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Use of Tannins in Livestock Nutrition

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ABSTRACT

This study aimed to evaluate the effects of tannins and tannin-containing plants at different inclusion levels in animal diets by reviewing various feeding studies involving different livestock species. Tannins are phenolic compounds produced by plants, particularly woody species, as a defense mechanism against external factors. They are classified into two major groups: hydrolysable tannins and condensed tannins. Tannins are known for their ability to bind proteins, inhibit microbial enzymes, and exert antibacterial effects by disrupting bacterial membranes. In ruminants, condensed tannins form complexes with proteins within the pH range of 3.5–7.5, thereby reducing microbial degradation in the rumen and improving bypass protein availability. Positive effects such as increased growth hormone levels, inhibition of gastrointestinal parasite larvae, and improved nitrogen utilization have been observed, especially in ruminants. However, high tannin levels (above 60 g/kg DM) may reduce feed palatability and intake due to their astringent taste. Safe inclusion levels have been reported as 8–10% in goats, 3–5% in cattle, and approximately 1% in poultry. In conclusion, tannins can be used strategically in livestock nutrition to improve health and performance parameters when administered at species-appropriate and controlled levels.

INTRODUCTION

Tannins are defined as phenolic compounds that are found in greater amounts in the structure of perennial plants, characterized by the ability to bind proteins and other nutrients, are easy to find in all plant kingdoms and agricultural by-products, and are produced by plants to protect themselves against external factors (Boğa et al., 2021; Menchi et al., 2021). Their molecular weights range from 500 Da to 3000 Da and are found in the leaves, bark, fruit, woody stems and roots of plants. Tannins are soluble in water (20-35°C temperature range) except for some high molecular weight structures (Dehghanian et al., 2022).

Tannins can greatly affect digestion, protein, cellulose and fat metabolism in ruminants, as they suppress general rumen microflora activity. Tannins can improve the bypass protein ratio up to certain levels due to their protein binding properties and can cause increased intestinal absorption of amino acids. In addition, this situation can provide environmental benefits by reducing methane and ammonia emissions from ruminant animals. It has been reported that by reducing saturated fatty acids and increasing polyunsaturated fatty acids and biohydrogenation (BH) intermediates, it can provide increases in the nutritional quality of ruminant animals (Menchi et al., 2021).

Structure and Classification

Tannin is a group of substances that have the ability to bind to proteins in aqueous solutions chemically (Makkar, 2003). The most common method used in the classification of tannins is the analytical method and according to this method, tannins are divided into two large classes as hydrolyzable tannins and condensed tannins. Hydrolyzable tannins include two subgroups as gallo tannins and ellagitannins. The non-hydrolyzable group is classified as oligomeric and polymeric proanthocyanidins 'condensed tannins'. Complex tannins, which contain the characteristic structural elements of both ellagitannins and condensed tannins, have been called 'unclassified tannins' so far (Molino et al., 2023).

The most common form of tannin is condensed tannin, which consists of two or more monomeric (-) epicatechin or (+) catechin units. These types of condensed tannins (CT) are called procyanidins (Dehghanian et al., 2022). While oak leaves and broad bean fruits contain more hydrolyzed tannins, condensed tannins have been reported in sorghum and clover species. Hydrolyzed tannins are broken down into 1 mole of glucose and 7 moles of gallic acid by enzymes (İmik and Şeker, 1999).

Effect of tannin on animals

Boğa et al. (2021), reported that condensed tannins inhibit the larval development of digestive tract parasites and show an antiparasitic effect by combining with proteins in the rumen and preventing microbial degradation. It has been recorded that giving tannin-containing rations to lambs and sheep with parasite infestation improves live weight gain and reduces parasite eggs excreted with feces by 20-50% (Kamalak et al., 2005). It has been reported that growth levels increase in animals to which condensed tannin is added in addition to anthelmintic application in lambs with parasite infestation (Üstün and Aydın, 2007).

It has been reported that tannins show antibacterial effect by inhibiting microbial enzymes such as protease and lipase (Kaya and Yalçın, 1999). Tannic acid (TA) prevents the use of iron by bacteria by forming a chelation with iron and inhibits the growth of microorganisms found in the intestine such as *Bacteriodes fragilis, Clostridium perfiringens, Escherichia coli* and *Enterobacter cloacae*. It has also been reported that tannins are effective against biofilm-forming bacterial infections such as *S. Aereus* (Ünver et al., 2014).

