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Potential Benefits of Propolis in Large and Small Animal Practices: A Narrative Review of the Literature

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ABSTRACT

Propolis is a resinous substance from a mixture of different plant parts and molecules bees compose. This narrative review article explored the application of propolis in large and small animal practices in PubMed, Scopus, and Google Scholar databases. Propolis is applied in different pharmaceutical forms. Due to its numerous biological actions, such as antimicrobial, anti-inflammatory, antioxidant, antiparasitic, antiulcer, antitumor, and immunomodulatory, propolis can improve animal health and production. Propolis could be used as an alternative treatment for many diseases, such as mastitis, lumpy skin disease, foot and mouth disease, reproductive disorders, and diarrhea in cattle. Moreover, it could improve weight gain in cattle. In equine, propolis has been used as a local anesthetic and for treating dermatomycosis, chronic bronchitis, and skin wounds. In pigs, propolis has been used to treat enzootic pneumonia and as a prophylaxis for gastrointestinal and respiratory diseases in weak pigs. Propolis has been applied to treat caseous lymphadenitis and parasitic diseases in sheep and goats. Furthermore, it improves the immune status of kids and the health status of late pregnant ewes. In dogs and cats, propolis has been applied to treat otitis externa, eye diseases, Cushing's syndrome, and dermatophytosis. In dogs, propolis can treat transmissible venereal tumors. Moreover, propolis positively affects animal production, average daily gain and milk yield in sheep, growth of calves, lambs, and piglets, and cow's milk nutritional quality. On the other hand, the addition of propolis to the diet of feedlot bulls and pigs has no effect on their feed intake, hematological, biochemical, and immunological parameters, nutrient digestibility, microbial synthesis, and carcass characteristics. Based on the available clinical studies, propolis has potential benefits for animal health in cattle, equine, sheep, goats, pigs, dogs, and cats. According to the available literature, propolis is a natural promising agent that can alternate conventional pharmaceuticals, particularly antibiotics. It improves animal health and production with no adverse effects and low cost. Most conducted studies on the efficacy of propolis on animal health and production are *in vitro*. Due to its scarcity, further controlled clinical trials are recommended to evaluate the exact usefulness of propolis in veterinary medicine and to obtain reliable conclusions on the benefits of propolis in animal health and production.

Keywords: Cattle, Dog, Horse, Pig, Propolis, Sheep

INTRODUCTION

The term "propolis" originates from the Greek language, where "pro" signifies "in front" and "polis" means "city." This combination conveys the concept of "in front of the city," which aptly characterizes the protective role of propolis within the bee colony. Propolis serves to safeguard the hive by sealing openings and crevices (Bogdanov, 2017). Moreover, propolis also serves as a protective shield for the bee colony due to its antibacterial and antifungal properties, which contribute to shielding the colony from diseases (Bogdanov, 2017; Özdemir et al., 2022).

Propolis has other common names, such as propóleos, bee glue, bee propolis, hive dross, propolis balsam, propolis cera, propolis wax, propolis resin, Russian penicillin, and synthetic beeswax (Farooqui and Farooqui, 2010; Righi et al., 2011; Bogdanov, 2017; Özdemir et al., 2022).

Propolis consists of various quantities of beeswax and resins collected by the honeybee from different plants' flowers, and leaf buds (Bogdanov, 2017). The chemical composition of propolis varies according to its geographic and botanical origin. Nevertheless, the pharmacological effects of different types of propolis are the same (Marcucci, 1995). Therefore, it is used in alternative medicine like wound and burn dressing and as a nutritional supplement due to its unique biological actions (Elshater et al., 2017; Elkhenany et al., 2019).

Propolis has antibacterial, antifungal, antiviral, antiparasitic, anti-inflammatory, immuno-stimulatory, anti-tumoral, local anesthetic, and antioxidant activities (Betancourt et al., 2015; Bogdanov, 2017; González-Búrquez et al., 2017). Therefore, propolis represents a promising medicine and natural supplement in the diet for supporting body activities without adverse effects on either animals or the environment. Moreover, propolis is considered a natural alternative to many pharmaceutical drugs to overcome the drug residue problem in food, such as antibiotics residue (Banskota et al., 2001; Özdemir et al., 2022).

