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REVIEW ARTICLE

Pelletization as a forage conservation technique: Enhancing feed efficiency and sustainability in livestock

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Abstract

Integrating crop and livestock production, especially with cattle, is vital for food security and economic growth in India. The livestock sector helps increase farm income, boosts the national economy and provides employment opportunities for millions of people. However, productivity lags global standards due to shortages of quality food, including green fodder, dry fodder, as well as concentrates. Stagnant fodder crop cultivation and dwindling permanent pastures exacerbate the challenge of meeting the rising demand for milk and meat. Addressing these issues is crucial for enhancing livestock productivity and sustaining agriculture. This review highlights the importance of fodder pelletization, compressing animal feeds into dense pellets using a pellet mill. Pelleted feeds offer balanced diets, improved digestibility and nutrient absorption, with benefits including long-lasting preservation, enhanced handling, stability, bulk density and palatability. Factors influencing the pelleting process, such as ingredient characteristics, drying, grinding, conditioning, steam pressure and moisture content, are examined in depth. The positive effects of pelleted feed on ruminant growth and productivity, particularly in cattle and goats, are emphasized, including improvements in milk yield, weight gain and reproductive performance. These findings emphasize the potential of pelletized feed to address challenges related to fodder scarcity, feed wastage and transportation costs. These insights contribute to more efficient diet management in livestock production.

Keywords

animal nutrition; feed and fodder; feed conversion; pelleting of feeds; sustainable livestock management

Introduction

The increasing demand for livestock products in India is hindered by fodder scarcity and low feed quality, affecting animal health and productivity. This review article explores fodder pelletization as a sustainable solution to enhance feed efficiency, reduce wastage and ensure year-round feed availability.

India supports a significant portion of the world's livestock (20 %) and human population (17.5 %) despite having a small fraction of the Earth's land (2.3 %). The human population is growing at a rate (1.6 %) annually, while the livestock population is increasing (0.66 %) per year. This growth intensifies competition for land resources dedicated to food and fodder production. Land competition limits fodder production as agricultural land is allocated to high-yield cash crops. India's grazing land has declined from 13 to 10Million hectares, contributing to a 35-40 % green fodder deficit (1). Intensification in states like Punjab and Haryana has further reduced dedicated fodder acreage, exacerbating livestock feed shortages.

Forage crops emerge as the most economically most viable feed resource for ruminant production by supplying vital nutrients like proteins, vitamins (Vit A) and minerals such as Calcium, Magnesium, Phosphorous, Potassium and Sodium (2). They contribute significantly to overall animal health, growth and resilience. The green fodder, dry fodder and concentrate requirements for cattle are 368086, 214580 and 39394 thousand tonnes, respectively, while for buffaloes, the figures are 376637, 186566 and 39021 thousand tonnes (3). In India, the demand for livestock products has surged with urbanization. Despite having ample livestock resources, the productivity of milk and other products lags significantly behind global standards. The primary hindrance to enhancing livestock production and reproductive capabilities in Indian livestock farming is the scarcity of feed and fodder. The area under cultivated fodder constitutes only 4 % of the total cultivated land (8.4 million ha) in the country and this has remained unchanged over the past few decades (4-5).

The persistent shortage of high-quality feed and fodder in India presents a major challenge in enhancing livestock performance. Persistent challenges in ensuring the year-round availability of high-quality green fodder stem from various factors including substantial land and labor requirements, water scarcity, inadequate water quality, prolonged growth periods for fodder crops, limited shelf life and crop failures due to natural disasters (6). Seasonal variations exacerbate the problem, leading to the unavailability of quality food during dry periods and posing a threat to the survival of animals. The decline in the reproductive capacity and yield potential of Indian livestock is attributed to the sub-standard quality of commercially available feeds. Almost 97 % of commercially accessible foods are of low quality, which adversely affects animal health, physical condition and milk yield (7).

Despite the abundance of green fodder during the monsoon season, scarcity in the summer and monsoon failure remains a significant concern. The protein deficiency during the dry season adds complexity to the problem, requiring the sustainable production of high-quality feed to meet the increasing demands for meat and milk. To mitigate this issue, surplus monsoon fodder can be processed and conserved for the lean season.

