

## EXPLORING THE FEEDING DYNAMICS: A REVIEW OF HAY UTILIZATION IN RUMINANT NUTRITION

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### ABSTRACT

Hay remains a fundamental component of ruminant diets across the globe and was introduced to conserve extra forage from grasslands for the use of livestock in the months of fodder scarcity and winter season. Both grasses and legume crops can be converted into hay, but the choice largely depends on the type of livestock farmers keep. Many studies have shown that good fertilizer management, tillage practices and seed rate affect the protein content, energy yield and digestibility parameters of the hay. This review explores the complex dynamics of hay utilization within the context of ruminant nutrition and the impact of hay quality on rumen fermentation, nutrient digestibility and overall animal performance. Factors influencing hay intake, such as physical characteristics and processing methods are also discussed. Additionally, strategies to optimize hay utilization, including supplementation and hay blending are also discussed. Furthermore, areas of future research direction to enhance understanding of hay role in ruminant feeding systems are highlighted in the article.

## 1. INTRODUCTION

According to recent worldwide assessments, it has been found that livestock consume 6 billion tons of feed (dry matter) each year, with approximately 86% considered unsuitable for human consumption (Mottet *et al.*, 2017). Crop production practices has been greatly impacted by technological advancements, particularly in areas like nutrient management, breeding techniques and irrigation methods. These innovations have played a significant role in ensuring a sufficient supply of feed for livestock. It is worth noting however, that as the livestock industry expands, there will be a corresponding flow in the global demand for feed. Research conducted by Legesse *et al.* (2018) indicates that this demand is projected to increase from 11% to 17% for crops that are suitable for human consumption and from 6% to 15% for crops specifically designed for livestock consumption. This signifies the need for sustainable agricultural to meet

the increasing requirements of the livestock sector without compromising the availability of food for human consumption. Roughage plays a vital role as a valuable resource in supporting the metabolism of ruminant animals. Through their distinct physiological structure, rumen microorganisms possess the ability to transform roughage into volatile fatty acids (VFAs) and proteins, thereby supplying essential nutrients to ruminants. It is important to note that the selection of roughage sources significantly influences the fermentation process carried out by rumen microbes. Consequently, gaining a deeper comprehension of the relationship between roughage composition and the rumen microbiota is crucial for enhancing animal productivity and optimizing economic efficiency (Chen *et al.*, 2022).

When it comes to good-quality hay, various key attributes are recognized. One essential characteristic is its vibrant green hue, as hay displaying shades of yellow or brown suggests lower quality resulting from delayed harvesting, exposure to rain or mold

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formation. Additionally, superior hay is characterized by its leafy composition, containing minimal stems. While it may not possess a distinct aroma, an unpleasant musty or sour smell can discourage animals from consuming it. Therefore, ensuring these attributes are present is crucial in obtaining high-quality hay (Dannhauser, 2021). In the cattle industry, producers typically collect feed in the summer and store it for winter use. A significant portion of the annual budget, ranging from 40-60%, is allocated for nutritional expenses. According to a survey conducted by Oklahoma State University, nearly half of the producers fed hay for 91–120 days during winter (Vestal, 2007).

Hay is a preserved form of fodder produced from grass and legume forage. In contrast to silages, hay is made by reducing the moisture level in chopped fodder to a very low level (Petty & Cecava 1995). Hay can be made from legumes and forage. However, legumes are preferred because of their low cell wall content and low neutral detergent fiber (NDF) ratio on a dry matter (DM) basis (Henning & Lawrence, 2019).

The seeds and technology for hay have spread worldwide. Approximately 300 years ago, there was hardly any specialized equipment available to cut, rake and harvest hay in the globe. On a good sunny day, farmers would be pleased if they ended up harvesting an acre of the land. Hay making began when some farmers began to import timothy, red clover and rye grass from Europe and converted the extra crop into hay during the winter months (Skrinjar, 2006). Although the mid-1800, equipment for seeding and harvesting has improved, hay making is still considered one of the most difficult tasks on livestock farms.

This review covers the history of Hay, geographic preferences of hay, advances in technology, typical inclusion levels and future of hay in the modern TMRs

#### **Advantages of Feeding Hay**

Feeding hay to ruminants offers various benefits that positively impact their health, performance, and overall well-being. Here are some key advantages of feeding hay to ruminants

#### **Improved Rumen Development and Function:**

Feeding hay can provide physical abrasiveness that prevents keratin build-up on rumen papillae, making the rumen more functional and capable of greater nutrient absorption (Hanson, 2021). Hay stimulates ruminating activity, resulting in a higher feed intake and promoting a healthy rumen environment (Heumilch).

#### **Nutrient Utilization and Digestion:**

Quality hay increases feed intake, which can lead to savings on concentrated feed and provides a higher protein stability than grass or silage, enhancing nutrient absorption in the small intestine (Heumilch). In an article by Paskewitz, (2020) reported that feeding long-stem hay increases saliva production due to increased rumination activity, which aids in nutrient breakdown and absorption in the rumen. Beigh et al. (2017) have indicated that hay intake can significantly impact the performance of ruminants. For instance, incorporating crop residues as a roughage source in Total Mixed Ration (TMR) for ruminants has been reported to improve nutrient utilization. Additionally, the physical form of the diet, such as densified or pelletized diets, can affect the rate of consumption, with densified diets being ingested more rapidly

#### **Health Benefits:**

Hay feeding can help prevent bloat by acting as an anti-foaming agent and balancing pH in the rumen, creating an optimal digestive environment (Paskewitz, 2020). Providing oat hay to weaned calves can improve rumen fermentation, nitrogen utilization, and reduce the incidence of diarrhea, contributing to overall health and performance (An et al., 2020)

