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The Application Of Tannin's In Ruminant Nutrition (A Review)

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Abstract

Tannin exists as a group of plant polyphenolic compounds which plays a vital role in animal feeding, especially for ruminants animals that exhibit protein cohesion properties. The hydrolysable tannin (HT) and condensed tannin which are two groups of tannin based on chemical structure were identified. The hydrolysable tannin when digested in the rumen of ruminants may release toxic compounds which when consumed in large quantities expose animals to health risks, while condensed tannin (CT) is the most common form of tannins which several nutritional benefits through the protection of dietary components from too much breakdown in the rumen, therefore enhancing protein use and reduction of Nitrogen (N) excretion. The study further highlighted the effects of tannin on feed intake, palatability, nutrient absorption, bloat prevention actions of tannins, and anti-parasitic functions. The moderate level of tannin in ruminant nutrition can enhance ruminant performance and excess consumption can lead to poor feed consumption with low nutrient absorption. This shows the need for selective diet formulation when including tannins in animal diets. There is a need for researchers to seek for strategic inclusion of tannins in ruminant diets especially types and amounts to optimize ruminant health and productivity. The need for future studies to continue with more understanding of tannin activities within the rumen and ways to develop protocols for effective consumption in ruminant nutrition is paramount.

Key Words: *hydrolysable tannin, condensed tannin, ruminant nutrition,*

Introduction

Tannins are various groups of polyphenolic substances that were identified for their dynamic effects in both plants and animals. In the field of ruminant nutrition, tannins were eminent to have both advantages and drawbacks. Traditionally, tannins' ability to cling to proteins and other feed material, makes it gain the anti-nutritional defects which causes a reduction the nutrient intake as well as its accessibility by the animal (Besharati et al., 2022). Despite these drawbacks, it was discovered that, with control usage of tannins in ruminant diet a positive outcome can be seen. These positive outcomes include; better protein use and animal health, there is also improvement in methane emission as well as a sustainable ruminant animal production (Fonseca et al., 2023).

Both the positive and negative effects of tannins were investigated, among the positive effect was the ability of the tannins to reduce protein and nitrogen loses in the rumen hence rumen improvement (Fonseca et al., 2023). The negative effect were associated with high tannin concentration leading to lower intake and poor digestibility, this make it necessary to be careful in deciding which dose to be given to the animal (Besharati et al., 2022; Price et al, 1980). There are a lot of loopholes on knowing how these tannins from different sources as hydroysable and condensed impact the ruminant animal wellbeing and their ability to enhance their production, even with the above stated results (Price et al, 1980).

Despite the tremendous contribution in this area there is still a need for a research that will clearly determine the optimal concentration of tannins to be included in the diet of ruminant animals according to the target production purposes. Also the need to understand the long term effects of tannins on animal wellbeing is eminent as well as the environment (Fonseca et al., 2023).

Therefore, the objective of these study is to carefully analyze the recent studies on the application of tannins in ruminant nutrition, with an emphasis in identifying the optimal condition of their usage to enhance production.