Fodder pelletization, a feed processing technology, emerges as a transformative solution, by compacting ground feed ingredients using steam, heat and pressure, to form dense pellets (8). Pellets are the preferred form of concentrating feed (CF) due to their benefits, such as providing a balanced diet, ease of use, reduced wastage, enhancing feed efficiency and improved productivity. This hydrothermal process increases nutrient digestibility and deactivates anti-nutritional factors (9). Converting feed into pellets can decrease wastage due to handling, storage and spoilage by 10 % to 20 %. The pelleting process reduces dust, prevents mold formation and improves storage longevity, all of which help mitigate feed losses (10). The exact reduction would depend on factors like feed type, current spoilage rates and local storage conditions. Pelleting enhances feed efficiency, reduces dust, improves storage and extends shelf life, thereby alleviating a portion of the fodder shortage.

The review process spanned nearly four months from September 2024 to December 2024, with one month dedicated solely to manuscript composition. A thorough literature search was conducted, screening approximately 110 scientific papers. The selection process used keywords such as "*fodder production, forage conservation, fodder pellet production, pelletization process, pellet quality, pellet feeding technology, composition and nutritional quality of pellets and storage and handling of fodder pellets".* Of these, 96 papers were utilized in manuscript preparation. Various databases, including Tamil Nadu Agricultural University e-library, Google Scholar, Scopus, ResearchGate and Web of Science, were utilized for the retrieval of review papers.

Forage conservation

Challenges of traditional forage conservation: Traditional methods like hay and silage are susceptible to weather dependency, nutrient loss and microbial spoilage (11-13). Weather fluctuations affect hay drying and silage fermentation, leading to mold growth and reduced nutrient retention. Effective preservation requires precise moisture control, harvest timing and proper management to maintain quality.

Advantages of fodder pelletization: Fodder pelletization offers a weather-independent solution by utilizing indoor processing, ensuring consistent nutrient preservation and reduced microbial risks through heat treatment (14-15). This method allows for greater harvest flexibility, mechanization and efficient storage, minimizing losses and enhancing resource efficiency. Additionally, uniform pellet composition prevents animal feed selectivity, reducing wastage while ensuring consistent quality and year-round availability (16) (Fig. 1). The comparative analysis of pelletized feed and traditional feeding methods including loose fodder and silage is given in Table 1.

Pelletization: The introduction of pelleting into the European and U.S. feed industry took place during the 1920s (19). Fodder pellet production involves compressing feed material into small cylindrical pellets using moderate heat and pressure, which enhances feed efficiency (20). This process ensures a steady supply of nutritionally balanced animal feed with physical benefits. while serving as an efficient fodder storage method during lean periods. Pelletization ensures uniform nutrient distribution, reducing selective feeding and promoting a balanced cattle diet (18).

Methods to improve pellet quality: The process typically involves several key steps (Fig. 2). The quality of compressed livestock feed can be improved by selecting high-quality raw materials and fortifying the feed with essential vitamins and minerals, which is crucial for meeting the nutritional needs of livestock. Pre-processing techniques, such as grinding to