#### **Economic Advantages:**

Feeding hay can lead to cost savings by reducing the need for concentrated feed and increasing milk yields, with potential savings of up to 28% on hay consumption. Utilizing quality hay in animal feeding can enhance animal health, fertility, and comfort, ultimately improving productivity and reducing costs associated with feed maintenance Paskewitz, (2020) In conclusion, feeding hay to ruminants is a beneficial practice that supports their nutritional needs, digestive health and overall performance. It plays a crucial role in optimizing rumen development, nutrient utilization and cost-effectiveness in livestock management

#### **Haymaking throughout History: A Global Perspective**

The beginning of agriculture can be traced back to the period when humans rejected their nomadic lifestyle and adopted a settled way of life. This led to the cultivation of land that was primarily used to grow crops such as lupines, linseed, barleycorn, einkorn wheat, emmer wheat and chickpea. These crops were cultivated on the best lands for an average duration of two years, a practice referred to as *ager* (Mazoyer & Roudart, 2010). Following a specific cultivation period, larger regions were left fallow and used for grazing cattle at night to rejuvenate the soil with animal manure. This was referred to as "alqueive." After a two-year cycle, the alqueive region was

switched with the ager region. The outlying areas of the "silver system" were covered by indigenous forests, which provided firewood and construction material for houses, as stated by [Neres et al. \(2017\)](#).

As the population grew and the demand for grain production increased, farmers faced challenges, such as soil fertility depletion and a shortage of winter fodder. To address this, they began to store additional feed produced in the silver zone. However, the process is slow and labor-intensive because of the use of hand tools for haymaking. The hay is usually kept on-site in piles, and during colder months, cattle must be transported to other regions for additional supplementation because of the lack of pastures ([Team, 2015](#)).

Through the middle Ages, haymaking techniques were enhanced with the use of animal traction and more efficient hand tools such as the cutlass. Subsequently, agriculture underwent significant advancements during the contemporary age, marked by the invention of the steam engine and gasoline tractor in 1892 in the US, as noted by [Vian et al. \(2013\)](#). Since then, there have been ongoing improvements in the production process, facilitated by advancements in the manufacturing of hay, resulting in rapid and efficient production methods ([Neres et al., 2017](#)).

**Selecting a Plant Species**

There is no debate on the benefits of hay, but on what crops should be used to make it. Both grasses and legumes produce excellent hay that can be used when fresh pasture is not available (“Legume Hay vs. Grass Hay” 2014). From grasses, popular varieties are Bermuda grass, Timothy, Rye grass and from legumes, Alfalfa and Red clover are the top selection ([Henning & Lawrence, 2019](#)). The table below shows the typical values for grass and legume hays ([NAS, 2007](#)).

Forage	Digestible Energy Mcal/Kg	Crude Protein %	Calcium %	Phosphorous %
Legume Hay	2.17	12.8	0.38	0.25
Grass Hay	2.04	10.8	0.47	0.28

**Source: National Academy of Sciences (US)**

One of the major considerations when selecting forage species is the type of animal that must be fed. For example, except for foals, grass hay is sufficient to match the general energy and protein demand in adult horses. When hay is to be purchased from the market, another major consideration is cost. Generally, hays made from legume forages cost nearly twice the price

of grass hays ([Beiranvand et al., 2014](#)). Similarly, for dairy cows, alfalfa is considered the best hay because of its highly digestible fiber and better protein and calcium values.

Special varieties, such as those with drought and winter resistance, can be grown in all environments and are less likely to be damaged during grazing. For instance, pioneer seeds have a long range of alfalfa varieties. On their website, a performance chart of each variety against a list of traits can be found, such as herbicide resistance, winter hardiness, forage yield, bacterial wilt and aphid resistance. For testing such traits, specialized growing chambers and techniques like Ultraviolet spectroscopy and chemigraphy are in use ([Loper, 1968](#)).

Climatic conditions and the soil are also important considerations. A great variety of hay production may fail when trying to grow under different conditions. A study was conducted in Pakistan to test the growth and other parameters of exotic grasses imported from different parts of the world. However, the grass variety *Brachiaria humidicola* from Brazil and the legume *Arachis glabrata* of Africa did not germinate under the new conditions of the pothwar plateau ([Qamar & Arshad, 2002](#)). In another study conducted in Faisalabad, warm season grasses were grown under long-term conditions. Elephant and Rhodes grass adopted Pakistani conditions and produced exceptional yields of biomass ([Ullah & Saleem, 2006](#)). Points to consider are that farmer should select between grass and legume keeping in view of the kind of livestock farmer keep. Modern science has changed beyond simple plant breeding, and now there are detailed scorecards available for resistance of seed varieties that could better complement the kind of insect attacks we might face in the field. Another, but probably the most important, thing to consider is the type of soil and the climatic conditions available versus required.

**Growing Crops for Hay**

Good hay can only be produced if the raw material (fodder) is of superior quality. This brings us back to good agricultural practices while growing the aforementioned crops. Land preparation is the cornerstone of good crop yield. Therefore, the recommended plowing and use of other implements are necessary before planting the seeds. The concept of zero tillage is now common in Europe and the USA, where a crop is sown just after the first crop is harvested, that is, wheat is sown just after rice in the Ganges belt of India ([Vikaspedia, 2019](#)).

The second most important factor is fertilizer management and general practice. A study on hay production from lowlands suggests that unfertilized pasture grasses could not only yield approximately 20% less dry matter but would also be 20% less digestible than the hay produced from intensively managed grasslands (Tallowin & Jefferson, 1999). Similar results were reported in another study where unfertilized hectare of grass yielded 30.27 USD worth of less forage as compared to the fertilized plot with the same specifications (Aase & Pikul, 1997).

Field trials on the results of plant density and nutrient content of forage have confirmed that with an increase in plants per hectare, crude protein, energy, and dry matter digestibility reduced while fiber increased (Baghdadi et al., 2012).