Hydrolysable and Condensed Tannins

Many different types of plants contain polyphenolic compounds known as tannins (TANs). They can be classified as either hydrolysable tannins or condensed tannins based on their chemical structure (Pastorelli, & Salvatori, 2021). Tannins that are hydrolyzable have a central carbohydrate, usually D-glucose. Some phenolic groups, such as gallic acid (gallotannins) or ellagic acid (ellagitannins), partially or completely esterify the hydroxyl groups of these carbohydrates. According to Mueller-Harvey (2001), plants typically contain small levels of hydrolyzable tannins.
According to Waghorn and McNabb (2003), these tannins are present in oak (Quercus spp.), Acacia, Eucalypts, and a variety of browsing and tree leaves. The dry matter (DM) content of the browse including the leaves and apices can range from 200g to 500g, and in certain species, the amount of phenolic compounds can surpass 500g per kg of DM (Lowry *et al.,* 1996). Although hydrolyzable tannins have the potential to be poisonous to animals, most ruminants are able to adapt to eating them (Waghorn and McNabb, 2003). Ruminants can tolerate these poisonous tannins because they can decrease the amount of products they excrete in their urine (Lowry *et al.,* 1996). While ruminants possess this ability, an overindulgence in this tannic diet can cause lesions in the liver and kidneys, as well as cause mortality (Waghorn and McNabb, 2003).
The poisonous substance that is responsible for the first over ingestion usually takes five to ten days to cause death. Rarely is information available on how hydrolyzable tannins are absorbed, digested, and affect metabolism and production. According to Le Bourvellec and Renarda (2012), condensed tannins (CTs) are flavanol units in oligomers or polymers that are usually joined by carbon-carbon bonds at the 4/6 or 4/8 position. These compounds are also called proanthocyanidins because they can degrade oxidatively in an acidic environment to produce anthocyanidin colours. In mild or anaerobic conditions, the polymer is stable, according to Hagerman *et al;* (1992). The amount and location of hydroxyl groups along with the spatial arrangement of atoms in molecules are dealt with by the form of comprise unit. Condensed tannin structure is influenced by the type and location of the connections between sequence monomeric units as well as the degree of polymerization (Dixon *et al.,* 2005). Polymeric units derived from flavanol monomers can take on several shapes. Positive and negative charges are possible for these units. According to Waghorn (2008), the amount of flavanol units in a chain length can vary from dimmers to over 20 flavanol units. Each polymer in temperate forages can consist of many flavan-3-ol structures. The number of flavonoid units in condensed tannins might range from two to fifty. Complex structures are found in condensed tannin polymers because of the various sites for interflaven bonds and the variability of flavonoid units to some substituents. Depending on their chemical makeup and level of polymerization, condensed tannins may or may not dissolve in aqueous organic solvents. Condensed tannin-containing plants are thought to have developed over time to enlist them as a defence strategy, shielding them from insects and grazing animals as well as harmful bacteria (Swain, 1979). These days, they are being taken out of different plants to help with animal health. Previously, acetone-water was used to extract these condensed tannins; however, this approach did not fully remove the CT (Barry *et al.,* 1999). Condensed and hydrolyzable tannins frequently coexist in the same plant (Waghorn, 2008). Hydrolyzable tannins are thought to be harmful to animal nutrition (Serrano *et al.,* 2009). They are polyesters of sugars (mostly glucose) and gallic or ellagic acids (Figure 1). Polymers containing flavan-3-ols are known as condensed tannins (Figure 2). They are also known as proanthocyanidins because they undergo oxidative cleavage, or heating in the presence of acid, to produce vibrant anthocyanidins. The flavan-3-ol subunits that make up each CT polymer can vary, but the most prevalent ones are gallocatechin, epigallocatechin, and catechin, which together create procyanidins and prodelphinidins.

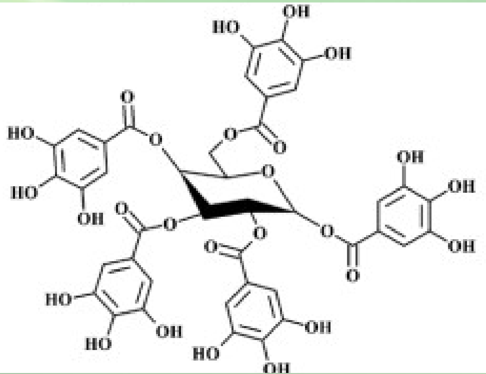

Figure 1. Structure of hydrolysable tannin (Serrano at al, 2009)

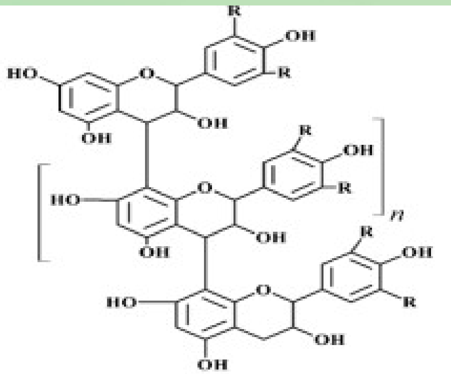

Figure 2. Structure of condensed tannin (Serrano at al, 2009)

