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Molasses and Its Additives for Fodder and Green Plants for Ruminant Nutrition

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A B S T R A C T

Molasses, as a by-product of sugar production, is a feed widely used in ruminant diets, which is rich in available sugars and minerals. The present review paper, under this context, evaluates in detail the chemical characterization and nutritional aspects of molasses with an emphasis on it as a rich source of energy, enhancing the feed palatability and encouraging ruminal microbial fermentation. Molasses has been successful in green and conserved forage systems, particularly with improved quality silage and a reduction in feed losses. Feeding molasses with additives such as urea, minerals, and probiotics enhances rumen function, nitrogen utilization efficiency, and fiber digestion. Research has also shown that it has a positive impact on production performance (such as weight gain, higher milk yield, and feed intake). However, limitation still exists with the factors of the risk from sub-acute ruminal acidosis, imbalancing of electrolytes , and variation of animal species and age. Overconsumption leads to ruminal pH and microbial imbalance. It suggests moderate (usually no more than 10% of dry matter) molasses inclusion with the product introduced slowly and balanced with other feed ingredients. It also provides farmers and nutritionists with working tools to realize these advantages without jeopardizing animal health. The need for further research on the activity of molasses in the long term, its interaction with rumen microbiota, and its activity with other additives in sustainable ruminant production systems is emphasised. The future requirements for research into the long-term activity of molasses, its interaction with rumen microbiota, and its activity with other additives in sustainable ruminant production systems is emphasized.

INTRODUCTION

Ruminant nutrition is one of the foundations of animal production systems and is of great significance for improving animal health and productivity, as well as the efficiency of use of the scarce resources in agriculture. Since feed components, digestion efficiency, and growth of ruminants were associated, there is a continuous demand to find practical and effective nutritional solutions by scientists and breeders (Wen Peng et al., 2024; Rodríguez & Preston, 1997; DeVries & Gill, 2012). As the animal production system increasingly grows to satisfy the increased demand worldwide for meat and milk, the necessity to implement new feed sources grows, including feedstuffs that are generated by by-products of the agricultural and food industries. Among these, molasses has a specific nutrient profile, making it one of the most used and desired by-products in ruminant animal nutrition, and is highly available in many countries. Molasses comes from either the sugar refining of sugarcane or sugar beet. It is a viscous, brownish liquid rich in fermentable sugars, such as sucrose, glucose, and fructose, being a fast energy source (Palmonari et al., 2020; Mirzaei-Aghsaghali & Maheri-Sis, 2008).

It is also rich in potassium, calcium, and other minerals such as magnesium and non-protein nitrogen compounds that increase its nutritional value (Mordenti et al., 2021; Hall, 2002). Molasses is an important source of feed ingredient, other than its nutritious properties, when it is incorporated into compound feeds or green fodder. Numerous other studies have demonstrated the benefit of including yeast in feed formulations, evidenced by enhanced palatability (feed intake) at the voluntary level of feeding of animals, especially when feeding roughage or medium-quality silage (Oba & Allen, 1999; Bowman et al., 1995; Konstantinou et al., 2024; Zhao et al., 2025).

Molasses has been fed as a fermenting agent in the silage industry as well as a catalyst for anaerobic fermentation, contributing to an immediate energy source for lactic acid bacteria; it rapidly reduces pH and enhances the stability of the quality of silage (Kung et al., 2018; Singh et al., 1985; Wen Peng et al., 2024; Pámanes-Carrasco et al., 2023). In addition, molasses is a good carrier of feed additives like urea and microminerals, and especially in the case of liquid feeds and supplementation feed blocks, assists in dispersion and absorption of nutrients (Moorby et al., 2008; Anindo et al., 1998; Wen Peng et al., 2024). In terms of economic circulation and eco-environmental operation, the application of molasses embodies the idea of circular economy in the sustainable agro-ecosystem, and this action processes low-cost agricultural by-products to produce high-quality feed as well as to decrease being sources, resulting in improved efficiency of livestock production in the rural area (Schiere et al., 1989; Mordenti et al., 2021). In light of the previous paragraphs, the present study was planned to provide a critical review of the functions of molasses in ruminant diet, addressing the chemical properties and action mechanisms of molasses in the rumen and its inclusion in green and compound feeds. The paper also discusses the application of different molasses by-products and attempts to highlight the major problems and recommendations for their use in sustainable animal production systems.