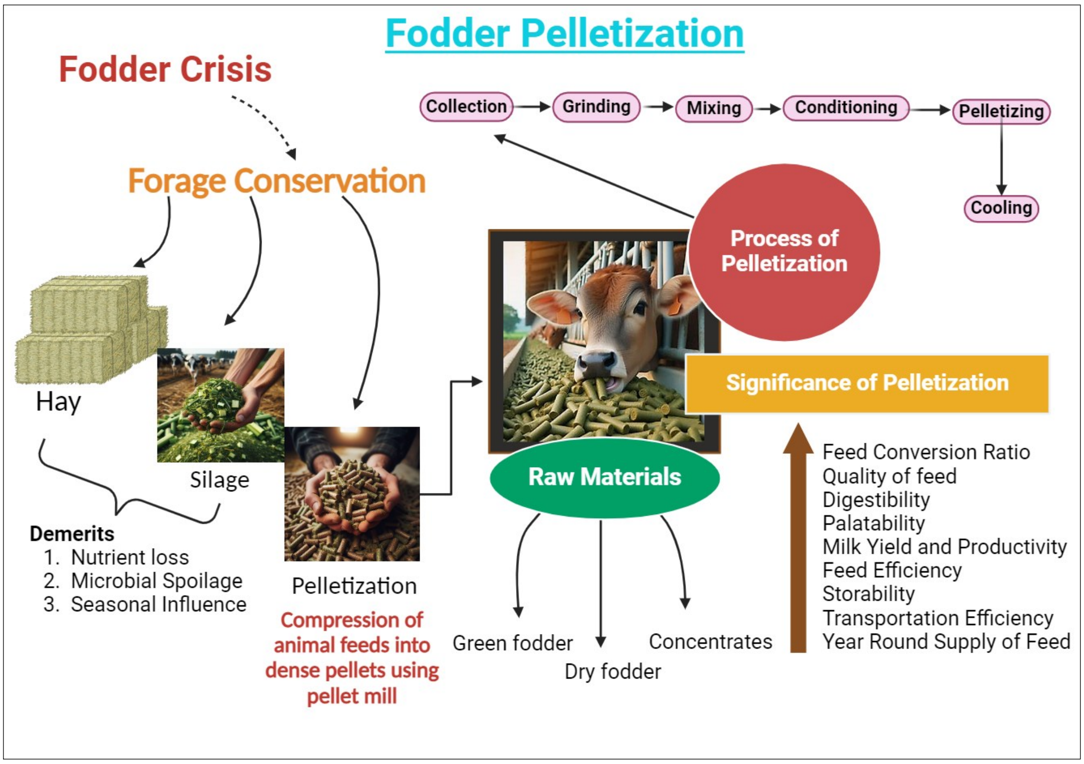

Fig. 1. Fodder pelletization - Process & significance.

Table 1. Comparative analysis of pelletized feed vs. traditional feeding methods (loose fodder and silage) (17-18)

Aspect	Pelletized feed	Loose fodder/silage
Nutritional quality	Balanced nutrient profile with consistent formulation. Improved digestibility and nutrient absorption. Leads to higher growth rates, milk yield and reproductive performance.	Nutrient content varies with forage quality, seasonality and storage. Silage may experience nutrient loss through fermentation. Inconsistent nutrient profile can affect productivity.
Cost-efficiency	Higher initial cost due to pellet mills or purchased feed. Long-term savings from reduced feed wastage and improved feed efficiency. Easier transport and storage due to higher bulk density. Better feed conversion ratio (FCR).	Lower initial costs, especially if locally available fodder. Higher feed wastage as animals may selectively eat. Silage requires specialized storage (e.g., silos), increasing costs. Higher spoilage rates.
Sustainability	Longer shelf life, reducing spoilage and wastage. Utilizes by-products like crop residues, contributing to the circular economy. Lower methane emissions due to improved feed efficiency.	Silage can contribute to carbon sequestration, but silage leachate can be an environmental pollutant. Loose fodder is land-intensive and subject to seasonal fluctuations. Higher spoilage and wastage.
Feed wastage	Reduces feed wastage by up to 50-60 % compared to loosen fodder. Better controlled portions and reduced spoilage.	Higher feed wastage due to spillage and selective feeding. Silage spoilage during fermentation can also result in losses.
Handling & storage	Dense and compact, making storage and transport easier and more cost-effective. Longer shelf life with less spoilage.	Requires large storage spaces (especially for silage). Prone to spoilage and requires specialized storage (silos for silage).
Environmental impact	Reduced greenhouse gas emissions from improved feed efficiency. Low carbon footprint if using crop residues. Less spoilage reduces food waste.	Silage production can have environmental benefits if well-managed. Potential pollution from silage leachate and higher land use for loose fodder. Spoilage contributes to food waste.