Tannin Sources and Preference in different types of forages

According to Mueller-Harvey (2006), animal feed including Acacia, Dichrostachys, Dorycnium, Hedysarum, Leucaena, Lotus, Onobrychis, Populus, Rumex, and Salix contains tannin. According to Dixon et al. (2005), they can be found in seeds, fruits, leaves, wood, bark, and roots. The most important plant parts, such as young leaves and flowers, have higher concentrations of tannins (Terril *et al.,* 1992). According to Waghorn and McNabb (2003), the primary drivers of plant tannin synthesis are defence against diseases, energy and nitrogen conservation, and defense against grazing animals. Tannin content varies from 2 to 5% of the fresh weight. Pathological circumstances, water stress, temperature, and nutrient availability can all cause concentration to rise (Treutter, 2006).Tropical forages contain condensed tannins that are believed to stimulate plant growth by decreasing the amount of animal excrement and leaf litter released into the soil (Waghorn and McNabb, 2003). Depending on the plant type, forages containing condensed tannins offer ruminants a variety of advantages. Lotus, for instance, has been shown to be effective in preventing bloat. Other condensed tannins have demonstrated efficaciousness in enhancing live-weight growth (Waghorn *et al.,* 1999).

MECHANISM OF ACTIONS

Hydrolysable and Condensed Tannin interacts with proteins and other dietary components in the rumen

Many tannic effects on biological systems are indicated by research findings. Chemical structure determines biological properties (Patra and Saxena, 2010), and according to Waghorn and McNabb (2003), it can even have a greater influence than concentration. Large structural differences exist amongst individual tannins, which explains this. Per Patra and Saxena (2011), tannins with a lower molecular weight have higher protein reactivity. The concentration of both tannins, their molecular weight, the size, conformation, and amino acid composition of the protein, as well as the solvent, temperature, and pH of the medium in which the interactions occur, all have an impact on protein tannin complexes' properties (Le Bourvellec and Renarda, 2012). Due to their capacity to create stable hydrogen bonds between pH 3.5 and 8, they mostly affect proteins (Jerónimo *et al.,* 2016).The nature of the complexes that form between proteins and tannins in sainfoin (Onobrychis viciifolia) was investigated by Jones and Mangan (1977) using both in vitro and in vivo methods. The pH range of the rumen is between 5.7 and 7.3, and protein complexes were stable in vitro between pH 3.5 and pH 7.0. Then, as the pH changed—the abomasum pH is less than 3.5—complexes separated. Because of their detrimental effects on protein intake, digestion, and palatability, as well as on polysaccharides and minerals, tannins were long regarded as antinutritive substances. According to Crozier *et al*; (2009), frequent usage of tannin was also found to be hazardous due to damage to the kidney, liver, rumen tissue, and microvilli morphological abnormalities. According to Murdiati *et al;* (1992), the HT primarily had a negative impact on body tissue because they are enzymatically depolymerized in the rumen to gallic acid, which is then further metabolised by microbes to pyrogallol and other low molecular weight phenols that are absorbed and cause cellular damage. It is unlikely that condensed tannins may harm organs because they are not broken down and absorbed into the bloodstream. Digestion of proteins and carbohydrates is linked to a decrease in voluntary intake and their negative effects. In vitro results were validated by trials conducted on sheep that were fed sainfoin.

According to Jones and Mangan (1977), the tannin protein complexes broke apart in the duodenum but remained stable in the rumen (pH 6.5). This gave rise to the theory that tannin–protein complexes are created in the rumen and become available for gastric or pancreatic digestion when the pH drops below 3.5 (in the abomasum, pH 2.5–3) or rises above 8 (in the duodenum, pH 8). Quebracho tannins were also found by Makkar and Becker (1996) to accelerate the rate of inactivation at pH 11. The findings implied that the tannins are rendered inactive by an alkaline pH. Because of the feeding of tannin-rich feeds, the rumen's pace and extent of protein decomposition have diminished, which may have the effect of lowering ammonia concentrations and, consequently, urea N excretion in the urine(West, 1993). Particular attention has been paid to condensed tannins because, depending on the source, they may contribute significantly to the nutritional value of feed, the calibre of products acquired, and the overall health and welfare of animals when present in diets at low-to-moderate concentrations. Enhancing the digestive utilisation of feed proteins is one of the most significant benefits of CT use for ruminants. The impact of dietary tannins in ruminants may be advantageous or harmful, depending on variables like tannin chemical structure and concentration in the diet, the makeup of the basal diet, and other factors that are intrinsically related to the animals, like species and physiological stage (Piluzza *et al.,* 2014).