Effect of tannin on nutrition

Tannins can cause color changes and decrease in flavor in feeds due to the enzymatic changes they cause and the astringent taste they give (Singh et al., 2023). Deterioration in the flavor of feed and a decrease in feed consumption due to disgust were observed in animals fed with feeds containing more than 60 grams of tannin per kilogram (Kamalak et al., 2005). It has been observed that the addition of grain to the ration at levels of 8-10% in goats, 3-5% in cattle, and 1% in poultry does not cause negative effects (Gürsoy, 2022). Köse and Kardeş (2021), reported that the astringent and bitter taste of foods containing tannin can be reduced by processes such as boiling (heat treatment) or peeling the shells.

While feed consumption decreased in sheep fed with feed containing 55 grams of tannin per kilogram, this effect was either less or not seen at all in smaller amounts (Kamalak et al., 2005). Tannin in feeds forms a complex with glycoprotein in saliva. In some animals, as they adapt to diets containing high amounts of tannin, the amount of proline-rich proteins in their saliva increases. These proteins form bonds with tannin, preventing it from forming compounds with other proteins in the diet (Kamalak et al., 2005).

Toxicity

It is known that tannins can cause structural problems after absorption in the digestive system by forming a complex structure with other compounds in feeds, can lead to essential amino acid deficiency and can cause toxicity (İmik and Şeker, 1999).

They can prevent digestion and absorption by binding to proteins, carbohydrates and minerals. It has also been reported that tannins can reduce the function of digestive enzymes and nutrient absorption by damaging the digestive system membrane by forming complexes. Tannins slow down digestion by binding to carbohydrates. When tannins combine with proteins, they can reduce digestion and reduce the animal's amino acid supply. This can reduce the energy level of the ration. Tannins can prevent absorption by binding minerals and lead to iron, zinc and copper deficiency. They can reduce protein bioavailability or increase fecal nitrogen, which can cause protein digestibility in humans and animals. They also inhibit amylase, chymotrypsin and lipase activity, prevent iron absorption and reduce protein digestibility (Singh et al., 2023). Gallic acid and pyrogallol, which are hydrolysis products of tannins, can cause hemolysis. Gallic acid and pyrogallol are more toxic than tannins. Tannins precipitate albuminous substances and, through their astringent activity, reduce mucosal secretions and mucosal permeability. They also affect water absorption and salivary flow. If food and water intake decrease, the process can progress to dehydration. When consumed in high concentrations, loss of appetite and constipation develop. Excessive amounts can cause gastroenteritis ulcerosa (Üstün and Aydın, 2007).

EFFECT OF TANNIN USE IN LIVESTOCK ON PRODUCTION CHARACTERISTICS

Since tannins reduce enzyme activity and protein digestibility in poultry and other monogastric animals, these animals are more affected than ruminants (Ünver et al., 2014). Condensed tannins form complexes with proteins and carbohydrates and inhibit microbial enzymes (Kaya and Yalçın, 1999). High consumption of tannins by poultry, negatively affects performance, decreases in live weight, decreases in egg production, retards growth, negatively affects feed consumption, and decreases feed utilization. This is evidenced by the presence of histopathological findings in the liver and kidneys, as well as the negative impact on energy, protein, arginine, leucine, methionine, phenylalanine, and starch digestibility, which can result in mortality in cases of consumption exceeding 5% (Gürsoy, 2022). When used in poultry diets, it has been determined that it binds to methionine, reduces the biological value of protein and reduces the metabolizable energy level of feed (Özen, 1980). It has been determined that 1% Tannic Asid added to poultry diets does not change egg yield, and 2% significantly reduces egg yield. In egg yolks, it creates pale spots and abnormal olive green color disorders (Özen, 1980).