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This narrative review aimed to describe the different clinical applications of propolis in large and small animal practices and its potential benefits in animal health and production.

DATA COLLECTION

This review relied on an extensive literature search conducted in January 2023, encompassing the utilization of propolis in both large and small animals. The search specifically targeted relevant articles published in the English language. Literature pertinent to propolis in veterinary medicine during the last 40 years (1982-2022) was explored in PubMed, Scopus, and Google Scholar databases. The relevant literature was reviewed and critically appraised in this review. The search terms included "propolis", "horse", "donkey", "equine" "cattle", "buffaloes", "bovine", "sheep", "goats", "dogs", "cats", and "pigs".

PHYSICOCHEMICAL PROPERTIES OF PROPOLIS

Propolis has various colors and types with no standard chemical contents due to the variation in botanical origin, season, and types of bees (Marcucci, 1995; Özdemir et al., 2022). Its color ranges from transparent or yellow to dark brown according to the source of resin. Ethanol (ethyl alcohol) ether, glycol, and water are commonly used to extract the propolis (Abdulkhani et al., 2017; Anjum et al., 2019).

Propolis has more than 300 compounds with various compositions and isomers. Among these compounds, vitamins (C, B, B1, B2, A, and E), acids (organic acid, gallique acid, isoferulic acid, ferulic acid, and phenolic acids), flavonoids (flavones, flavonol, flavonones, and flavononol), cafeique, pectolinarigenine, chrysine, acacetine, coumarines, vaniline, pinocembrine, tectochrysine, galangine, izalpinine, kaempferidae, querestin rhamnocitrine, pinostrobine, sakuranetine, pinobanksine, isovaniline, P-coumarique, cinnamique, scopoletin, and terpene, are the most common bioactive chemical agents present in all kinds of propolis (Boukraa, 2013; Bankova et al., 2014; Bogdanov, 2017; Anjum et al., 2019; Özdemir et al., 2022).

Propolis is composed of 50% resin compounds and balsams, 40% beeswax, 5% aromatic oils, and 5% bee pollen (Figure 1). Moreover, propolis is rich in albumin, calcium, magnesium, iron, zinc, silica, potassium, manganese, cobalt, copper, sodium, aluminum, nickel, chromium, and cadmium (Abdulkhani et al., 2017; Özdemir et al., 2022). Nevertheless, the various chemical compositions of propolis may induce a problem with its clinical application and quality control (Özdemir et al., 2022).

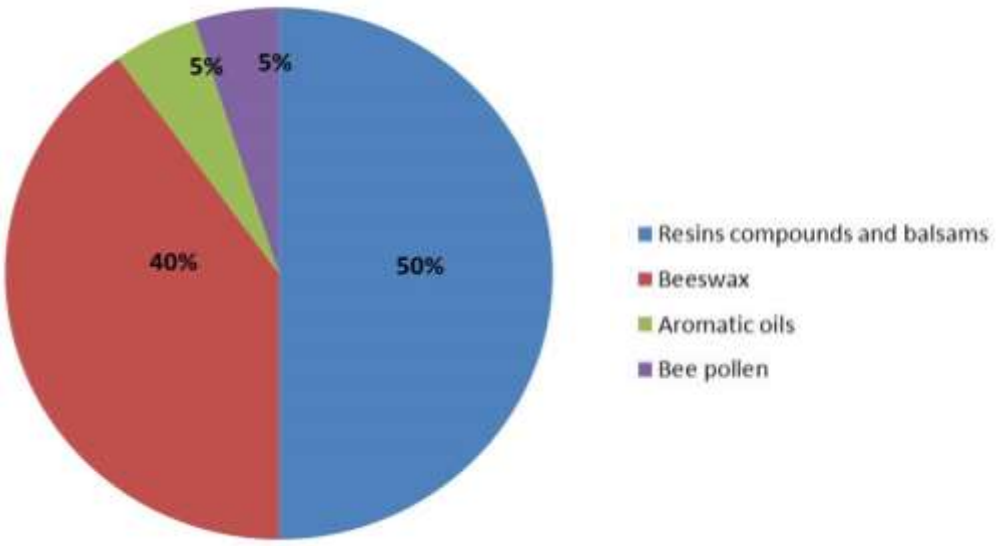

Figure 1. Chemical composition of raw propolis (Sources: Abdulkhani et al., 2017; Özdemir et al., 2022).

