemical production, antioxidant and biological activities of *Solanum xanthocarpum* callus cultures. Molecules. 2020;25(9):2201. doi: 10.3390/molecules25092201, PMID 32397194.
31. Tyagi R, Waheed A, Kumar N, Mujeeb M, Naved T, Rashid Khan M, et al. *In vitro* and *ex vivo* antidiabetic, and antioxidant activities of Box-Behnken design optimized *Solanum xanthocarpum* extract loaded niosomes. Saudi Pharm J. 2023;31(10):101785. doi: 10.1016/j.jsps.2023.101785, PMID 37766819.
32. Gupta RK, Hussain T, Panigrahi G, Das A, Singh GN, Sweety K, *et al.* Hepatoprotective effect of *Solanum xanthocarpum* fruit extract against CCl 4 induced acute liver

toxicity in experimental animals. Asian Pac J Trop Med. 2011;4(12):964-8. doi: 10.1016/S1995-7645(11)60227-7, PMID 22118032.

33. Joghee S. *Solanum xanthocarpum*: a review. Int J Pharmacogn Chin Med. 2019;3(3):1-7. doi: 10.23880/ipcm-16000177.
34. Malviya N, Jain S, Malviya S. Antiasthmatic potential of indigenous medicinal plants. Complement. Drug Discov. 2011;1(1). doi: 10.5455/spatula.20101223032951.
35. Sastry KS, Mandal B, Hammond J, Scott SW, Briddon RW. *Solanum xanthocarpum* (Yellow-berried nightshade). In: Encyclopedia of plant viruses and viroids. New Delhi: Springer India; 2019. p. 2455-. doi: 10.1007/978-81-322-3912-3_883.
36. Nithya M, Ragavendran C, Natarajan D. Antibacterial and free radical scavenging activity of a medicinal plant *Solanum xanthocarpum*. Int J Food Prop. 2018;21(1):313-27. doi: 10.1080/10942912.2017.1409236.
37. Rahman G, *et al.* Empowering silver and copper nanoparticles through aqueous fruit extract of *Solanum xanthocarpum* for sustainable advancements. Biomass Convers Biorefin. 2024. doi: 10.1007/s13399-024-05270-5.
38. Screening, P. Phytochemical Screening and analgesic activity of "Kantkari". Int J Herb Med. 2013.
39. Kumar S, Pandey AK. Medicinal attributes of *Solanum xanthocarpum* fruit consumed by several tribal communities as food: an *in vitro* antioxidant, anticancer and anti HIV perspective. BMC Complement Altern Med. 2014;14:112. doi: 10.1186/1472-6882-14-112, PMID 24678980.
40. Perera MG, Soysa SS, Abeytunga DT, Ramesha R. Antioxidant and cytotoxic properties of three traditional decoctions used for the treatment of cancer in Sri Lanka. Pharmacogn Mag. 2008.
41. Gupta AK, Ganguly P, Majumder UK, Ghosal S. Hepatoprotective and antioxidant effects of total extracts and stereoidal saponins of *Solanum xanthocarpum* and *Solanum nigrum* in paracetamol induced hepatotoxicity in rats. Pharmacologyonline. 2009.
42. Gunaselvi G, Kulasekaren V, Gopal V. Anthelmintic activity of the extracts of *Solanum xanthocarpum* schrad and wendl fruits (Solanaceae). Int J PharmTech Res. 2010.
43. Kadam AP, Salunkhe NB, Aparadh VT, Kadam DA, Chavan JJ. Discrepancy in polyphenol content and mineral composition from various organs of *Solanum xanthocarpum* schrad & wendl. Natl Acad Sci Lett. 2014;37(2):187-90. doi: 10.1007/s40009-013-0211-6.
44. Sarmah P. Ethnomedicinal plants and their traditional use for treatment of diabetes in Kokrajhar District of Assam. Int J Curr Microbiol Appl Sci. 2021;10(1):464-77. doi: 10.20546/ijcmas.2021.1001.057.
45. Akhtar MS, Munir M. Evaluation of the gastric antiulcerogenic effects of *Solanum nigrum, Brassica oleracea* and *Ocimum basilicum* in rats. J Ethnopharmacol. 1989;27(1-2):163-76. doi: 10.1016/0378-8741(89)90088-3, PMID 2515396.

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