Finally, the timing is not the least. In old times, farmers would just feel the stage of the plant and decide on the visible parameters. This part of the problem has been solved with the availability of on-field testing equipment, but the real challenge is to coincide the stage of the plant cut with the environmental conditions (Porter, 2009). After all, hay making is all about turning stuff that is easily perishable into a product that can be stored, transported, and fed to livestock safely under uncertain weather and machinery conditions (Suttie, 2000).

In essence, the quality of hay production depends on a combination of superior raw materials, agricultural practices, and precise timing. It's all about balancing nature and human know-how to, ensuring a vital resource for livestock nutrition despite the uncertainties of weather and machinery.

### Hay Storage Losses

Storage is a significant factor that contributes to the loss of dry matter (DM) during hay production. Large round hay bales can be stored using various techniques, but stacking them in rows edge-to-edge on the floor, leaving them exposed to the environment, is the most common approach. Storage losses can vary from two to 18 percent of the DM based on the type of fodder, storage method, external conditions, and length of preservation (Huhnke, 1987). Degradation of weathered hay across different storage methods, such as substantial round bundles and compacted hay piles, with the aim of determining the amount and intensity of weather damage that occurs when grassy hay is stored outdoors in large buckets (Lechtenberg et al., 1974).

In this study, the hay remained outdoors between June and November. After this period, four samples from

each treatment were collected and divided into two portions, one of which was weathered, while the other remained unweathered. The results revealed that compressed hay stacks had a lower waste rate owing to weathering than large round bales, with loss rates of 12.6% and 22.3%, respectively. They suggested that the difference in bale density was the reason for the disparity between the two storage methods.

Brasche et al. (1988) examined the effects of different storage methods on large round bundles of brome grass and alfalfa. The bales were kept on the ground without any covering, raised on tires, and wrapped in plastic film. After the storage period, researchers discovered that protecting the bales with plastic sheets resulted in a 4.5% increase in dry matter (DM) recovery, which was the main benefit of this storage method.

During storage, hay may experience losses caused by spontaneous heating, which can lead to a reduction in the nutritional value of the forage. This phenomenon is often referred to as the Maillard Reaction, non-enzymatic browning reaction, or browning reaction, as described by Goering et al. in 1973. As per the findings of Goering et al. in their study, the Maillard Reaction leads to the formation of a pitch black colored nitrogen containing polymer that collects in the lignin portion of the ADF. When hay is baled with excessive moisture content, it can result in the aforementioned changes owing to the Maillard Reaction. These alterations can have a significant negative impact on the nutritional quality of hay, ultimately leading to reduced animal performance (Coblentz et al., 2000).

Coblentz et al. (2000) conducted a study to explore how the spontaneous heating of hay is affected by the initial bale moisture and density. They created bales with five different moisture levels to induce spontaneous heating after storage, and produced bales of medium and high densities. The study discovered that bale density had a minimal influence on the nutritional value of forage post-storage and the incidence of spontaneous heating. However, the research indicated that a positive correlation was observed between the levels of nitrogen that were insoluble in acid detergent and those that were insoluble in neutral detergent with the occurrence of spontaneous heating.

In conclusion, effective storage methods play a crucial role in minimizing dry matter loss during hay production, with techniques such as plastic wrapping showing promise in enhancing dry matter recovery. Understanding the impact of storage conditions on hay

quality is essential for optimizing nutritional value and ultimately ensuring better animal performance.

### **Techniques of Hay Feeding**

The way a farmer gives hay to livestock for consumption can significantly impact the amount of hay that goes on to waste. There are various methods to feed hay, including the utilization of hay-ring feeders. These feeders come in different shapes and sizes, but the aim is to prevent cattle from trampling the hay, which would make it unappealing. [Buskirk et al. \(2003\)](#) carried an experiment to investigate the dry matter loss of large round hay bales fed in cone, ring, trailer, and cradle-type feeders.

According to [Comerford et al. \(1994\)](#), the type of feeder used can contribute to significant feeding loss when providing hay to beef cows. This study involved two feeder varieties: traditional and elevated cone-type feeders. According to the findings of this study, the proportion of hay wasted per feeder was 8.0% and 1.9% of the dry matter provided for the traditional ring and raised cone feeders, respectively.

In 2007, Miller and colleagues conducted a research project to examine how cow performance and hay waste were affected by restricting the length of time that cows could consume alfalfa hay. The experiment involved cows being allocated to one of four treatments of hay access time: unrestricted or time-limited to 9, 6, or 3 h per day. Variation in cow BW and body condition score varied between treatments and increased as the access time increased to 9 h. Additionally, the study found that hay waste significantly differed between treatments, with 3, 6, 9-hour and unrestricted access resulting in hay waste amounts of 2.7, 2.6, 4.2, and 6.1 kg dry matter per day, respectively.

[Volesky et al. \(2002\)](#) conducted a study to compare windrow grazing and providing large round bundles in ring type feeders. Windrow grazing allows livestock to graze forage directly from windrows stored in the field instead of providing round bundles of hay. The aim of this investigation was to assess calf growth and forage utilization, comparing windrow grazing and bale feeding management techniques. Therefore, understanding the dynamics of hay feeding methods is crucial for minimizing waste and maximizing efficiency in livestock management practices.

### **Key Determinants of Hay Intake in Livestock Forage Texture and Form**

A number of traits associated with fodder can influence dry matter intake, both positively and negatively. NRC identifies several of these traits,

including protein deficiencies that are common in forage diets with low nitrogen and high fiber content. When nitrogen is added as a supplement, it often leads to a significant increase in dry matter intake (NRC, 1996). Additionally, according to the NRC, fine grinding of forage can boost intake by accelerating the passage rate of digestion and increasing dry matter intake.