Biochemical pathways affected by Tannins

Nutrients in ruminants undergo fermentative digestion by rumen microbes first. Products of the microbial fermentation eventually become accessible for animal tissue metabolism as protein in the form of microbial cells and energy in the form of volatile fatty acids (Bunglavan, 2013). The ability of tannins to connect with proteins is a key characteristic that accounts for many of their biological actions (Hagerman and Butler, 1991). According to Bernays *et al*. (1989), they can be harmful to a variety of bacteria and fungi, which may be a primary factor in their evolution (Aerts *et al.,* 1999). Many leguminous fodder plants, herbs, and grasses, such as Onobtychis viclifolia (sainfoin), Lotus (L.) corniculatus (birdsfoot trefoil), L. pedunculatus (big trefoil), Hedysarum coronarium (sulla), and Lespedeza cuneata (sericea lespedeza), have intense tannin deposits in their epidermis at varying concentrations (Terrill *et al.,* 1989). Remarkably, it has been documented that plants with higher tannin concentrations yielded less leaves in comparison to those with lower tannin concentrations (Coley, 1986). Proteins in feed become quickly soluble when ruminants are fed forages with a high protein concentration. High ammonia levels result from the breakdown of proteins in the rumen by rumen bacteria. A significant amount of ammonia is taken up from the rumen and expelled in the urine (Ulyatt *et al.,* 1975). Certain tannins have the ability to decrease the quantity of protein that is broken down in the rumen and increase the quantity of protein that is accessible for digestion in the small intestine (Frutos *et al.,* 2004).Tannins and proteins combine to generate complexes. This is because phenolic groups are abundant and can form bonds with the carbonyl groups of peptides. Complexes are resistant to rumen microbe hydrolysis and deamination. More dietary amino acids are becoming available for post-ruminal absorption as a result of stable complexes. Complexes are thereafter accessible in the abomasum and undergo intestinal digestion (Bunglavan and Dutta, 2013).

IMPACT ON DIGESTION EFFICIENCY

Tannins influence on Ruminant Nutrition and Absorption

The impact of quebracho tree tannin extract on Angus steers and heifers was investigated by Beauchemin *et al*. in 2007. Research revealed that average daily gain (ADG), body weight, or nutritional intakes were unaffected by feeding with quebracho tannin extract. Moreover, it did not affect the digestion of DM, energy, or fibre (neutral and acid detergent fibre). Mezzomo *et al;* 2017 examined the effects of substituting soybean meal treated with a tannin mixture (85% CT and 15% HT) on the intake, digestibility, carcass traits, and performance of young cattle fed a diet high in concentrates. Replacing soybean meal with soybean meal treated with tannin resulted in a linear decrease in the consumption of DM. There was no discernible drop in carcass weight. A decrease in fat deposition and a rise in muscle were observed in the carcass gain composition. When tannins are used, animals' body gain composition changes and their consumption of DM decreases, improving feed conversion efficiency (Mezzomo *et al.,* 2017). When fed a high-grain diet supplemented with roughly 0.84 g tannin kg-1 body weight (BW), Frutos *et al.* (2004) showed no effect of chestnut tannin (HT) on lamb carcass qualities; there was also no effect of HT supplementation on ADG, feed efficiency, and length of finishing phase.

To feed young bulls (HT), Doce *et al.* (2007) employed oak leaves. According to the experiment's findings, giving the animals up to 5 kg of tannin per day had no discernible negative effects on ruminal fermentation or toxicity. When dairy crossbred cows were provided a 40 g HT supplement per day, Ali *et al.* (2017) discovered that the milk production increased considerably. Additionally, they saw that adding HT increased the amount of lactose (%) and milk protein. According to Dubey's (2007) findings, crossbred cows' milk output increased significantly from 9.44 to 10.35 kg/day/cow when 3% tannin from Acacia nilotica pods was added. In ewes grazing Lotus corniculatus during the early stages of lactation, Kushwaha *et al.* (2012) found no effect of CT; however, during the mid- and late-lactation stages, there was an increase in milk output of two litres. A research on Friesian dairy cows fed Lotus corniculatus was done by Woodward *et al.* (2000). When lotus was fed to cows instead of ryegrass, the increase in milk yield was noticeably higher (46%). While tannins had no influence on intake, they did enhance the concentration of milk protein, improve efficiency, and decrease the concentration of milk fat. The milk output of cows fed 88 g CT per kg DM increased by 10%, according to Anantasook *et al.* (2014). Comparing crossbred cows fed 1.5% CT per kg DM to cows not provided CT in their ration, Dey *et al.* (2014) found that the latter group's milk output decreased by 24.7%. Conversely, when cows were fed 244 g of tannins (CT) per day, Grainger *et al.* (2009) saw a drop in milk production of 29.7%. Grazing animals consume a vast range of vegetation, yet they frequently favour some while avoiding others. Taste, smell, and chemosensory irritation are the three anatomically unique chemical senses that animals use to decide which plants to consume. (Beauchamp and Mennella, 2009). Physical and chemical properties of feed define its flavour, and during consumption, post-stomach impacts of toxins and nutrients combine with flavour cues to influence palatability (Atwood *et al.,* 2001). According to a number of studies, saliva has a significant impact in how taste and texture sensations are perceived (Engelen *et al.,* 2007). The composition of saliva can affect how feed is perceived while also being influenced by the type of diet (Mese and Matsuo, 2007). A defensive mechanism of the animal against tannins has been found to be salivary proteins (Shimada, 2006).