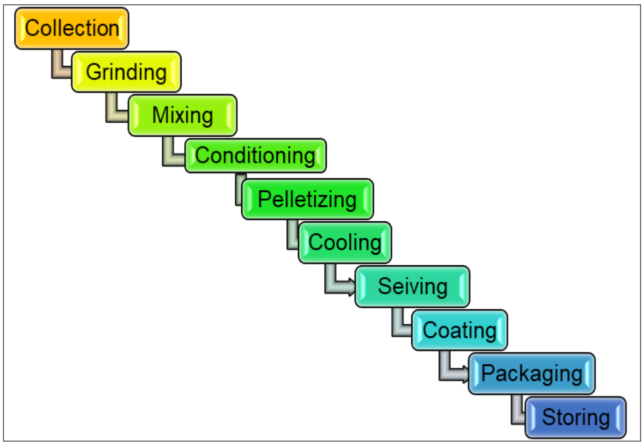

Fig. 2. Process involved in fodder pelletization.

reduce particle size and conditioning with steam to gelatinize starches, can enhance nutrient availability and digestibility (21). It is also important to control pelleting conditions, by maintaining optimal temperature (70-80°C) and moisture levels (12-15 %) to ensure effective binding without degrading nutrients, while tailoring pellet size to the specific species for better intake (22). The incorporation of natural binders, like molasses, can improve durability and reduce breakage, while additives such as enzymes or probiotics can further enhance nutrient absorption and gut health (23). The most widely used probiotic agents in livestock today include *Lactobacillus, Streptococcus, Enterococcus, Lactococcus* and *Bifidobacteria* (24). Regular quality control through testing for nutritional content, moisture and microbial contamination is essential, allowing adjustments to formulations based on livestock performance. Finally, cooling pellets after production prevents spoilage and extends shelf life, while proper storage in airtight containers minimizes exposure to moisture and oxygen.

Pellet size and ruminants: The size of feed pellets plays a critical role in feeding efficiency of both small and large ruminants. For small ruminants, such as goats and sheep, smaller pellets (typically 4-6 mm in diameter) are ideal because they are easier to chew, swallow and digest (25). These smaller pellets also reduce the risk of choking and improve feed intake consistency, leading to better nutrient utilization. On the other hand, large ruminants, such as cattle and buffalo, can handle larger pellets (typically 6-12 mm in diameter) due to their stronger jaws and larger digestive systems (26, 27). Larger pellets may promote slower feeding, which encourages better salivation and digestion, as ruminants rely heavily on microbial fermentation in the rumen (28). However, excessively large pellets can result in poor feed intake and digestibility, as they may be more difficult to break down.

In ruminants, appropriately sized larger pellets can help balance digestion by promoting healthier gut function and preventing rapid fermentation of nutrients. Cattle and buffalo possess larger reticulorumen capacities, allowing for the retention and fermentation of larger particles (29). Further research is needed to optimize pellet dimensions for both digestion and welfare. Balancing pellet size is essential for optimizing feed efficiency, digestibility and overall animal health in both small and large ruminants. Moreover, the ideal pellet size can vary depending on the species, age and production stage of the ruminants, highlighting the importance of considering these factors when designing pelletized feeds.

Significance of fodder pelletization

Feed conversion ratio: A higher feed conversion ratio (2.25 %) for pelleted feed compared to crumble feed (1.22 %) was reported previously (30). Pelleting fodder reduces feed wastage by animals and promotes feed and fodder homogeneity, resulting in a 4-6 % increase in feed conversion rate (31). noted that Goats fed with pelleted napier grass exhibited superior feed conversion efficiency (7.44 kg dry matter/kg gain), 74.2 % neutral detergent fiber digestibility and 80 % higher crude protein digestibility than those fed with unpelleted napier grass (32).

Quality improvement: The kenaf pellet exhibited a chemical composition that comprised 12.6 % crude protein (CP), 41.2 % neutral detergent fiber (NDF) and 14.4 % acid detergent fiber (ADF) (33). Pelleting feeds stabilized rumen environments, reducing the risk of acidosis (34). Increased crude protein retention, higher calcium content, reduced nutrient losses in pelleted feed due to their dry nature, superior nutritional content and storage stability in legume pelleted feeds (35, 36). Incorporating additives like molasses, bran, minerals, jaggery and salts can enhance low-quality forages, including unconventional fodder and crop residues. This improves not only the nutritive value but also animal acceptance by enhancing palatability (23).