In view of the well-established feed value of molasses together with ruminants and the expectations of its wine effect, there is currently no review that provides an overview and critical evaluation of the different types of molasses and their combination with modern additives, and of the possible long-term impact on rumen health available in the literature. Previous research on this subject has been focused mainly on short-term performance metrics and has failed to consider in-depth issues such as safety reference values, interspecific response, or sustainability implications. This review attempts to address this gap, incorporating the most recent insights and providing perspectives for future directions on the safe and efficient use of molasses in ruminant feeding.

METHODS

This review is a narrative literature review. Data sources: Journal articles that were peer-reviewed and indexed in Scopus, Web of Science, PubMed, and Google Scholar were included in the review. Key words were "molasses", "ruminant nutrition", "silage additives", and "feed palatability". Eligibility criteria: This summary included articles published from 1990 to 2025, prioritizing the recent publications from the last five years. Eligible studies were reviewed with respect to the purpose, design, results, and limitations. This review did not include any original experiments and was instead designed to integrate the results of previously conducted studies so that practical and research conclusions can be arrived at.

RESULTS AND DISCUSSION

Chemical and Nutritional Properties of Molasses

Molasse is a by-product in the sugar industry obtained from Sugarcane (Saccharum officinarum) and sugar beet (Beta vulgaris). Although it is a by-product, it is valuable in chemicals and nutrition, mainly used as animal feed, especially ruminant feed, due to its high content of energy, minerals, and fermentable sugar. This is consistent with current and future tendencies of the food industry toward agricultural sustainability and food industry waste recycling in animal production chains (Mordenti et al., 2021; Rodríguez & Preston, 1997; Fu et al., 2023).

Chemically, molasses is a majority (65-80%) sucrose, along with significant levels of glucose and fructose. These sugars are fast energy sources and fermentable in the rumen of ruminants, supporting the increase in growth of anaerobic microbes (lactic acid bacteria) to improve fermentation efficiency and also to enhance the degradation of dietary fiber (Palmonari et al., 2020; Mirzaei-Aghsaghali & Maheri-Sis, 2008; Abreu et al., 2022). It is observed that the sugarbeet molasses has a higher content of reducing sugar and lower sucrose content compared to sugarcane molasses, thus it is less palatable and has a lower fermentation rate (Valli et al., 202012; Zhang et al., 20247). In addition, molasses has a high concentration of essential minerals for ruminants, including potassium, which could represent 4–5% of the dry matter, and calcium, magnesium, and iron, which are fundamental in controlling fluid equilibrium, enzyme activation, and muscular and nervous performance (Mordenti et al., 2021; NRC, 2005; Lean & Rabiee, 2011).

There are some studies showing that regular use of molasses promotes the absorption of those minerals, which means that there will be a lower requirement for additional supplements of synthetic sources, resulting in lower feed costs (Izquierdo et al., 2021; Hou et al., 2023). Molasses also facilitates the use of feed additives, such as urea, because fermentable sugars are able to help stimulate the growth of ruminant microorganisms, increasing microbial protein synthesis and increasing the efficiency with which crude protein is converted. This results in higher digestibility and animal production, particularly in traditional systems that make use of low-quality feeds (Moorby et al., 2000; Toppo et al., 1997; Wen Peng et al., 2024; Tiwari et al., 1990).

Differences in taste, aroma, and mineral profile between these two kinds of molasses are contrasted. The beetroot molasses were found to be higher in salts, potassium, and chloride, which could interfere with the palatability, while the higher palatability of sugarcane molasses in the animal diets could be attributed to its high content of sucrose and low salinity (Palmonari et al., 2020; Nakata et al., 2014; Yu et al., 2023). The chemical and physical characteristics of molasses are dependent on a variety of factors, including plant type, soil conditions, industrial processing techniques, and extraction/refining processes. This needs to be tested in the laboratory to guarantee feed balance (Corino, 1991; Qiu et al., 2024). The recent literature has suggested including 5–10% of molasses for the dry matter in total rations to reach the maximum nutritional improvements with no adverse effects on the feed palatability and water content (Mordenti et al., 2021; Bowman et al., 1995).

According to these results, the molasses (both from sugarcane or beet) could be a good option to increase the nutritional and physical value of feed for ruminants. It's favorable to digestibility, feed intake, and milk or meat production, particularly in medium- or low-efficiency production systems. It is also an essential, potential tool for a sustainable environment, since it also recycles resources and minimizes the use of high-cost traditional feedstuffs (Mordenti et al., 2021; Wanapat, 2000; Wang et al., 2025).