According to [Patterson et al. \(1994\)](#), processing forage through pelleting or grinding increases the rate of passage and reduces ruminal digestion. However, coarsely chopped forages have minimal negative effects on DM ingestion, milk yield, and fermentation in the rumen. Ruminant animals have two distinct systems that control their intake, depending on the characteristics of their diet. Nutritional needs have controlled animal intake for highly digestible and energy-dense diets. Meanwhile, the intake of less digestible and lower energy diets, such as forages, is reduced by the physical capacity of the gastrointestinal tract. [Waldo, \(1986\)](#) explains that the latter is under physical control.

[Loya-Olguin et al. \(2008\)](#) conducted a study investigating how slice baling affects the nutritional quality of alfalfa hay in feedlot cattle that are being fed and finished. Slice baling was defined as a method of cutting hay to a normal length of 7.6 cm after sun drying, but before baling. Cattle that were newly received were given a receiving diet for 28 days that included alfalfa hay which was either slice baled or ground to pass through a 5.08 cm screen. Slice-baled hay resulted in greater final body weight due to greater ADG and G:F. No significant variance was observed in the dry matter consumption between slice-baled and ground rations. The intake amount for both was 2.69 and 2.68 kg/steer, correspondingly. These findings support the conclusions of [Patterson et al. \(2004\)](#), who suggested that fodder with small grains had a faster passage rate, leading to reduced digestibility.

In 1983, Jaster and Murphy carried out a study where they tested the effects of different physical forms of alfalfa hay diets on Holstein heifers. The experiment consisted of three types of hay: long, roughly chopped, and finely chopped. They used a 3 × 3 Latin square experimental design and housed 18 heifers in the stanchions. The heifers were given the freedom to choose one of the three hay types for a period of 21 d, and their intake was recorded daily. They showed that heifers had a higher intake when given coarse or finely chopped hay compared to lengthy hay. Nonetheless, no significant variation was observed in the dry matter intake between the two chopped hay forms. It was also found that heifers demonstrated a higher level of

digestibility for long hay utilization of dry matter, neutral detergent fiber, hemicelluloses, and crude protein compared to heifers ingesting either of the two chopped hay types.

Adams *et al.* (1987) conducted studies similar to Jaster and Murphy's, but their results were mixed. They fed chopped hay to dairy cows and heifers freely and found that reducing the length of forage particles had no impact on dry matter intake, milk yield, dry matter, or digestion of fiber during their experiment.

In summary, the characteristics of fodder, including protein deficiencies and processing methods such as fine grinding or slice baling, can significantly influence dry matter intake in ruminant animals. Understanding these factors is crucial for optimizing nutritional intake and overall animal performance.

### Chemical Shape of fodder

The composition of the fodder can significantly affect the amount of feed consumed by an animal. Feed intake plays a crucial role in animal production, whether it is for meat, milk, or wool. Previous studies have found that feed intake is highly correlated with the concentration of Neutral Detergent Fiber in the animal's diet (Ruiz *et al.*, 1995). To maintain rumen function and optimize milk production, dairy cows require an adequate amount of NDF in their feed, as noted by Oba *et al.* (1999). Additionally, as stated by Ruiz *et al.* (1995) the concentration of NDF is believed to have a negative correlation with the energy level of the feed, and a positive correlation with the gut fill effect of the diet.

An experiment was conducted to investigate the effect of dietary neutral detergent fiber concentration on milk yield and DM utilization in lactating dairy cattle. The results indicated that, as the concentration of NDF in the feed increased, the percentage of dry matter intake relative to body weight decreased, as noted by Ruiz *et al.* (1995). Furthermore, as the concentration of NDF in the rations increased, milk production decreased. Digestion of NDF is crucial, as the degradability of forage neutral detergent fiber in the rumen can differ significantly, and the digestion of NDF significantly impacts animal performance, as mentioned by Oba *et al.* (1999). According to the NRC, a significant range of dry matter intake was observed at any given NDF concentration in the feed. Therefore, it is recommended that the origin of neutral detergent fiber in the feed is influenced by factors such as particle size, digestion rate, and speed of passage from the reticulorumen had an impact on dry matter intake. The findings highlight the pivotal role of neutral detergent fiber concentration in dairy cattle diets, with

implications for milk yield and dry matter utilization. Factors such as particle size, digestion rate, and reticulorumen passage speed must be considered in optimizing feed composition for optimal animal performance.

### Impact of Particle Size and Forage Source

The particle size and source of forage play crucial roles in ruminant feeding behavior and performance. Research has shown that longer particle sizes in hay can improve performance by increasing rumination time, saliva production, and subsequently enhancing the buffering effect on the ruminal environment. However, interactions exist among forage source, level, and particle size, highlighting the need to determine the optimal inclusion level based on these factors (Xiao *et al.*, 2020).

### Supplements

The winter feeding program for beef cows usually focuses on feeding them low-quality forage, such as grazing dormant native grasses or providing hay as harvested forage. To meet the nutritional needs of the cows, a protein supplement was added to their diet. Studies have demonstrated that the addition of monensin to feed can improve feed efficiency by reducing dry matter intake. (Clanton *et al.*, 1981). Various studies have investigated the impact of monensin supplementation on the weight and body condition score of beef cows, but the results have been inconclusive (Lemenager *et al.*, 1977; Lemenager *et al.*, 1978). A 1988 review by Sprott *et al.* concluded that although the addition of monensin may not affect the performance of cows, it often reduces dry matter intake. On the other hand, Turner *et al.*, discovered that dry matter intake was not affected by the addition of monensin as a supplement.