Comparism of Tannin effects on Fiber Digestibility and Overall Feed Efficiency

Tannins in fodder affect nutritional value in both good and negative ways (Mueller Harvey and Mc Allan, 1992). High amounts of tannins impair animal performance, protein and carbohydrate digestibility, and intake (Reed *et al.,* 1990). Tannins reduce ruminal NH3-N by slowing down the rate of protein deamination and breakdown in the rumen (Woodward, 1989). When sheep and goats were fed tannin-containing legumes, there was a decrease in plasma urea nitrogen, ruminal NH3-N, and urinary N loss (Woodward, 1988). Tannins may improve the urea recycled to the rumen's efficiency. Depending on the chemical structure and concentration of meals, the makeup of the base feed, and other aspects that are inherently related to the animals, including the species and physiological stage, tannins are thought to have both negative and positive effects (Piluzza *et al.,* 2014). Reduced feed intake, nitrogen and fibre digestibility, and animal performance are examples of adverse impacts (Waghorn, 2008). On the other hand, tannins have been shown to reduce the risk of bloat, increase the digestion of protein, suppress internal parasites, and promote milk production and growth performance (Piluzza *et al.,* 2014). Additionally, it is well known that tannins contain antioxidant activity. According to certain research, eating tannins may enhance an animal's antioxidant status (López-Andrés *et al.,* 2013).Studies have indicated that adding plants or plant extracts rich in tannins to ruminant diets increases levels of health-beneficial FA in meat and milk and improves the oxidative stability of meat; however, the potential negative effects of tannins on animal performance and organoleptic properties of products pose a significant barrier to the widespread use of this nutritional strategy. In recent years, there has been a growing interest in using plants and plant extracts rich in tannins for use in nutritional strategies for improving some aspects of the quality of products from ruminants, specifically fatty acids (FA) composition and oxidative stability. Given that an animal's physiological state influences its nutritional requirements, it appears that one of the elements influencing ruminants' reactions to diets containing CT is the animal's physiological status (Waghorn, 2008).
Many experiments have been carried out on animals with higher protein requirements, such as lambs (Ramírez-Restrepo *et al.,* 2005) or lactating ewes and cows (Woodward *et al.,* 2004). These animals can respond to an increase in dietary protein and can therefore perform better in response to an excess of amino acids (Barry and Manley, 1984).The productive response to CT-containing forages is primarily beneficial, with potential improvements in daily gain of 8–38% and milk output of 10–21% as compared to controls (Waghorn, 2008). Increased availability of amino acids, especially branched-chain amino acids, methionine, and lysine, may stimulate the synthesis of milk protein and lactose (via neoglucogenesis) in relation to milk production, thereby augmenting total production (Wang *et al.,* 1996). However, the quantity eaten as well as the general quality of the meal will also have an impact on the performance of the animal. Greater availability of amino acid absorption may result from an intake of less than 50 g CT/kg DM (Min *et al.,* 2003). When combined with a medium-poor quality diet, the consumption of CT from browse has a negative impact on performance (Waghorn, 2008). Bloat is a digestive disease that affects ruminants who graze on legumes that are highly digested fodder, such clove or lucerne. When soluble protein-rich legumes are digested, stable foam may form, which restricts the amount of gas released during eructation during fermentation. The accumulation of gas causes the rumen to expand or stretch. Legumes containing CT, such as Astragalus cicer L., Lotus corniculatus, Coronilla varia, and Onobrychis vicciifolia, have been shown to reduce bloat in ruminants whether fed alone or in combination with forages that cause it (Wang *et al.,* 2012).