Use of Molasses in Fodder and Green Forages

The inclusion of molasses in green and conserved forages is a technique for production that has several nutritional and technical advantages in ruminants. These benefits include enhancing feed palatability, increasing nutritional availability, and reducing the loss of nutrients during storage and fermentation. Furthermore, it is considered the key success factor in silage production as it is a good fermentable sugar source required for lactic acid bacteria growth (Mordenti et al., 2021; Singh et al., 1985; Wang et al., 2025). Palatability Research has also indicated that green fodder or silage supplemented with molasses stimulates higher palatability of animal feeding, particularly in animals fed with unpalatable or low-quality feedstuffs such as hay, old green fodder (besure) 1 (Kung et al., 2018; Oba and Allen, 1999; Bowman et al., 1995). This is attributed to the palatable flavor that emanates from the high sugar content in molasses, which is known to stimulate appetite in cattle and sheep, resulting in increased dry matter intake and hence better production performance and feed conversion ratio (Abreu et al., 2022; Liu et al., 2023). The function of molasses is to maintain nutritional value and minimize loss by improving anaerobic fermentation conditions in the ensilage process. The readily fermentable sugars in molasses (sucrose and glucose) offer a source of energy to lactic acid bacteria, leading to a more rapid pH decline in the green mass and also limiting the activities of Clostridia and proteolytic bacteria (Andrighetto et al., 1987; Kung et al., 2018; Guo et al., 2024).

This rapid pH drop is necessary to save on protein, decrease nitrogen wastage, and avoid the formation of ammonia and undesirable organic acids like butyric acid. Moreover, the addition of molasses also contributes to the improvement of the final quality of the silage because molasses-treated silage has higher chemical stability and higher lactic acid (LA), enhancing its chemical composition and the feeding efficiency (McDonald et al., 1991; Palmonari et al., 2020). Studies have reported that the concentration of lactic acid and soluble carbohydrates is significantly high with 2–5% (w/w) of molasses, as an optimum ratio for efficient fermentation without any deleterious effect on cost and moisture (Mordenti et al., 2021; Zhang et al., 2024).

Supplementation of molasses in preserved feeds is now of paramount importance in areas short of concentrated feeds or high-quality plant proteins to improve the nutritional imbalance in the straw or low-digestible rations based diets (Wanapat, 2000; Fu et al., 2023). It is occasionally used as a good medium for the effective mixing of other feed additives like minerals and urea, thereby enhancing the distribution and absorption efficiency, particularly in feed blocks or in liquid feeds for mass feeding (Moorby et al., 2000; Anindo et al., 1998; Wen Peng et al., 2024).

In general, molasses is a dual-purpose product with the combined benefits of feed conservation and enhancement of feeding value and acceptance by ruminants as described by Benavides et al. It's also a critical element of sustainable agriculture strategies that can reduce the loss of feed and improve material use in production, effectively maintain the sustainability of livestock production systems (Qiu et al., 2024; Yu et al., 2023).

Additives Combined with Molasses

Molasses-containing additives are a promising development in feed applications, particularly in energy-intensive ruminant production systems and in animals that rely on low-nutritional-value forage. This method consists of combining molasses with various products, like urea, mineral salts, probiotics, or other bio-additives, so as to improve digestion, improve protein conversion rate, and increase the efficiency with which the rumen is fermented. This balancing act between energy source accessibility from sugar of molasses and microbial activity is important to enhance the utilization of fiber and NPN in the diet (Mordenti et al., 2021; Toppo et al., 1997; Pámanes-Carrasco et al., 2023).

Of these additives, urea is considered to be an efficient and low-cost non-protein nitrogen for ruminant feeding. When molasses is added, the highly fermentable sugars create a rumen environment for the fermentation of urea by the rumen microbes, resulting in enhanced microbial protein production and digestibility in general. The energy to nitrogen balance is important to prevent toxic buildup of ammonia in the rumen. The energy–poor nature of urea feeding results in increased accumulation of ammonia, which is harmful to animals (Moorby et al., 2000; Tiwari et al., 1990; Loest et al., 2001).

As far as minerals (phosphorus, calcium, sulphur or zinc, etc), molasses increases their bioavailability when provided in palatable or soluble forms. The use of molasses as a vehicle for these minerals enhances voluntary intake of the mineral mix and increases the animal's nutritional status and capacity to support essential physiological functions such as milk production, growth, and reproduction (Mordenti et al., 2021; Suttle, 2010; EFSA FEEDAP Panel, 2019). This is particularly true in roughage-based systems of low mineral quality or where the soil has low mineral content (Fu et al., 2023). Today's additives contain probiotics and prebiotics, which are substances that provide beneficial intestinal bacteria, including Lactobacillus and Bacillus subtilis, to the digestive system. It favours the growth of these organisms due to the fermentable sugars in molasses that can support the suppression of undesirable microorganisms, enhance the immune system and digestibility, and consequently improve the health and production of animals (Palmonari et al., 2020; Wanapat, 2000; Liu et al., 2023).