In 1980, Walker *et al.* discovered that as cows were given more monensin as a supplement, their dry matter intake decreased. It seems that the effect of monensin on a cow's performance is linked to the quality of the forage they consume. According to Sprott *et al.* (1988), when monensin was added to low-quality forages, it led to a decrease in DMI, but an improvement in feed conversion. However, when higher quality forage was supplemented with monensin, there was an increase in weight and condition gain. It is worth noting that the effect of supplemental monensin on apparent digestibility has only been studied in growing cattle. Dinius *et al.* (1976) discovered that when beef cattle were fed a forage diet supplemented with monensin, there were no variations in the digestion of DM, CP, NDF, or ADF. Similarly, Muntiferung *et al.* (1981) observed that supplementing beef cattle, who mainly consumed

a concentrate diet, with monensin had no impact on the apparent total tract OM, starch, ruminal, ruminal, or total tract crude protein digestion.

### **Effects of Hay on cattle and buffalo**

Feeding hay depends on the type of system animals are kept in. Stall-fed dairy cows fed 60% or more concentrate and without any other source of forage can be fed up to 20% alfalfa hay. However, feeding chop length should be considered, because a longer chop size may induce higher sorting behavior (Leonardi & Armentano, 2003). In a trial, the effect of chop size on milk quality was examined, and it was found that cows fed with finer hay particles produced more fat. Animals fed with coarse particle size were prone to milk fat depression (Grant & Mertens 1990). Some experiments have completely replaced hay, but it has been observed that keeping small quantities of hay improves feed intake as it has a higher mineral content and DCAD difference (Erdman & Kohn 2011).

Some hays have a significant tannin content, that is, *Phaseolus calcaratus*. In an experiment conducted on fistulated buffalo, males fed up to 900 g per animal daily of this hay along with a concentrate of moderate CP at a rate of 0.3% of BW, improved feed utilization, and minimized methane gas emission (Chanthakhoun *et al.*, 2011).

Feeding hay to cow calves is common practice. Usually, hay is kept alongside the calf starters. However, studies suggest that the consumption of long particles and coarse hay may result in decreased nutrient digestibility (Hill *et al.*, 2019). Feeding rates may change with changes in the type of animals, stage of life, body weight, and type of feedstuff. However, the fact remains the same low-quality hay fed with higher grain quantity can't compete with the functioning of high-quality hay fed with medium-quality grains (Wilkinson *et al.*, 2020).

A recent study showed that combining calf starter and hay had a minimal effect on various aspects of calf growth and health before weaning, including plasma metabolites, hormones, performance, and feed consumption. However, there was no significant difference in growth, plasma metabolite, and hormonal levels between the treatment groups. Calves that were fed a combination of hay and starter had lower feed efficiency and less NDFIP than those fed separately at weaning. Interestingly, calves fed hay blended with starter had higher NDFIP, resulting in greater gut fill, dry matter intake, and lower ADG, despite being screened for longer grains (Engelking *et al.*, 2020). In this study, feeding Alfalfa Hay led to an increase in overall DMI, ADG, and final weight, resulting in a shorter weaning time. This positive

effect of Alfalfa Hay was attributed to its physical properties that minimized plaque formation in the wall of the rumen and improved the macroscopic and microscopic appearance of the rumen. Nevertheless, it was noticed that FE was reduced during the entire experimental period, irrespective of the level of Alfalfa Hay added to the feed. According to Beiranvand *et al.* (2014), propionate supplementation did not have a significant impact on production, but it enhanced weaning duration, possibly due to the reduced molar proportion of butyrate. Nevertheless, no other significant connections were observed between performance, skeleton growth, or ruminal fermentation characteristics at the end of the experimental period, in terms of supplemental forage and sodium propionate. With the exception of the molar ratio of butyrate. This study indicates that forage, as a physical factor, plays a more crucial role in calf performance and rumen development than sodium propionate, which is a chemical factor, under current feeding conditions.

Khan *et al.* (2011) discovered that feeding chopped hay to calves fed a higher amount of milk at a young age improved their total solid diet consumption and was advantageous for the physical growth of the rumen. The experiment revealed that the cows selected the longest particles in their diet the most. With decreasing particle size, the utilization of particles in relation to the quantity offered gradually increases. The sorting of each screen was comparable for long and chopped hay, suggesting that long-hay feeding resulted in an improvement in the consumption of long particles. In contrast, diets that relied on long hay tended to exhibit a greater variance between the total mixed ration that was provided and the amount that was actually consumed, primarily because of the higher existence of long particles. Diets primarily composed of long hay tend to have a greater disparity between the total mixed ration provided and the actual amount consumed, primarily because they contain more extended particles. Moreover, when 40% chopped alfalfa hay was used in the diet instead of 20%, the sorting tendency increased. Consequently, there was a reduction in the consumption of lengthy particles in the 40% feed, despite having more extended particles in the total mixed ration. Although the quality of hay does not necessarily affect the sorting activity, its inferior quality can magnify the effect of categorization by focusing the dietary neutral detergent fiber into the longest and most easily classified feed particles. It is worth noting that cows exhibit varying behaviors and degrees of sorting, which was observed in individually fed animals that sorted their feed as the day progressed, resulting in a coarser diet (Leonardi & Armentano, 2003).

In studies on dairy calves, the provision of a mixed ration or separate components of hay and concentrate did not affect their feed intake or growth. However, calves tended to choose hay more frequently the week prior to weaning and showed a preference for concentrate after weaning. It was also found that providing separate components led to a higher intake of concentrate than providing a mixed ration. Once all calves were provided with a mixed ration, those that had been previously exposed to the mixed ration began to prefer concentrate, while those previously given separate components did not show any preference. When transitioning to a new TMR, differences in feed-sorting behavior persisted, with calves that had previously been fed a mixed ration continuing to sort their feed more. These findings indicate that early exposure to different feeding methods can influence the behavior of diet classification for at least five weeks after differential feeding treatments. Therefore, it is possible that the way pre-weaning calves are fed could help to reduce or delay the onset of feed sorting, according to [Miller et al. \(2013\)](#).