It has been reported that the inclusion of 10–40 g/kg of condensed tannins in dry matter (DM) has beneficial effects on ruminant nutrition (Kamalak et al., 2005). Condensed tannins form complexes with proteins within a pH range of 3.5 to 7.5, preventing their degradation by rumen microorganisms and thereby reducing the rate of microbial digestion (Ünver et al., 2014). These tannin-protein complexes bypass the rumen and are broken down in the abomasum and small intestine, allowing the released proteins to be absorbed more efficiently in the small intestine. Additionally, tannins in the ration stimulate saliva production, which facilitates the recycling of urea nitrogen back into the rumen, enhancing microbial protein synthesis and overall productivity (Kamalak et al., 2005). The effectiveness of tannins in ruminant diets depends on factors such as their concentration, chemical structure, the overall composition of the ration, and the animal's adaptation to tannin-rich feeds (Ünver et al., 2014). The inclusion of 20-45 g/kg DM of condensed tannins has been associated with improvements in milk and wool yield, as well as reproductive performance, whereas levels exceeding 55 g/kg DM may negatively affect feed intake, digestibility, growth, and wool production (Öztürk, 2015). Furthermore, condensed tannins can help mitigate ruminal tympani caused by highly soluble proteins in feed. Supplementation with tannin-containing plants at levels of 5 g/kg DM or higher has been shown to significantly reduce rumen gas production and prevent bloat by precipitating foam (Üstün and Aydın, 2007).

A study reported that approximately 25% of global CH_4 emissions are formed by enteric fermentation of animals (Önel et al., 2021). It was determined that the amount of methane gas in the atmosphere has doubled over the last few centuries, and it was stated that the effect of methane on global warming is 21 times greater than carbon dioxide gas. (Öztürk, 2015). According to the Kyoto Protocol, which Turkey joined on August 26, 2009, it was reported that greenhouse gas emissions in the world should be reduced to the levels of 1990 (Öztürk, 2015). A 13% decrease in methane emissions was achieved by using 2.5% acacia tannin in dry matter in sheep rations (Meral and Biricik, 2013). In a feeding study conducted on lactating Holstein cows, a mixture of tannin obtained from Quebracho and chestnut trees was added to the rations of the experimental groups. The mixture was added to DM at two different rates of 0.45% and 1.8%. The results of the study, as reported by Keser and Kutay (2021), showed a decrease in daily methane emissions per animal of 56 and 48 g in the low and high tannin groups, respectively.

Condensed tannins have been widely studied for their ability to form complexes with proteins within the pH range of 3.5-7.5, preventing microbial degradation in the rumen and allowing more proteins to reach the small intestine for absorption (Ünver et al., 2014). Kamalak et al. (2005), reported that supplementing 10-40 g/kg DM of condensed tannins in ruminant diets increases protein efficiency by enhancing bypass protein and stimulating saliva production, which promotes nitrogen recycling via urea return to the rumen. Boğa et al. (2021), found that supplementing sheep rations with 20-40 g/kg DM condensed tannins resulted in a 62% increase in essential amino acid absorption, a 20% improvement in milk yield and milk protein, and a significant rise in wool yield. Similarly, in cows, tannin supplementation lowered milk urea nitrogen (MUN) and ruminal ammonia nitrogen levels without negatively impacting milk protein content.

Moderate levels of condensed tannins (20-45 g/kg DM) have been shown to enhance milk and wool yield and reproductive parameters. However, inclusion rates exceeding 55 g/kg DM have been observed to have a negative impact on feed intake, digestibility, growth, and wool yield (Öztürk, 2015). Üstün and Aydın (2007), observed that diets containing more than 55 g/kg DM condensed grain reduced feed consumption and digestibility. Moreover, the incorporation of condensed tannins at levels of ≥5 g/kg DM has been demonstrated to curtail rumen gas production and efficaciously forestall bloat by precipitating foam.

Williams et al. (2020) conducted a study on eight Holstein cows using ruminal cannulation to evaluate the effects of tannin and cottonseed oil supplementation. Four diets were tested: control, 800 g/day cottonseed oil, 400 g/day tannin, and a combination of both. Methane production decreased by 14% with cottonseed oil, 11% with tannins, and 20% with the combined supplementation. Similarly, the addition of *Lotus corniculatus* (27 g/kg DM) to dairy cow diets led to a milk yield of 16.5 kg, while the inclusion of polyethylene glycol (PEG) alongside *L. corniculatus* reduced yield to 13.8 kg.

