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Potential applications of propolis

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Abstract
Propolis is produced by honeybees from plant exudates. It is a natural and viscous substance known for its various bioactive qualities which includes antibacterial, antioxidant, anti-inflammatory and anticancer properties. Chemically propolis is rich in flavonoids and phenolic complexes such as CAPE (caffeic acid phenethyl ester), which varies by geographic and botanical origin. This article covers the pharmacological and industrial applications of propolis. In medical studies its efficiency against pathogens, its capability to eliminate oxidative stress and inflammation have been reported. In addition, in the food industry, propolis is utilised as food preservative due to its anti-microbial effect; in cosmetics, its anti-inflammatory properties are utilised, and it's used in the development of active, biodegradable packaging materials, highlighting its important cross-industry potential.

Keywords: Propolis, Bioactive Properties, Antimicrobial, Antioxidant, Anti-inflammatory, Anticancer, Food Preservation, Active Packaging, Natural Products

Introduction

Propolis, an organic product used in beehive protection, is derived from the Greek word "pro", which means "at the entrance to", and "polis", which means "community" or "city". Honeybees gather materials from flowers, shoots, and exudates to make propolis, an organic, resinous mixture. It is also known as bee glue. Because of their waxy composition and systematic goods, bees service them in the building and healing of their hives by closing gaps, flattening off the inner and defensive wall counter to peripheral attackers such as snakes and lizards, or in contrast to wind or rainwater. They gather it from many plants in various temperate climate zones, and it's a broad variety of propolis with many diverse characteristics, fragrances and colours which range between black and yellow, reddish-brown, and dark-brown. Its antiseptic, anti-inflammatory, antiviral, antioxidant, anti-cariogenic, immunomodulatory, and anaesthetic traits are well established. Propolis has a well-recognized usage in pharmacology and medicine, and reports have indicated that it can be used in agriculture, specifically to manage crop pathogens, like vegetables. *Colletotrichum gloeosporioides*, *Corynespora cassiicola*, *Lasiodiplodia theobromae*, *Peronospora manshurica* and *Puccinia polysora* are only a few of the fungi that have been found to be susceptible to the antifungal properties of EEP, which has led to the use of propolis in crop management. The effectiveness of propolis on the regulation of various fungi and phytopathogenic ailments may be associated to the development of waxen cover caused by the usage of EEP, which covers the leaves inhibiting fungal invasion. One more likely trait is the stimulating ability of the phenolic mixtures held in it which can promote the resistance of the plant to pathogens.

Historical overview of propolis

In the long and rich history of human apiculture, beehive products have been widely utilised because of their acknowledged therapeutic benefits. Specifically, the historical benefits of propolis have been recognised since 300 B.C. The Egyptians reversed the bee and applied propolis in embalming rituals. It was also familiar to priests who at that time controlled the practice of medicine. Bees played a significant role in Greek and Roman spiritual presumptuous emblematic significances and were depicted in numerous myths of the Greek and Roman gods. Between them, one says of Zeus (Jupiter for Romans), who, to escape his father, the god Cronus, was concealed in a hidden cavern by his mother and nourished with honey from divine bees. Possibly due to this story, one of Zeus' epithets was "*Melissaios*", or "bee-man". According to this legend, Zeus himself bestowed bees with golden hues and made them resilient to cold and storms.

Historically, in Georgian treatment, several diseases were treated employing propolis salves. Similarly, there is the tradition of putting a propolis cake on the infant's navel. Throughout the Anglo-Boer War and World War II, doctors treated propolis to facilitate tissue repair effectively. In 1969, orthodox medicine in the USSR finally recognised the use of propolis (30% alcohol solution) for medical purposes. The Greek perfume polyanthus, which includes propolis, olibanum, styrax, and fragrant herbs, includes propolis as a significant component. More than 15 Greek and Roman authors, including Aristotle in his "*Historia Animalium*" and Hippocrates, who is credited with using propolis to treat wounds and ulcers, have commended it (with honey and wax). Additionally, Dioscorides listed honey, wax, and various honey wines as medications when discussing the medicinal use of propolis in his primary work "*De materia*

Medica". The Romans held propolis and bees in high esteem.