The size of the particles in alfalfa hay is more crucial than their chemical properties in determining the performance, feeding habits, and blood metabolites of dairy calves, particularly in the post-weaning phase. Researchers have suggested that modifying the particle size of alfalfa hay from fine to medium can enhance ruminant diets, resulting in better performance and lower instances of non-nutritive oral behaviors ([Nemati et al., 2015](#)). According to [Downey & Tucker's \(2023\)](#) study, providing long hay, regardless of how it was presented, enhanced rumination, improved performance, and reduced some of the abnormal oral behaviors observed in dairy calves. However, despite the positive effects, calves in all groups exhibited a range of abnormal behaviors, such as pseudo-rumination, excessive grooming, repetitive tongue movements, and polydipsia.

According to this study, providing dairy calves with only high-quality hay as their solid feed instead of concentrate-rich starter feed is a viable alternative that does not have any negative impact on their growth performance and feed intake, particularly during the critical weaning phase. Conversely, using medium-quality hay as a feed source can lead to decreased feed intake and lower daily gain in calves. The excellent nutrient digestibility and elevated crude protein levels in high-quality hay enabled dairy calves to consume daily quantities of crude protein and I comparable to those fed concentrate-rich starter feeds. Moreover, hay promotes the intake of water-soluble carbohydrates and neutral detergent fiber, resulting in an increase in serum beta-hydroxybutyrate levels even before

weaning. This, along with elevated beta-hydroxybutyrate and cholesterol levels post-weaning, implies that the rumen epithelium had improved metabolic capacity, with enhanced ruminal ketogenesis and cholesterogenesis during the crucial weaning period in calves. It is imperative to conduct additional studies to examine the potential long-term effects of providing high-quality hay as a feed source for dairy calves, particularly regarding the positive changes in ruminal ketogenesis and cholesterogenesis noted during weaning ([Terler et al., 2022](#)).

The study found that cattle provided with treated teff straw, Napier grass hay, and *Brachiaria* hybrid grass hay had finer nutrient utilization, diet consumption, and milk yield than cattle supplemented with ordinary grassland hay. Providing cows with these improved forages and treated teff straw silage as a basic feed also reduces nutrient excretion and methane emissions to the environment. This study highlights the potential for improving milk yield in tropical areas, such as Ethiopia, where precision feeding may be limited, and for reducing greenhouse gas emissions ([Mekuriaw et al., 2020](#)).

The fatty acid profiles of buffalo and cow milk were similar in the presence of palmitic, oleic, and meristic acids. When it comes to the impact of changing the source of roughage on milk FAs, buffaloes consistently showed improvements in all indicators when fed hay. However, the effect on the bovine milk profile was inconsistent, and the three health-related indicators were adversely affected after two months of hay feeding. The only similarity between the two species was the higher linoleic acid content in the experimental groups ([Penchev et al., 2016](#)).

According to [Wang et al. \(2022\)](#), a study found that Bacteroidetes were the predominant bacteria in the rumen flora of buffaloes fed with king grass and straw. However, Firmicutes were not dominant. This study also suggests that increasing protein levels in the diet can lead to a higher abundance of Proteobacteria. On the other hand, higher dietary fiber content can increase the prevalence of *Prevotella* and *Staphylococcus*. According to this study, the predominant fungi found in the rumen two hours after ingestion were aerobic fungi, which were probably introduced into the rumen via the diet.

According to [Tauqir et al. \(2022\)](#), treating rice husks with 2% sodium hydroxide has no negative impact and can be incorporated into the diets of lactating buffaloes at levels of up to 20% without causing any apparent harm. However, additional research is needed to enhance the quality and usefulness of rice husks in animal nutrition and to investigate their impact on livestock productivity. Given the ongoing shortage in

both quantity and quality of animal feed, particularly during periods of feed scarcity in Pakistan, it is necessary to explore methods of utilizing agro-industrial byproducts for ruminant feeding. These findings provide the foundation for further research in this area.

This study compared the effects of feeding oat hay and oat silage on methane production and nutrient utilization in Murrah buffaloes. Both groups were supplemented with a mineral mixture and salt, and after a 60-day feeding period, a digestibility trial was conducted. The findings indicated that the group fed hay had notably greater NDF and ADF consumption, but the digestion of most nutrients remained unaffected by the feed type. However, hay supplementation resulted in higher methane emissions than silage feeding. The total methane production was reduced by 6.86% in buffaloes fed oat silage compared to hay. Therefore, storing oats as silage instead of hay may reduce methane emissions from Murrah buffaloes, according to [Sontakke et al. \(2019\)](#).

The study found that replacing 25-50% of dietary alfalfa hay with *L. leucocephala* leaves did not have a negative impact on growth performance and dry matter digestibility in buffalo. However, complete substitution resulted in reduced digestibility, and further treatments are needed to improve animal performance. The economic feasibility of using *L. leucocephala* should be evaluated in comparison to high-quality feeds such as alfalfa hay. In conclusion, *L. leucocephala* could be a valuable alternative forage source for ruminants in dry regions ([Mohammadabadi et al., 2021](#)). [Ampapon et al. \(2016\)](#) incorporated urea and cassava hay into the buffalo diet. Feeding rice straw to buffaloes led to an enhancement in rumen ecology, elevated production of fermentation byproducts, a boost in microbial protein synthesis, and a decrease in protozoal populations and methane production. They suggested that swamp buffaloes consuming rice straw could benefit from the addition of urea at a rate of 60-90 g/head/day when combined with cassava hay.