METHANE EMISSION

Roles of Tannins in Reducing Methane Production in Ruminants

During the process of reducing enteric methane (CH4) emissions from ruminants, tannins are thought to be a potential class of chemicals. Methane generation in rumen poses both an environmental and financial challenge. Methane is widely recognised as a powerful greenhouse gas, and 28% of all anthropogenic methane is produced by ruminants (Beauchemin *et al.,* 2008). Additionally, according to Lopez and Newbol (2007), the CH4 generated during ruminal fermentation represents a 5-8% loss in gross energy intake. A greenhouse gas known to cause large energy losses in ruminants, enteric methane is projected to contribute 2,079 and 2,344 Mt CO2-eq/year globally in 2010 and 2020, respectively (Hristov *et al.,* 2013). Methanogenic archaea and symbiotic protozoan partnerships create enteric methane during feed fermentation as a means of disposing of metabolic hydrogen (Leng, 2008). Decrease of methane developing a plan that reduces the activity and proliferation of the microbiota that produces methane without impairing rumen function is essential. As per the Bhatta *et al;* (2009) report, tannins are being explored more and more as a potential strategy to lower methane emissions from ruminants. This is because they are thought to be chemicals that show promise in reducing rumen methanogenesis. One of the most important nutritional objectives for ruminants is to reduce methane (CH4) emissions (Ramaiyulis *et al;* 2022). Animal breeding, feed modification, and rumen manipulation are the three categories of methane emission reduction strategies (Arndt et al., 2021). Concentrate and tannin supplementation reduced CH4 Yield (g/kg DMI) by 13.7–17.4% and CH4/Gain by 20.1%, according to a meta-analysis (Congio *et al.,* 2021).

EFFECTS OF TANNIN ON RUMINANTS ANIMAL HEALTH AND WELFARE

The benefits of tannins in terms of lowering intestinal parasites are also linked to their significance in animal diets. Traditionally, anthelmintic medication has been used to control ruminant gastrointestinal parasites. Unfortunately, as a result of growing parasite resistance to popular anthelmintics and the detrimental effects of chemical treatments used in animal agriculture on the environment, animal welfare, and feed safety, this process is getting harder to carry out (Min and Hart, 2003). A direct effect of tannins on nematodes has been demonstrated by feeding studies (Butter *et al.,* 2000), wherein they inhibit eggs and infective larvae and reduce larvae mobility. An indirect effect is also demonstrated by tannins, as they increase protein availability, which fortifies the immune system and increases resistance to infections (Min and Hart, 2003). Using feeds high in tannin has been suggested as an alternative to conventional parasite control methods (Nguyen *et al.,* 2005). This approach has been researched. Due to their impact on internal nematodes in ruminants, plants high in tannin have garnered the greatest interest. It has been utilised to prevent a variety of intestinal parasites in ruminants by using external tannins from plants including mimosa (HT), chestnut (HT), and quebracho (CT) (Min and Hart 2004). One of the suggested substitutes for conventional parasite control methods that has been researched is the use of diets high in tannin (Nguyen *et al.,* 2005). The effect of tannin-rich plants on internal nematodes in ruminants has garnered the greatest attention. Mimosa (HT), chestnut (HT), and quebracho (CT) are examples of external tannins that have been utilised to suppress a variety of intestinal parasites in ruminants (Min and Hart, 2003). According to a summary of in vivo research conducted by Hoste *et al;* (2006), tannins from chicory, sainfoin, sulla, Lotus pedunculatus, Sericea lespedeza, and Acacia nilotica significantly acted as anthelmintics in the digestive tracts of sheep, goats, and deer. Furthermore, Hedychium coronarium, Lotus pedunculatus, Lotus corniculatus, and Onobrychis viciifolia CTs were shown to exhibit anthelmintic-like activity against deer lungworm and gastrointestinal larvae, indicating that these forages may offer an alternate method of managing internal parasites in deer (Molan *et al.,* 2000).