Molasses is also used as a carrier for other additives like natural antibiotics, plant essential oils, and digestive enzymes that can be added to improve nutrient utilization or to inhibit undesirable fermentation. When dissolved or premixed with molasses, these additives are more efficient because the liquid character of molasses results in good adhesion of the additives to the mixed feed, promoting a homogenous distribution (Anindo et al., 1998; Domino, 1987; Qiu et al., 2024). The widespread use of these additives should be followed by a careful evaluation of the basal feed and the nutritional goal to be targeted. An example of these is urea-heavy diets, where the moist ingredients are most concentrated with urea, leading to excessive intake and the toxic effect of urea, while a subtle ratio of urea to sugars contained in molasses results in enhanced protein conversion efficiency without side effects (Pámanes-Carrasco et al., 2023; Mordenti et al., 2021; Toppo et al., 1997).

In summary, adding molasses in combination with other feed additives is a beneficial and versatile approach in ruminant feeding. It improves taste, increases available energy, increases the absorption of micronutrients, and encourages the growth of microbes in the rumen. This is of great importance in the overall efficiency of the feed, and makes molasses a key ingredient in the development of nutritionally sound, low-cost/ profitable, and environmentally friendly feeds.

The reviewed experiments consistently showed the advantageous effects of inclusion of molasses on ruminant performance, with similar results for energy availability, microbial protein synthesis, and enhanced palatability. But the review also suggests that results largely depend on the nature and dose of molasses inclusion, the species of animal, and the environment in which they are fed. For example, sugarcane molasses is more attractive and more palatable in cattle than sugar beet molasses, and is relatively well-tolerated, while sugar beet molasses cannot be fed solely or to an extent at which it will cause electrolyte disturbance, because of its high potassium levels. Moreover, co-supplementation with molasses of additives such as urea and probiotics can lead to an improvement of feed utilization, although it can also lead to ruminal acidosis and metabolic stress when added to the diet at more than 10% dry matter inclusion. These results emphasize the necessity of a controlled use of molasses and a demand for outlined feeding guidelines. The review also notes that there are no long-term studies examining adults as a major limitation of the current literature.

Impact of Molasses Use on Ruminant Performance

Molasses is a well-known ruminant feed additive, and many research results have revealed the positive impact on production performance of ruminants, including growth performance, weight gain, milk production, and increased digestibility of animals. This is mainly because molasses is rich in fermentable sugars, allowing an immediate source of energy for ruminal beneficial microflora to grow, indirectly improving the digestion and nutrition of the animals (Mordenti et al., 2021; Wanapat, 2000; Abreu et al., 2022).

As for the replacement of growth and weight gain, studies show that molasses feeding at 5–10% of DM of calves and lambs increases average daily growth (ADG) and improves feed conversion efficiency (FCR). The higher fermentation rate and nutrient utilization (Ivan et al., 2000) may be due to improved feed palatability and an enhanced rumen microbial environment in the rumen (Palmonari et al., 2020; Brito et al., 2015; Liu et al., 2023). Molasses in combination with urea is also responsible for a balance between energy and non-protein nitrogen to increase synthesis of microbial protein, which is crucial for proper development (Pámanes-Carrasco et al., 2023; Toppo et al., 1997; Loest et al., 2001). With respect to milk production and quality, studies have demonstrated that supplementing the diet of dairy cows with 3–7% DM of fermentable carbohydrates as molasses, has increased milk production of 1–2 kg/d of milk, as well as substantial improvement in fat and protein content (Mordenti et al., 2021; Broderick & Radloff, 2004). The increase is mediated by higher rumen propionate concentration, which serves as the major energy source in the synthesis of lactose, the main determinant of milk production (Monteiro et al., 2017; Peterson et al., 2012).

Digestibility: molasses also plays a cleaner role in general digestion (fimeptic effects) because it favors the growth of cellulose-degrading bacteria and reduces the retention time of the feed in the rumen. This enhancement is accompanied by an enhanced rumen microbiome composition, an increase in the number and activity of beneficial microorganisms, a decline in negative microorganisms, and an excess of ammonia-producing ones. This minimizes the occurrence of ruminal acidosis and bloating (Kung et al., 2018; Chibisa et al., 2015; Wang et al., 2025). In terms of inclusion levels, it is reported that the best use of molasses in ruminant diets is at the rate of 5–10% DM, with a view to ensuring that feed moisture status and nutrient balance is not adversely affected (Mordenti et al., 2021; Bowman et al., 1995). The use of lower levels in silage 2–5% of the green matter weight will improve the fermentation quality (Wen Peng et al., 2024; Singh et al., 1985; McDonald et al., 1991).