In comparison to rice straw, field pea hay demonstrated higher levels of organic matter, CP, and TDN content, along with greater digestibility, except for the fiber fractions. Supplementing the diet with field pea hay significantly increased the dry matter intake of buffaloes, leading to higher crude protein and total digestible nutrient intakes, subsequently resulting in an increase in body weight. Furthermore, the incorporation of field pea hay tended to increase fat-corrected milk yield. The increase in fat-corrected milk yield can be ascribed to the increased dry matter intake and total digestible nutrient intake, as well as

the slower rate of degradation of nonstructural carbohydrates found in field pea hay. This suggests that incorporating field pea hay into rice straw-based diets can improve the feed quality and milk production of buffaloes, particularly milk fat yield. However, it is worth noting that while increasing crude protein intake can lead to weight gain in buffaloes, there is a decrease in milk production efficiency with increasing crude protein intake, as identified by [Hayashi et al. \(2007\)](#).

According to research findings, the addition of cassava hay as a supplement had a positive impact on the nutritional status of swamp buffaloes and Brahman cattle. Supplementation led to an increase in the consumption and digestion of DM, organic matter, proteins, and energy. The addition of cassava hay also improved the rumen ecology and decreased ruminal NH<sub>3</sub>-N. Additionally, both species experienced a decrease in weight loss, and their overall health improved, with a reduction in the number of parasite eggs in their feces. The response to cassava hay supplementation appeared to differ between the two species, with swamp buffaloes showing a tendency to have a greater response than Brahman cattle. Buffaloes tended to have higher ingestion and digestion of protein, organic matter, DM, and total digestible energy intake than cattle did. Additionally, the reduction in parasite eggs per percentage was also observed to be higher in buffaloes than in cattle. However, no significant interactions were found between the species and treatments in the study conducted by [Granum et al. \(2007\)](#).

In summary, the provision of hay in livestock diets has been shown to impact various aspects of animal health, performance, and environmental sustainability. Understanding the optimal feeding strategies, including particle size considerations and hay quality, can lead to improvements in feed utilization, methane emissions reduction, and overall production efficiency? Further research into alternative forage sources and supplementation methods holds promise for addressing challenges in feed availability and enhancing the nutritional status of ruminant animals, particularly in regions facing feed scarcity.

#### **Effect on Goat and sheep**

According to [Boukrouh et al. \(2023\)](#) including *Hedysarum flexuosum* L hay in the feed of dairy goats did not have any negative impact on animal production or the characteristics of raw milk. It is possible that the tannins available in *Hedysarum flexuosum* L hay may have played a defensive role in the ruminal biohydrogenation of fatty and influenced the activity of the enzymes responsible for fatty acid desaturation in the mammary gland. The findings indicate that incorporating *Hedysarum flexuosum* L hay into the

diet with at least half of the DMI may produce distinct results. Thus, it could be a feasible alternative forage and protein source for lactating goats. However, further research is recommended to investigate the use of *Hedysarum flexuosum* L and its impact on feeding goats with fresh or ensiled forage on ruminal microbiota, as well as its influence on various products derived from goat milk.

Zhao et al. (2023) carried out an experiment to evaluate the rumen degradation of grain amaranth hay at 4 growth stages, including squaring stage, initial bloom, full-bloom, and mature stage. The finding indicates that the rumen degradation of CP during squaring and initial bloom stages was over 80%. The effectual degradation of crude protein was prominent during the squaring stage compared to other stages. On the other hand, the degradability of CP was the lowest during the mature stage. The successful degradation of NDF was greater during the initial bloom stage, while the effective degradability of ADF was highest during the mature stage. Additionally, the impressive degradation of DM and CP was the highest during the squaring stage. In conclusion, the initial bloom stage was found to be better on the basis of chemical structure and ruminal degradation features when compared to the other three growth stages.

The study aimed to examine how the inclusion of yellow sweet clover hay in the diet of kid goats affects their growth performance, meat quality, and carcass characteristics. The findings revealed that the addition of this hay did not have any significant impact on the carcass performance parameters or certain meat quality parameters. Nonetheless, the results demonstrated that yellow sweet clover hay had a positive impact on some crucial parameters that are highly valued by consumers, such as tenderness, protein content, and intramuscular fat. Moreover, the addition of sweet clover to the diet was found to elevate the levels of DFAs. This finding holds promise for breeders in the northwestern region of Morocco, as yellow sweet clover has the potential to serve as an alternate source of nutrition, ensuring a well-balanced diet for livestock throughout the year while simultaneously minimizing the costs associated with fattening (Mouad et al., 2022).

Araujo et al. (2022) reported that young goats fed a control diet had the highest intake of certain nutrients and the lowest feed conversion compared to butterfly pea hay + cactus pear mea diets. The 83% butterfly pea hay seventeen % cactus pear mea diet resulted in lower digestibility of certain nutrients, while the 67% butterfly pea hay + 33% cactus pear mea diet showed better digestibility and weight gains. The 50%

butterfly pea hay + 50% cactus pear mea diet led to a lower intake of certain nutrients and longer idle times. According to the findings of Rao et al. (2015) and Makkar (2016), incorporating hay made from a sunflower and chickpea intercropping system into the diet of milking goats can enhance animal efficiency and productivity in comparison to a conventional corn straw-based diet. Recent research by Estrada et al. (2022) also suggests that supplementing goat diets with sunflower and chickpea hay may lead to higher milk production, protein content, and total solids compared to corn hay. The findings of the study suggest that native browse species could provide adequate nutrients, particularly protein, to support the growth of growing goats in the absence of high-quality forages like grass. To enhance feed utilization through tannin deactivation Kemboi, (2022) recommends supplementing a browse-based diet with Polyethylene glycol and bentonite clay,

It is safe to include Sesban hay as a protein source in lamb feed up to 30%. The study revealed that Sesban hay can replace clover hay without any adverse impact on lamb's growth, metabolic parameters, blood profile, pubertal parameters, semen characteristics, or overall health. Sesban hay enhanced the nutritional quality, feed conversion, and certain rumen parameters, leading to higher economic returns and increased economic efficiency for Ossimi sheep when supplemented with Sesban hay. As a result, the study suggests cultivating Sesban plants during the summer in Egypt as a replacement for clover hay (Mahgoub et al., 2022).