THERAPEUTIC ACTIONS OF PROPOLIS IN LARGE AND SMALL ANIMAL PRACTICES

Propolis is commonly applied in veterinary medicine for its antibacterial (El-Tayeb et al., 2019; Przybyłek and Karpiński, 2019), antifungal (de Mendonça et al., 2015), antiviral (Alp, 2018), antiparasitic (Anjum et al., 2019), antioxidant (Torres et al., 2018), anti-inflammatory (Machado et al., 2016), antitumor (Doğan et al., 2020), immunomodulatory (Shvarzbeyn and Huleihel, 2011), antiulcer (da Silva et al., 2018), local anesthetic (Özdemir et al., 2022), and cytotoxic (Bonamigo et al., 2017) actions as shown in Figure 2. Moreover, propolis enhances wound healing (Abu-Seida, 2015), dentinogenesis after pulp capping (Saleh et al., 2016; Abo El-Mal et al., 2021), and hard‑tissue deposition as well as soft‑tissue formation inside the necrotic dental pulp in dogs (El-Tayeb et al., 2019; Abdelsalam et al., 2020; Abo EL Wafa et al., 2021; Mohamed et al., 2023).

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Figure 2. Therapeutic actions of propolis (Sources: Machado et al., 2016; Torres et al., 2018; Anjum et al., 2019; Doğan et al., 2020; Özdemir et al., 2022).

Antibacterial action

Propolis has potent bacteriostatic and bactericidal effects since it inhibits protein production of bacterial growth by inhibiting cell division (Havsteen, 2002). In addition, some active ingredients of propolis induce disorganization of the cytoplasmic membrane and cell wall of the bacteria and cause partial bacteriolysis (Havsteen, 2002). Polyphenols, flavonoids, terpenes, pinocembrin, galangin, and ferulic acid are the common components of propolis responsible for the antibacterial action (Banskota et al., 2001; Özdemir et al., 2022). Propolis affects biofilm formation in its different diluents and has a marked antimicrobial activity of mastitis due to *Staphylococcus spp.* in goats (Dos Santos et al., 2019). In an *in vitro* study, propolis efficiently inhibits the *Pythium insidiosum* causing pythiosis in horses and dogs (Araújo et al., 2016). In addition, the antimicrobial activity of an alcoholic extract of Italian propolis, particularly on *Listeria monocytogenes*, could be used in ready-to-eat refrigerated dairy products, such as sterile skim milk, pasteurized cow's milk, as well as cow's and goat's whey cheese (Pedonese et al., 2019). Fouad et al. (2021) treated sheep experimentally infected with *Clostridium novyi* type B by administering 50 mg propolis extract/kg body weight daily for 15 days. In this study, the authors documented the antibacterial action of the propolis. Considering the inexpensive nature, widespread availability, natural source, and effectiveness of propolis as an antibacterial substance based on the *in vitro* investigations, it is imperative to conduct further *in vivo* studies to establish its antibacterial. Additionally, it is crucial to conduct experiments to evaluate the potentially toxic effects of various propolis extracts.

Antiviral action

Propolis has antiviral action due to its ability to inhibit the body's enzymes from removing the viral protein coating and changing the virus to an inactive form (Bogdanov, 2017). The antiviral activity of propolis is related to its content of polyphenols, flavonoids, caffeic acid, and quercetin (Farooqui and Farooqui, 2010; Shvarzbeyn and Huleihel, 2011; Özdemir et al., 2022). *In vitro* studies indicated that propolis has antiviral action against the herpes virus, rotavirus, pseudorabies virus, feline calicivirus, canine adenovirus type 2, bovine viral diarrhea virus, bovine respiratory syncytial virus and coronavirus strains (Cueto et al., 2011; Affonso et al., 2012; González-Búrquez et al., 2017; Gamil Zeedan and Abdalhamed, 2021). On the other hand, Tsuchiya et al. (2018) mention that Brazilian green propolis does not prevent acute equine encephalitis caused by herpes virus-9 despite its immune-stimulating action.