Historical applications

In traditional medicine, propolis has been extensively utilised as a bactericidal, antiviral, and antifungal drug to cure inflammation in many body parts. It was incorporated in practically all home first-aid kits because it has been used for skin rejuvenation, damage healing, and as a local anaesthetic. Because propolis has been verified to improve wound healing and reduce other forms of irritation, it has been recommended in traditional medicine for the treatment of infected illnesses. Propolis was also utilized by artisans for non-healthy purposes, like sealing windows, impregnating costly wooden items, polishing, and fixing tools. Numerous propolis-based products, including sprays, ointments, and powders (mostly tinctures and ethanolic extracts), were utilized as replacements and comparable medications to treat human ailments such as gastrointestinal problems, colds, flu, and bronchial asthma. Moreover, several dietary supplements, cosmetics, and medical candies still contain propolis as an active ingredient. It has little nutritional value, unlike honey and bee pollen, but has a strong multidirectional biotic impact. Propolis has lately gained popularity in food and drinks as a means of promoting wellness and warding off disease. It is still used to cure stomach ulcers, dental cavities, sore throat, burns, and wounds. Propolis' ethanolic extract is used as an immunomodulatory agent and has anti-inflammatory Properties. It plays a beneficial role in dentistry and can be used for numerous endodontic applications. Scientists have used nanoparticles to demonstrate the diverse uses of propolis. Hydrophobic substances, such as propolis, can be made dispersible in aqueous systems via nanoparticle-based transport mechanisms, thereby avoiding issues related to low solubility.

Overview and Composition

Propolis is an evolved natural product prepared by bees with plant resins, wax, saliva, and pollen, with over 300 identified chemical compounds, as well as phenolic acids, flavonoids, terpenes, and aromatic aldehydes. Its composition differs based on geographic origin, botanical sources, and bee species, affecting its colour, aroma, and biological activities. Significant bioactive components confer antiseptic, anti-inflammatory, antioxidant, antimicrobial, and immunomodulatory properties, creating it effective in traditional medicine and emerging industries.

Applications of propolis in different industries:

1. Food Industry Applications

In the food industry, propolis is utilized as a natural preservative due to its antimicrobial and antioxidant effects. Challenges such as bitter taste and low water solubility have been addressed through encapsulation, microencapsulation, and incorporation into edible films and coatings. Propolis-enhanced packaging materials, often amalgamated with biopolymers, such as chitosan, improve food shelf life by improving mechanical strength, oxygen/moisture barriers, and microbial resistance. These "active" and "intelligent" packaging systems can inhibit food spoilage pathogens and increase loading periods for meat, dairy, fruits, and vegetables.

2. Cosmetic Uses

Propolis has a rich history of therapeutic applications in wound healing, infections, oral health, and inflammation. Bacteria, fungi, viruses, and parasites are acted against by it; immunomodulation is assisted, and the anticancer potential affects it. Nanobiotechnological formulations enhance propolis bioavailability and targeted delivery of pharmaceuticals, which are involved in modern developments. Examples include topical gels, creams, throat sprays, and mouthwash. Its improvement in cosmetics is sustained by its anti-inflammatory and antioxidant activities.

3. Packaging and Biomaterials

The development of biodegradable packaging films, incorporating propolis, enhances environmental sustainability while leveraging the antimicrobial traits of propolis. Propolis films are employed to coat plastic or cellulose substrates, enhancing barrier functions and allowing the detection of food spoilage through colour changes. Chitosan-propolis composites indicate eco-friendly alternatives to synthetic polymers for food packaging.

4. Pharmaceutical importance of Propolis

Various studies have demonstrated that Indian propolis have exhibited antioxidant, antimicrobic, anti-inflammatory, and antitumour effects. However, Indian propolis is lacking in periods of an accomplished outline for its chemical components and healing ability proportional to propolis from further amounts on Earth. In the article, it surmises main discoveries on the medical possessions of it concentrating on its anti-microbial, antitumor, antioxidative and anti-inflammatory qualities.

5. Anti-bacterial activity

Propolis inhibits bacteriostatic action against *Streptococcus aureus,* typhoid bacillus, and other microbes in these reports. Lindenfelser also studied the antimicrobial effects of propolis, finding the propolis solution at concentrations of < 10 mcg/ml had *in vitro* activity against Bacillus larvae, the etiological agent of American foulbrood (AFB) of Apis mellifera honeybees. Medical studies have shown that its antibacterial action must be reflected in two stages. First, it refers to the direct effect on the microbe and the other, the activation of the immune classification, resulting in stimulation of natural defence mechanisms of the body. Research on the mechanism of action of propolis revealed that the cell wall of the microbes was penetrable, the membrane function of the microbes was disturbed, adenosine triphosphate synthesis (ATP) and the bacteria flexibility were damaged. Propolis is effective against Gram-positive and Gram-negative bacteria, aerobic as well as anaerobic. This is due to chemical composition.