Nevertheless, overuse of molasses in liquid feeds should be avoided, as it can induce digestive disorders if not complemented with other ingredients of feed (Wen Peng et al., 2024; Pámanes-Carrasco et al., 2023; Ghedini et al., 2018). The results of this study indicated that the addition of selenium-or zinc-enriched yeast enhanced antioxidant profiles and liver and kidney function in Iraqi goats native breed (Shareef, 2025). Recent research pointed out the significant enhancement in fertility and hematological traits of Awassi ewes by using such hormonal treatments, indicating that hormonal regulation may have a notable role in improving the productivity of livestock animals (Alwan, Majid, & Ismail, 2018a; 2018b). In the practical use, molasses should be distributed uniformly throughout the TMR, in feed blocks, or as a carrier of other additives such as minerals and urea, to maximize its use and required nutritional balance (Anindo et al, 1998; Moorby et al., 2000; Abreu et al., 2022).

Challenges and Limitations in the Use of Molasses

Although the advantages of using molasses in ruminant diets are numerous, there are potential problems associated with the use of molasses that should be addressed to maintain safety and achieve optimal nutrient utilization. Among the most relevant potential issues are the abuses in the feeding of molasses; the imbalance to which it may lead against other feed sources; the variations of animal responses linked to their species and to their stage of growth or production (Mordenti et al., 2021). Over-use of molasses, especially when it is present at more than 10% of feed dry matter, is one of the main causes of dysbiosis of the rumen microflora, because molasses is high in rapidly fermentable sugars (such as sucrose and glucose). This surplus results in overproduction of organic acids that rapidly drive the ruminal pH to low values and can result in subacute ruminal acidosis (SARA). This leads to reduced feed intake, decreased digestion efficiency, production performance reduction, and animal health impairment (Kung et al., 2018; Ghedini et al., 2018).

Some types of molasses also contain high levels of potassium, which can lead to electrolyte imbalances and increase the incidence of metabolic diseases such as milk fever, particularly in dry cows (Knowlton et al., 2007; NRC, 2005). Furthermore, Kamphues et al. (2014) reported that the high content of sulfur in some molasses types can help to explain neurological disorders induced by sulfur over-consumption. With respect to feeding of molasses, it needs to be balanced with other nutrients, particularly rumen available protein. The fast benefit surpluses provided by molasses are wasted if nitrogen is not sufficient, for they are not effectively utilized, resulting in low synthesis of microbial protein and decreased digestion (Palmonari et al., 2020; Loest et al., 2001).

Additionally, inclusion of a large volume of molasses in TMR increases the moisture level, accentuating the risk for microbial contamination and reducing the shelf life of the feed mix (Dixon and Egan, 2002). Also, there is a wide variation in animal response. The young calves and un-weaned lambs are more susceptible to rumen disturbances associated with high levels of sugar, whereas adults are less likely to be affected, as the ability of adult animals to resist is higher compared to young calves fed on high sugar feeding. Ruminant species also differ in terms of sensitivity to the feed ingredients, so that sheep and goats can be more sensitive than cattle to the high salt content in some molasses types (Mordenti et al., 2021), with gains in cattle being arrested later in the production process (Reed et al., 1998; Reed and Arambel, 2001). The literature also suggests the gradual application of molasses in the ration of susceptible animals or animals with poor digestion in order to avoid abrupt disturbances (Schiere et al., 1989; Wen Peng et al., 2024). From what has been discussed so far, the effective use of molasses in ruminant feeding depends on the manipulation of its composition, animal needs and the immediate environment, and in devising a package of nutrition that carefully combines the influences of the balance between energy and nitrogen levels, mineral status, and lick-feeder preferences, to receive maximum benefit without rendering the animals more vulnerable to ill-health, or lowering its productivity.

CONCLUSION

The current paper reviews the potential of molasses in ruminant nutrition with a whole range of positive effects, such as feed palatability, nutrient digestibility, and animal production. It is increasingly used in silage making to increase feed value and minimize feed loss. However, its use is cautioned against to prevent the risk of factors such as rumen acidosis and electrolyte imbalance, especially if excessive or unbalanced with other feed ingredients. The use is recommended in moderation and depending on the needs of the animal, both for climacteric and carnivorous animals and puppies, kittens from weaning. More research on its exact effects on rumen health and its interaction with feed additives is required.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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