Antifungal action

Pinocembrin, galangin, benzoic acid, salycilic acid, and vanillin are the most common antifungal components of propolis (Özdemir et al., 2022). Propolis can inhibit *Malassezia pachydermatis*, *Dermatophytes*, *Trichophyton*, and *Microsporum* in dogs (Cardoso et al., 2010; Cruz Sánchez et al., 2014; Betancourt et al., 2015).

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Antiparasitic action

The propolis contains compounds such as chrysin, quercetin, and galangin, which exhibit antiparasitic properties (Morsy et al., 2013; Dos Santos Araujo and Levistk, 2019; Linécio et al., 2022). Propolis reduces the intensity of infection with giardiasis and trypanosomiasis in experimentally infected mice (Abdel-Fattah and Nada, 2007) and treats rats infected with *Trypanosoma evansi* after oral administration of 100- 400 mg/kg daily for ten days (Gressler et al., 2012). Additionally, Fouad et al. (2021) successfully treated sheep experimentally infected with *Fasciola gigantica* by oral administration of 50 mg propolis extract/kg body weight daily for 15 days.

Anti-inflammatory action

Polyphenols, flavonoids, caffeic acid phenethyl ester, acacetin, etheric oils, and polyprenylated benzophenones are the main components of propolis responsible for its anti-inflammatory action (de Almeida and Menezes, 2002; Ramos and Miranda, 2007; Özdemir et al., 2022). Propolis inhibits myeloperoxidase activity, NADPH-oxidase ornithine decarboxylase, tyrosine-protein-kinase, and hyaluronidase from guinea pig mast cells (de Almeida and Menezes, 2002). Moreover, propolis inhibits the lipoxygenase pathway of arachidonic acid metabolism during inflammation (Mirzoeva and Calder, 1996). Future studies are necessary to obtain reliable conclusions on the effectiveness and underlying mechanisms through which propolis functions as an anti-inflammatory agent.

Immunomodulatory action

Polyphenols, flavonoids, and caffeic acid phenethyl ester are linked to the immunomodulatory action of propolis (Farooqui and Farooqui, 2010; Shvarzbeyn and Huleihel, 2011). Propolis has immune-boosting activity due to its antioxidant and broad-spectrum antibiotic actions. It inhibits the growth of fungi, viruses, bacteria, and other microbes. Moreover, propolis increases antibody production, activates B and T lymphocytes, enhances phagocytosis, stimulates the thymus gland, and thus boosts the thyroid gland to improve immunity (Boukraa, 2013; Gao et al., 2014). Oral use of alginate-propolis nanoparticles improves the immune status of Egyptian-Nubian newborn kids because it increases the immunoglobulins, IgG, and IgA and reduces the pro-inflammatory cytokines (Hegazi et al., 2021). Moreover, ethanolic extract of propolis has been used as a vaccine's adjuvant for some viral vaccines like canine parvovirus (CPV), and enhanced the production of antibodies against CPV in rats (El Ashry and Ahmad, 2012; Ferreira et al., 2012).

Antioxidant action

The antioxidant effect of propolis is related to its content's polyphenols, flavonoids, caffeic acid phenethyl ester, polyprenylated benzophenones, artepillin C, and Prenylated flavanones (Banskota et al., 2001; Farooqui and Farooqui, 2010). Propolis prevents tissue destruction from oxidative stress due to its ability to decrease the overproduction of superoxide anion and to restore the respiratory control ration in mitochondrial tissue. Propolis extract has a dose-dependent free radical scavenging action and inhibits xanthine oxidase activity (Banskota et al., 2000; Bogdanov, 2017, Özdemir et al., 2022).