6. Antioxidant activity

Propolis, which is abundant in flavonoids and phenolic mixtures owing to its antioxidant properties, may protect humans from toxic oxidative progressions. Ibanrikynti examined the antioxidative potential of Meghalaya propolis. Their examination using GC-MS detected 20 groups of mixtures, of which eight composites accompanied by their natural movement were noted. N-hexadecenoic acid (34.88%), oleic acid (26.37%), tetra decanoic acid (4.90%), 2-furancarboxaldehyde, 5- (hydroxymethyl) (3.21%), and 3,7, 11, 15-tetramethyl-2-hexadecene-1-ol (1.95%) were the

main components of propolis from Meghalaya. It demonstrated significant antioxidant activity in every test.

In 2024, Alshehri described that propolis separation indicated considerable defensive power on the liver and kidneys as a result of its antioxidant and anti-inflammatory qualities. Its ability to go through free activists, prevent lipid peroxidation, and enhance intracellular antioxidant defences, such as glutathione and superoxide dismutase, emphasises the wide-ranging protecting systems that it supports, contrary to oxidative stress-related injury to these body parts. In the 1,1-diphenyl-2-picrylhydrazyl (DPPH) free-radical system, we evaluated its unrestricted radical foraging activity and vitamin C. The basic foraging movement of EEP at the application dose of 100 mcg was 70.96% and 72.97% out of hundred after 30 min and 1 h, respectively. Laskar mainly reported the antioxidant action of the aqueous and ethanol fraction of Indian propolis (AEP and EEP) respectively. Chemical and electrochemical endeavours were made to find the antioxidant power. AEP showed obviously better mobility in these tests than EEP, which conflicts with previous claims from other countries. This is possibly attributable to its high polyphenol content. It is the bee outcome with the maximum quantity of phenolics, and thus, it has been intensely learned aimed at antioxidant and radical sifting actions. As a result, Indian propolis is considered a valuable source of natural antioxidants that can be useful for curing a diverse range of diseases produced by limitless revolutionaries.

Anti-inflammatory activity

Inflammation is a complex biological reaction of an individual's body to harmful stimuli, such as viruses, annoyances, or wounds from foreign invaders. Numerous studies have examined the anti-inflammatory properties of propolis. According to previous studies, propolis inhibits the activity of tyrosine kinase, myeloperoxidase, NADPH-oxidase, ornithine decarboxylase, and hyaluronidase. The active flavonoids and cinnamic acid end products applied anti-inflammatory effects. The latter contain caffeic acid and caffeic acid phenyl ester (CAPE), while the former comprises acetin, quercetin, and naringenin. CAPE is thought to be primarily a potent anti-inflammatory component that may exactly target NF-kB signalling.

Moreover, this component has been indicated to modulate ERK MAPK signalling in T cells and mastocytes and control the PI3K/Akt pathway in additional cell lines. In animal models, CAPE and galangin have demonstrated anti-inflammatory properties and significantly reduced oedema, pleurisy, and arthritic inflammation.

An ethanol extract of propolis prevents acute peritoneal inflammation caused by zymosan and regulates the production of prostaglandins and leukotrienes in mouse peritoneal macrophages. The lipoxygenase (LOX) pathway of arachidonic acid metabolism was inhibited *in vivo* by nutritional propolis. CAPE was also a greater significant modulator of arachidonic acid metabolism than naringenin, quercetin and caffeic acid.

Inflammation has been associated with several diseases. Several reports have shown that propolis has anti-inflammatory properties, which may be a result of the presence of phenolic acids. Propolis has been sourced in conventional treatment for a longtime, though it is not a constituent that can be applied to cure very diseases since of their miscellaneous pharmacologic actions and chemical arrangements, defining quality values for propolis holding goods is presently a main problem. Anti-inflammatory property is one of the advantages of conventional pharmaceutical products of propolis, and it is widely used for the treatment of inflammatory disorders.

Anticancer activity

Several functional composites have been described in propolis that show anticancer properties. Several researchers have examined the tumour-hindering causes of propolis removal and their elements, observing that polyphenols have chemo-preventive features and that honey with maximum phenolic content is useful in preventing cancer cell multiplication.

As per described suggestion, the anti-cancer processes of propolis differ broadly *i.e.*, anti-angiogenesis, initiation of apoptosis, cell cycle detention and anti-proliferation activity. Numerous procedures of activity have been revealed for the main combination, comprising control of tyrosine kinase movement and production of cell cycle block in the G1 or G2/M stage. Programmed cell death, cell-cycle arrest and metabolic process have been considered as the core processes. The antioxidant activity of Indian stingless bee propolis has been proven to enhance its anticancer effects.