PRACTICAL APPLICATION OF TANNINS

With an estimated 1076.3 kilotons of tannin needed in 2015 and a compound annual growth rate (CAGR) of 5.8% from 2016 to 2025, the global tannin market is growing quite quickly. Specifically, the wood, wine, leather, and pharmaceutical industries were in high demand. Only the leather industries utilise 62.3% of the roughly 282.4 kilotons of tannins that were generated in the USA. Tannings and goods containing tannins are also seeing growth in Europe. The reason for this is that 38% of Europe's revenue is generated by the large-scale wine industry. As a result, the tannin-related industries could have a $3.3 billion global market by 2025. Condensed tannin applications are predicted to reach 424.8 kilotons by 2025, up from 242.9 kilotons in 2015 (Grandview, 2017). However, there are a number of unanswered questions regarding tannin applications, including antinutrient effect, resistance to enzymatic hydrolysis, and incomplete knowledge about interactions with other biomolecules and animal and human modes of action. For both established and developing sectors, tannins may be the ideal natural raw material. Tannin's distinct chemical structure, natural qualities, and commercial qualities are responsible for this (Luckeneder, *et al;* 2016). Tannins have many benefits, including being an effective medicinal, biopesticide, antioxidant, biomaterial, and nutraceutical agent. There have been efforts made to create packing materials from biological sources, such as chitosan, starch, gelatin, tannins, and methylcellulose, and the idea of natural and active packaging has been developed (Kamari and Phillip, 2018). The best choice is active packaging, which not only shields the feed item from oxidation, UV rays, and moisture-based degradation but also serves as an addition to boost the antioxidant qualities of feed and absorb undesirable things like heavy metals or used oils. Packaging films based on chitin now have far better antioxidant and antibacterial qualities because to the addition of tannins. Chitin and tannins form hydrogen and hydrophobic bonds, which is primarily responsible for the improved quality of chitin-based films (Wang *et al.,* 2016). Animal skin is typically turned into leather in the leather industry by the addition of tannins. As stated by Kaygusuz *et al;* (2018), tannins have a major role in shielding leather from deterioration caused by heat and microorganisms.

RESEARCH CHALLENGES AND FUTURE RESEARCH

Aside their biological functions, they hold significant roles in the mining, chemical, tanning, and industrial sectors. They also feed animals. However, there are a few restrictions related to tannins. The primary drawback of tannins as feed is that they bind and absorb many kinds of biomolecules in the digestive tract, including proteins, carbohydrates, and metal ions. This prevents humans and animals from getting the nutrients that some biomolecules, such proanthocyanidins, provide. According to certain studies, the digestive systems of animals contain complexes of tannins and proteins that are resistant to different kinds of proteases, rendering the proteins unfit for feeding livestock. Dietary tannins attach to proline-rich proteins, forming soluble and insoluble complexes that give rise to an astringent feeling (He *et al.,* 2015). Additionally, some studies reveal that tannins also lower the activity of intestinal bacteria, which results in less soluble fibre and organic matter being absorbed and is linked to harm to the digestive system's mucosal lining. Most tannins utilised in the livestock industry today are either entire plants containing a wide range of secondary chemicals or crude extracts of combinations with varying molecular sizes. Combining this with the differences in the chemical structures and compositions of the compounds from various sources and growth environments would lessen the possibility that microbes would develop a resistance to the complex tannins. Though not much research has been done in this area, the scientific community, regulatory agencies, and the production industry must work together to stop microorganisms from developing resistance to tannins and other plant secondary compounds that are crucial to human health because doing so will have far-reaching effects on all of humanity.

CONCLUSION

The review concluded that tannin play several roles in ruminant nutrition through the complex connection of beneficial and non-beneficial effects. There is need to properly regulate hydrolysable tannin amount included in the ruminant diet to avoid negative impacts on animal health. The inclusion of condensed tannin on the other hand offers a number of advantages which aid protein utilization improvement and reduction of nitrogen excretion thus improving the performance of ruminant animal significantly. The balance incorporation of tannin in animal diet have positive effects which includes better feed efficiency, improved nutrient absorption, bloat prevention, and fight against parasitic infections. There is need to include a required level of tannins in animal diet for better formulation. There is need for researchers to seek for strategic inclusion of tannins to diet especially types and amount to optimize ruminant health and productivity. The need for future studies to continue with more understanding of tannin activities within the rumen and ways to develop protocols for effective consumption is ruminant nutrition is paramount.

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