Anti-tumoral action

Chrysin, quercetin, artepillin C and caffeic acid phenethyl ester are responsible for the anti-carcinogenic effect of propolis (Özdemir et al., 2022). Brazilian propolis is reported to have Artepilin C, which has a significant cytotoxic activity against transmissible venereal tumor cells from dogs. This cytotoxicity is due to DNA fragmentation and apoptosis induction (Bassani-Silva et al., 2007). Propolis can eliminate the canine osteosarcoma (OSA) cells obtained from naturally affected dogs (Costa Cinegaglia et al., 2013).

Wound healing

Propolis's antimicrobial, anti-inflammatory, and antioxidant activities enhance wound healing (Abu-Seida, 2015). Histologically, propolis-treated skin wounds exhibited moderate to complete thick vascular granulation tissue, more fibroblasts and collagen deposition, mild inflammatory cell infiltration, and complete epithelialization (Abu-Ahmed et al., 2013). Propolis also ameliorates the healing of burn scars in guinea pigs treated with daily topical application of 100 mg propolis extract/kg body weight (Elshater et al., 2017).

CLINICAL APPLICATIONS OF PROPOLIS IN LARGE AND SMALL ANIMAL PRACTICES

Due to its biological actions, Propolis has been used successfully in large and small animal practices. The clinical applications, dose, and pharmaceutical form of propolis are indicated in Table 1.

In veterinary medicine, propolis has been applied clinically to treat subclinical mastitis and mastitis (Fiordalisi et al., 2016; Šuran et al., 2020), lumpy skin disease (Farag et al., 2020), diarrhea and gynecological disorders in cattle (Gubicza and Molnar, 1987). It treated enzootic pneumonia in pigs and prevented gastrointestinal and respiratory diseases (Boukraa, 2013; Bogdanov, 2017). While in sheep, propolis treated the parasitic infestations such as

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gastrointestinal nematodes and trematodes (Morsy et al., 2013; Kalil et al., 2019; Linécio et al., 2022), stimulated the immunity in Nubian breed kids (Hegazi et al., 2021), enhanced diet digestibility, and improved health status of ewes (Morsy et al., 2021). Otitis externa (Lozina et al., 2010; Betancourt et al., 2015), dermatophytosis (Cruz Sánchez et al., 2014), and Cushing's syndrome (Boukraa, 2013; Betancourt et al., 2015) could be treated with propolis in dogs. In equine practice, propolis could be used for local anesthesia (Bogdanov, 2017), enhancing wound healing (Abdel-Wahed et al., 2011; Abu-Ahmed et al., 2013) and treatment of chronic bronchitis as well as dermatomycosis (Flores Rodríguez et al., 2016; Zoja et al., 2019).

Table 1. Clinical applications, form, and dose of propolis in different animal species