The medicinal effects of honey on various cancers have been studied both *in vitro* and *in vivo*, but some research has been conducted and their results are controversial. A number of studies have reported that normal bee effects overwhelm tumour cells development and promote apoptosis of carcinogenic cells, suggesting the potential use of these natural products (or their active elements) as replacement treatment for different tumours. According to Xuan, it can treat human breast cancer because of its anticancer activity by inducing apoptosis in breast cancer cells. It similarly demonstrates small or no poisonousness near natural cells because of its selectively toxic qualities in contrast to tumour cells, and is considered that propolis may developed a pronounced cause to cure breast cancer.

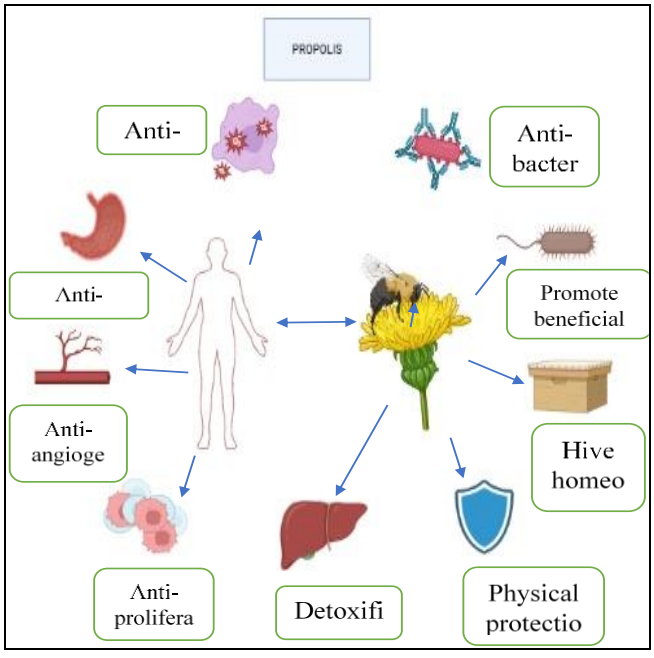

Fig 1: Benefits of propolis in different ways

Physical protection
Detoxification
Anti-proliferative
Anti-angiogenic
Anti-inflammatory
Anti-oxidant
Hive homeostasis
Anti-bacterial
Promote beneficial microbiome

Future prospects

There is an utmost necessity for multiple clinical experiments investigating collective propolis in isolation and its main functional elements. Furthermore, the therapeutic efficacy of propolis against normal human pathogens and its ability to prevent cancer growth permit *in vitro* and *in vivo* testing in animal models. In addition, there is exciting research into improving and standardising innovative systems for propolis delivery, for example, applying nanotechnological methods to advance specific dressings. Additional research is needed to authenticate the synergistic ability of conventional medicines and propolis, which could lead to advanced adjunct therapies. Usually, given the significant volume of technical work on propolis in recent years, it is rational to expect that future comprehensive studies may reveal additional properties of propolis and expand its clinical uses. Significantly, authentication of the usual uses of propolis from folk medicine through advanced investigation methods and clinical tests highlights its therapeutic potential.

Challenges

Nevertheless, early propolis can be largely combined into medicinal practice, and several problems arising from its intrinsic features must be resolved. The main limitation is the difference in the chemical arrangement of propolis among several topographical areas, which hinders the standardisation of propolis formulations. Standardisation is supreme not only for health care practitioners, but also for maintaining the dependability of exploring findings on the properties of propolis. One method of standardisation involves concentrating on the attentiveness of the main effective components of propolis, which is supposed to use a synergetic result. As well, regulating the most ideal removal systems, preparations, and types of administration for propolis tailored to exact disease conditions, an alternative trial to be undertaken.

Conclusion

Propolis is an extremely versatile natural product with enormous value in various fields. Its potential organic properties, including antimicrobial, antioxidant, anti-inflammatory, and anticancer actions, stem entirely from its complex chemical structure and rich content of bioactive compounds, such as flavonoids and phenolic acids. Due to these qualities, it has long been used in traditional medicine and is now extensively used in the food industry as a natural preservative, in cosmetics for its therapeutic benefits, and in sustainable packaging. Its efficiency in regulating plant pathogens in agriculture is especially noteworthy, showing its promise as an eco-friendly substitute for synthetic pesticides. Despite its potential, challenges persist, for instance, standardising its variable components and enriching its bioavailability using advanced formulations. Ongoing research is essential to fully realise the vast potential of this bee-derived substance and to strengthen its significant role in health, agriculture, and industry.

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