Adugna et al., (2023) demonstrated that incorporating a blend of dried *Vernonia amygdalina* leaves and wheat bran into natural pasture hay at varying ratios was found to enhance the dry matter and nutrient intake, feed conversion rate, and digestibility, as well as promote body weight gain in Arsi-Bale sheep. The study indicates that the most effective outcome was achieved when the animals were fed a mixture of *Vernonia amygdalina* leaves and wheat bran in a 2:1 ratio, which resulted in the highest economic gain. As a result, the authors recommend supplementing natural pasture hay with this mixture as a cost-effective method to enhance weight gain in this type of sheep. The findings demonstrated that incorporating dry distilled grains with soluble into Rhodes grass hay had a favorable impact on sheep by decreasing their methane emissions. This positive effect was linked to an increased dry matter intake, as well as a higher digestibility and energy concentration in the diet. As a result, the study suggests that utilizing industrial by-products as a supplement for low-quality diets could

be a promising approach to mitigating methane emissions (Gere *et al.*, 2022).

In conclusion of studies discussed above which highlights various alternative forages and supplements that can positively influence the performance and health of livestock. Incorporating these novel sources, such as *Hedysarum flexuosum* L hay, yellow sweet clover hay, butterfly pea hay, sunflower and chickpea hay, Sesban hay, *Vernonia amygdalina* leaves, and dry distilled grains with soluble, into the diet of goats and sheep shows promising results in terms of improved growth, nutrient intake, feed conversion and even environmental impact. Further research is necessary to explore optimal inclusion rates and potential synergistic effects with other feed components for maximizing the benefits of these alternative feed sources.

#### **Future Research Directions**

Continued research is essential to fully understand the long-term effects of forage supplementation in ruminants. Factors like feed selection and harvesting early in life can have lasting impacts on adult ruminant behavior and performance.

**Diversification of Feeds:** Future directions may involve exploring a wider range of feed options beyond traditional hay to enhance ruminant nutrition and health

**Innovative Feeding Systems:** Research suggests that new feeding systems are emerging in intensive and semi-intensive production systems, indicating a shift towards more efficient and sustainable feeding practices

**Nutritional Strategies:** Emphasizing a lifetime approach to nutrition in ruminants, incorporating essential micronutrients and specific feed additives, can be a key focus for future hay utilization

**Total Mixed Ration (TMR):** Considering the benefits of ensiling Total Mixed Ration (TMR) for ruminants, future directions may involve optimizing TMR formulations that include hay to improve feed efficiency and animal performance.

#### **Implications of hay utilization**

The implications of hay utilization on soil health and forage production are multifaceted and influenced by various factors, including the method of hay production, storage and feeding. Here are some key findings:

**Soil Health:** Hay utilization can lead to reduced soil erosion, increased soil organic matter, improved soil

physical properties and improved water retention capacity. Proper grazing management strategies, such as rotational grazing can positively impact soil health by increasing microbial activity, improving pasture productivity and enhancing soil structure (Government of Alberta, 2004). While Bale grazing involves feeding hay in specific areas to add nutrients to the soil, can be a useful strategy for building soil health in areas that are deficient in nutrients (Aljoe).

**Forage Production:** Hay production is a significant component of forage production, and factors such as fertilization and stage of maturity at harvest can affect hay quality. Hay that is wasted represents a significant loss of resources and can impact the economics of a livestock operation. The quality-versus-quantity concept is important in forage production, as give up on hay quality to obtain higher yields can be counterproductive. Forage quality is also important in pastures, and the main way that fertilization affects forage quality is by increasing the protein content of forages (Ball, 2009)

**Nutrient Cycling:** Hay production can lead to the removal of substantial amounts of nutrients, such as phosphorus and potassium from the soil and these nutrients will need to be replenished with commercial fertilizer or manure applications Nutrient recommendations for grass hay production should be based on an annual or recent soil test and a accurate crop yield and should account for the need to replenish nutrients removed by hay harvest (Heckman, 2018)

**Grazing Management:** Grazing management is critical for maintaining soil health and forage production as continual severe grazing can cause depletion of plant food reserves and reduce stand vigor. Proper stock distribution is important for nutrient cycling, balanced use of the land base, and improved range health, and can lead to additional animal units from un-grazed or lightly grazed areas (Government of Alberta, 2004).

Thus, hay utilization can have both positive and negative implications on soil health and forage production, depending on the methods used. Proper grazing management, fertilization and nutrient cycling are all important for maintaining soil health and forage production.

## **2. CONCLUSION**

Hay remains a cornerstone of ruminant nutrition, providing essential fiber, nutrients and a platform for rumen fermentation. But in order to make good hay, all factors from selecting a suitable variety to growing and processing play their role. Understanding the

complex relationship between hay quality, intake and animal performance is crucial for optimizing feeding strategies. By focusing on factors like hay quality, processing methods and strategic supplementation, producers can maximize the utilization of this valuable feed resource. Feeding hay to ruminants is a multifaceted aspect that influences their nutrition, behavior and performance. Understanding the nuances of hay intake, including particle size, forage source and early feeding practices in ruminants, is crucial for optimizing ruminant health and productivity. There is a need for more efficient tools and techniques required to maintain quality. Feeding hay to ruminants is a multifaceted aspect that influences their nutrition, behavior and performance. Understanding the nuances of hay intake, including particle size, forage source and early feeding practices in ruminants, is crucial for optimizing ruminant health and productivity. Continued research exploring novel processing techniques and the interaction between hay characteristics and rumen microbes holds promise for further enhancing ruminant production efficiency.

### 3. CONFLICT OF INTEREST

All authors have declared that there is no conflict of interests regarding the publication of this article.

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