Clinical application	Form/Dose of propolis	References
Cattle		
Mastitis	Propolis liniment	Fiordalisi et al. (2016)
Subclinical mastitis	- 1% intramammary propolis formulation - Propolis non-alcoholic extract given as intra-mammary infusion three times at 12 h intervals	Bacic et al. (2016) Šuran et al. (2020)
Gynecological diseases	Propolis candles	Bogdanov (2017)
Improvement of weight gain in calves	Feeding with 5 ml of 20% ethanol extract	Gubicza and Molnar (1987)
Anti-diarrhea in calves	- Feeding with 5 ml of 20% ethanol extract. - 4 mL/d of 30% red propolis ethanolic extract in whole milk	Gubicza and Molnar (1987) Slanzon et al. (2019)
Lumpy skin disease	Oral administration of Alginate-Propolis nanoparticles in a dose of 300 µl/ animal/ 3 days	Farag et al. (2020)
Foot and mouth disease	Propolis extract spray	Bogdanov (2017)
Pigs		
Enzootic pneumonia	Feeding with 0.5% propolis extract in milk	Bogdanov (2017)
Feeding of weak pigs	Feeding with 0.5% propolis extract in milk	Bogdanov (2017)
Prophylaxis of gastrointestinal diseases	Feeding with 0.5% propolis extract in milk	Bogdanov (2017)
Prophylaxis of respiratory diseases	Feeding with 0.5 % propolis extractin milk	Bogdanov (2017)
Sheep and goats		
Caseous lymphadenitis	Filling of the cavity with green propolis-based ointment once after surgery	Kalil et al. (2019)
Antiparasitic action and improvement of the health status of ewes during the flushing period	Oral administration of propolis ethanolic extract at a dose of 3 g/ewe/day for 21 days	Morsy et al. (2013)
Respiratory diseases	Oral administration of 0.06 ml Alginate-propolis nanoparticles (twice/week)	Hegazi et al. (2021)
Enhance diet digestibility, rumen microbial biosynthesis, mitigating methane formation and health status of late pregnant ewes	3 g red propolis extract/ ewe/ day	Morsy et al. (2021)
Dogs and cats		
Dermatophytosis	Weekly baths with a commercial soap made with propolis for 3 to 8 weeks and application of a topical ointment daily for three weeks	Cruz Sánchez et al. (2014)
Cushing's syndrome	Propolis in water at a dose of 0.4 - 0.5 g crude propolis per kg body weight every 12 hours for three months	Betancourt et al. (2015)
Otitis externa	Ear drops using 2.5% Propolis ethanolic extract in a mixture of glycerin-propylenglycol (1:1)/ twice daily for 14 days	Lozina et al. (2010)
Equine		
Dermatomycosis	A weekly bath with propolis-based shampoo and application of propolis-based ointment on the lesions 2 to 3 times a week for 4 weeks	Flores Rodríguez et al. (2016)
Chronic bronchitis	Ethanol extract of propolis and honey inhalation 3 times per day for 7 days	Zoja et al. (2019)
Local anesthetic	1-10% propolis extract preparation	Bogdanov (2017)
Wound healing	5% propolis in fish oil	Bogdanov (2017)
Wound healing	Dressing with propolis powder or propolis with honey proved	Abdel-Wahed et al. (2011)

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Infectious diseases

Due to its antimicrobial, anti-inflammatory, and local antioxidant activities in the udder, propolis can control mastitis in cattle (Wang et al., 2016; Šuran et al., 2020). Intramammary infusion with 1% propolis formulation induced satisfactory antibacterial and antioxidant effects in dairy cows (Bacic et al., 2016; Šuran et al., 2020). Therefore, propolis may alternate the conventional antimicrobial drugs used to prevent and control subclinical mastitis in dairy cattle.

Kalil et al. (2019) used green propolis as a promising post-operative dressing agent for ovine caseous lymphadenitis. Propolis enhances wound healing and hair recovery, as well as inhibits wound infection. Inhalation with ethanolic extract propolis in combination with honey for 7 days showed antibacterial and antifungal actions, low heart and respiratory rates, and mucolytic action in the lower respiratory tract in horses with chronic bronchitis (Zoja et al., 2019). In addition, Farag et al. (2020) treated lumpy skin disease in cattle with oral alginate-propolis nanoparticles at a dose of 300 µl/ animal for three successive days and topical dressing and eye drops of propolis in some cases.

Dermatophytosis is a superficial skin infection caused by pathogenic dermatophytes, *Trichophyton, and Microsporum* (Betancourt et al., 2015). These pathogens have high zoonotic potential. Commercial propolis-based soap was used successfully to treat three dogs with dermatophytosis in 3-8 baths at one-week intervals together with using a topical propolis-based ointment for three weeks (Cruz Sánchez et al., 2014). Flores Rodríguez et al. (2016) treated dermatomycosis in horses with four baths at one-week intervals using propolis-based shampoo and topical dressing with propolis-based ointment two to three times a week for 28 days. *Staphylococcus aureus* is the commonly isolated bacteria from dogs with otitis externa (OE). Topical propolis ear drops treated the OE in dogs due to propolis's wide antimicrobial spectrum, anti-inflammatory, and antimycotic effects (Cardoso et al., 2010).