A study was conducted by İmik and Şeker (1999) to investigate the effects of oak leaves, tea factory waste, and sorghum as part of the rations for Akkaraman yearlings. The study found that oak leaves did not significantly affect the live weight or wool quality of the subjects, indicating their suitability as roughage. Sorghum, which was found to contain high levels of tannins, was found to be safe up to a level of 400 g included in the ration. In a subsequent study, Kamalak et al. (2005), reported that the supplementation of condensed tannins at levels of 22-38 g/kg DM resulted in a 10% increase in wool production, while the inclusion of 50 g/kg had deleterious effects.

Güçlü and Yalçın (2004), found that treating cottonseed meal (CSM) with 3-9% tannic acid and 5-10% lignosulfonate reduced crude protein digestion in rams. Aktaş and Akkan (2011), evaluated the effects of acorn tannins (3% and 4%) on in vitro rumen fermentation. They observed no impact on rumen pH but found significant reductions in ammonia levels and protein degradability, suggesting improved protein efficiency.

Şentürk et al. (2015), studied the effects of tannin supplementation (90 g *Quebracho Colorado* per animal) on negative energy balance in dairy cows. Blood and milk samples collected before and after calving revealed significant reductions in BHB levels at parturition and on days 7 and 14 postpartum. This suggests that tannin may help mitigate the effects of negative energy balance during early lactation.

İmik et al. (2003), replaced barley with dehulled *Sorghum vulgare* at 8–32% in lamb diets and observed improved live weight gain, feed intake, and digestibility. Ibrahim and Hassen (2022), evaluated unencapsulated and encapsulated *Acacia mearnsii* tannins in Merino lambs. Both forms reduced enteric methane and regulated rumen fermentation without compromising dry matter intake or growth. Encapsulated tannins had a stronger effect on methane reduction.

Getachew et al. (2008) reported that increasing levels of tannic acid (30-90 g/kg DM) reduced NH_4-N concentrations by up to 67% in sheep diets. PEG addition reversed this effect, highlighting the protein-binding role of tannins. TA also reduced isovalerate production, with no significant changes in blood metabolites or enzymes. Menchi et al. (2021), compared tannin extracts (kebrako and kebrako + chestnut) and found that the mixture increased the CO_2/CH_4 ratio and influenced rumen biohydrogenation.

Buccioni et al. (2011), showed that chestnut and quebracho tannins altered the rumen bacterial fatty acid profile and increased C18:1 trans11 accumulation in vitro, supporting their role in modulating fatty acid metabolism. Orlandi et al. (2020), found that 7.7 g/kg DM Acacia tannin reduced urinary urea excretion in sheep without affecting net flow of urea, ammonia or glucose. Sarnataro and Spanghero (2020), compared chestnut tannins and *Stevia rebaudiana* (SB) extract, finding that chestnut tannins reduced rumen ammonia and protozoa counts, while SB extract significantly decreased protozoa population without affecting ammonia levels.

CONCLUSION

Poultry and other monogastric animals are more affected by the negative effects of tannins than ruminants. Tannins can provide an increase in protein efficiency by allowing valuable protein sources to pass through the rumen without being destroyed and allowing more protein to flow into the small intestine. When plants containing condensed tannin at moderate levels are added to the diet, an increase in essential amino acid absorption in the intestine can be achieved, while when used in high concentrations, it can combine with proteins, reduce digestion and reduce the animal's amino acid supply. Adding tannin to the diet can increase milk yield by limiting grain intake and can also be used to protect against negative energy balance. Adding certain levels of condensed tannin to ruminant diets positively affects wool yield and reproductive parameters. However, it is recommended not to add more than 55 g/kg DM of condensed tannin to the diet because it negatively affects feed consumption, digestion rate, growth and wool yield.

Consequently, the utilisation of specific quantities of condensed tannin in animal rations may either not exert any influence on animal production parameters or may engender favourable outcomes. However, elevated levels have the potential to yield adverse consequences.

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Conflict of Interest
The authors declare that they have no competing interests.

Authorship contributions
Concept: Ö.B., M.B., Design: Ö.B., M.B., Literature Search: Ö.B., M.B Writing: Ö.B., M.B

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