Dos Santos Araujo and Levistk (2019) found that propolis is efficient in controlling gastrointestinal helminths in sheep and recommended its use. However, it is still necessary to conduct more research on the ideal concentrations of propolis and its mode of action and residual effects. A single dose of 10 mL of 30% propolis alcoholic extract given orally demonstrated an antiparasitic effect in sheep and can be used in the control of endoparasites in sheep (Linécio et al., 2022).

Diarrhea

Red propolis supplementation improved health and reduced the incidence of diarrhea in calves and piglets (Bogdanov, 2017; Slanzon et al., 2019). This anti-diarrheal action could be attributed to the various biological actions of the propolis, such as antimicrobial, anti-inflammatory, and antioxidant actions.

Wound healing

From ancient times to recently, propolis was used to treat full-thickness skin wounds in horses and donkeys. Propolis treats wounds that exhibited better healing than wounds dressed with honey or saline (Abdel-Wahed et al., 2011; Abu-Ahmed et al., 2013).

Ocular diseases

Propolis has been used successfully in cats and dogs with different eye diseases. These diseases include blepharitis, infectious conjunctivitis, corneal edema, tear duct obstruction, keratoconjunctivitis sicca, corneal ulcers, and glaucoma. Propolis drops have been used for 5-7 days in acute cases and 10-15 days in chronic cases (Betancourt et al., 2015). Due to the numerous aforementioned medicinal actions, propolis is a promising eye therapeutic in animals.

Cushing's syndrome

A few studies indicated positive effects of propolis in treating Cushing's syndrome in dogs. In this regard, propolis was given at a dosage of 0.4-0.5 g/kg body weight twice daily for 3 months (Boukraa, 2013; Betancourt et al., 2015).

Reproductive performance

Prepartum using antibiotic growth promoters as feed additives in ruminant diets helped the transition from pregnancy to lactation and resulted in measurable health benefits (Morsy et al., 2016). Nevertheless, their use in animals is controversial due to the risk of residues transfer into meat and milk with increasing the development of resistant strains of bacteria (Mirzaei et al., 2022). Therefore, there is a continuous search for alternative natural feed additives to improve the reproductive performances of ruminants (de Aguiar et al., 2014). Propolis supplementation in ewes' diet increased the average daily gain and milk yield. However, it had no effect on lamb birth and weaning weights. The prepartum supplementation of propolis positively impacted the transition of ewes from pregnancy to lactation with good health of both ewes and lambs (Morsy et al., 2016). In contrast, propolis had no effect in maintaining sperm integrity and viability after thawing and was toxic to spermatozoa at concentrations of 0.25 and 0.5% (de Castilho et al., 2009). Moreover, the dietary addition of 3g of propolis/animal/day had no effect on bull mating performance or feed efficiency (Valero et al., 2016).

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POTENTIAL BENEFITS OF PROPOLIS IN ANIMAL PRODUCTION

Antibiotics are effective feed supplements, particularly the ionophores (monensin, lasalocid, and salinomycin). However, these agents have recently faced reduced social acceptance in many countries due to the risk of residue in the milk and meat that develops resistant strains of bacteria (Morsy et al., 2013; Mirzaei et al., 2022). Therefore, several natural alternative feed additives have been tested, such as propolis.

Propolis has received increased attention in the last decade as a potential animal growth promoter due to its potent bacteriostatic and bactericidal properties (Righi et al., 2011). It had beneficial actions in animal production, such as increasing the average daily gain of lambs and milk conversion ratio in ewes (Morsy et al., 2016). Propolis also promoted the growth in calves, lambs, and piglets, improved the reproductive performance and increased the nutritional quality of the cows' milk (Gubicza and Molnar, 1987; Morsy et al., 2016; Cottica et al., 2019).

Propolis has better features than antibiotics as a feed additive due to its antimycotic and antiprotozoal actions, natural origin, availability, low cost, and safety for humans and animals (do Prado et al., 2010; da Silva et al., 2015). Considering these characteristics, it is suggested that a diet supplemented with propolis may inhibit the proteolytic bacteria with protein deamination, proteolysis, and production of gases. Consequently, propolis enhances the function of the gastrointestinal tract and feed digestibility (Morsy et al., 2013; da Silva et al., 2015).

Addition propolis to the animal's diet induced more rapid muscular growth than animals fed a standard diet. Daily intake of propolis ethanol extract improved the daily weight gain in feedlot calves, lambs, and piglets and increased animals'productivityy and meat quality in cattle (Ítavo et al., 2011; Bogdanov, 2017).

Moreover, adding 5g propolis/kg to the diet improved milk production, milk composition, and the antioxidants in Barki ewes. In addition, supplemetion of propolis improved lambs' immune functions, growth performance, and antioxidant status in arid environments (Shedeed et al., 2019). Nevertheless, the addition of propolis extract into the sheep diet (40-50, and 60-50 forage/concentrate ratio) had no effects on their feed intake hematological, biochemical, immunological, and nutrient digestibility features (Prado-Calixto et al., 2017; da Silva et al., 2018). Moreover, adding propolis to the lambs' diet did not influence carcass characteristics (Ítavo et al., 2009).

Soybean oil interacts with ethanolic extract of propolis when added to the diet of dairy goats; therefore, soybean oil decreases the intake of dry matter, organic matter, and neutral detergent fiber only in the presence of propolis and increases the intake of crude protein in the absence of propolis (de Paula Lana et al., 2005).

Using ethanolic propolis extract as a feed additive for dairy cows increased milk protection against lipid oxidation responsible for a rancid smell (Cottica et al., 2019). Therefore, the antioxidant capacity of the milk increased, and consequently, propolis improved the milk quality when added to the diet of dairy cows from this aspect (Cottica et al., 2019). However, adding propolis to the diets of dairy cows had no effects on dry matter intake, milk production, feed conversion efficiency, milk solid concentrations, or somatic cell score (Aguiar et al., 2014).

On the other hand, the addition of propolis to the forage-based diet had a negative effect on the concentration and intake of digestible energy of roughage-based diets for growing steers (do Prado et al., 2010). In addition, adding propolis extract to the diet of water buffaloes reduced the population of ciliate protozoa in the rumen (Ríspoli et al., 2009). Moreover, the addition of propolis to the diet of feedlot bulls had no effect on microbial synthesis and carcass characteristics. These characteristics include conformation, carcass length, leg length, cushion thickness, *Longissimus* muscle area, *Longissimus* muscle area/100 kg of live weight, fat thickness, color, texture, and marbling (Zawadzki et al., 2011; Valero et al., 2014; 2015). Propolis did not significantly affect weanling pigs' live weight gain, feed consumption, or feed conversion ratio (Dierckx and Funari, 1999).

According to the available literature, the performed clinical studies on the efficacy of propolis as a feed additive reveal controversial results. Therefore, future *in vivo* studies on this topic are highly recommended.

CONCLUSION

Propolis is a promising natural agent that can alternate conventional pharmaceuticals, particularly antibiotics. It improves animal health and production with no adverse effects and at a low cost. Propolis can prevent and treat several animal diseases like mastitis, lumpy skin disease, foot and mouth disease, reproductive disorders, and diarrhea in cattle. Furthermore, propolis could improve weight gain in cattle. In equine, propolis has been used as a local anesthetic for treating dermatomycosis, chronic bronchitis, and skin wounds. In pigs, propolis has been used to treat enzootic pneumonia, feeding weak pigs, and acts as a prophylaxis for gastrointestinal and respiratory diseases. Regarding sheep and goats, propolis has been applied to treat caseous lymphadenitis and parasitic diseases and improve the immune status of kids and the health status of late pregnant ewes. In dogs and cats, propolis has been applied to treat otitis externa, eye diseases, Cushing's syndrome, and dermatophytosis. In addition, propolis is used to treat transmissible venereal tumor in dogs. Moreover, propolis positively affects animal production, by increasing the average daily gain and milk yield in sheep, the growth of calves, lambs, and piglets, the reproductive performance, and cow's milk nutritional quality. However, further extensive clinical studies are recommended to declare the usefulness of propolis in veterinary medicine and to obtain reliable conclusions on its potential benefits in animal health and production.

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