Digestibility: Compressing animal feed into dense pellets improves digestibility and nutrient absorption by breaking down the feed particles and reducing the space between them. This process increases the surface area for digestive enzymes to act upon, improving starch digestibility and promoting uniform feed intake, thereby reducing sorting and ensuring balanced nutrition making it easier for animals to digest and absorb nutrients efficiently (37). The heat and pressure applied during pelletization can also alter the structure of certain components, such as starch, improving their digestibility. Pelleting feeds has been shown to improve the digestibility of organic matter and crude fat in fodder (38). The physical alteration of feed components during pelleting, such as starch gelatinization, contributes to enhanced digestibility (39). Preservation of legume feeds as pellets enhanced feed intake and digestibility by reducing fiber content (40), a lower protein digestibility in wheat-based pelleted meals (41), whereas no significant impact in sorghum -based diets (42) and substantial increase in dry matter digestibility through pelleting corn soybeans (43).

Feed efficiency: Reduced feed wastage, diminished selective feeding, decreased pathogen risk, lower prehension effort, thermally altered starch and protein, prolonged feed preservation, improved handling, enhanced stability, increased bulk density, increased nutritional intake, reduced energy expenditure, increased palatability, reduced dustiness, minimized waste reduced selectivity of feeds, lowered feeding costs, reduced material volume and transportation costs and increasing cattle productivity (44-46).

Storability of feed: Forage crops can be pelletized with other nutritional by-products and stored to create a complete ration for ruminants in the dry season (47). Pelleted feed has improved storability due to higher density. The use of pelleted total mixed ratio reduces on-farm labor costs by eliminating the need for forage handling and feed mixing (35, 36, 48).

Environmental benefits of pelletized feeds: Pelletized feed offers significant environmental benefits for livestock production. It improves feed efficiency, reducing the amount of feed required for growth or milk production, which in turn lowers methane emissions from livestock (49). Additionally, pelletization utilizes agricultural by-products like crop residues (50) which minimize the need for dedicated fodder crop cultivation and reducing the carbon footprint (51).

Process of feed pelletization

The process typically involves collecting and grinding raw materials, followed by mixing them into a uniform blend. The mixture is then conditioned under a temperature of 70-90 °C before being pelletized in a mill (31). The pellets are cooled, sieved to remove fines and coated if needed. Finally, they are packaged and stored for later use or distribution. Raw materials such as forage, grains and supplements are collected. The next step involves grinding or chopping these materials into a consistent size, optimizing pellet uniformity. Feed grinding plays a crucial role in cattle health, digestion and nutrient absorption (52, 53). Around 20 % of pellet quality relies on the grinding process, a crucial stage in feed production that reduces particle size for uniformity, improved nutrient availability, enhanced pellet quality and ensures optimal extrusion in the pelletizing phase.

Techniques in feeding pelletization

The process of feed pelleting typically includes grinding raw materials to achieve optimal particle size, conditioning to improve binding properties and pelletizing through various techniques (Table 2). Standard techniques such as compression through flat die or ring die, along with the utilization of methods like steam pelleting, extrusion and micronization, are applied to augment the nutritional value and digestibility of animal feed. The process of pelleting is essential in delivering well-rounded and effective nutrition to livestock, poultry and aquaculture, thereby supporting their overall health and performance.

Impact of pelleting process on quality of feed and fodder pellets

Pelletizing animal feed requires balancing multiple factors beyond just scientific principles. Numerous elements come into play, such as the type of machinery employed, the characteristics of the feed materials and the feed conditioning process. Factors like formulation, particle size, conditioning, die specifications and cooling methods affect pellet quality (63). Pellet quality is predominantly influenced by the cooling/drying phase (5 %), die selection (15 %), fineness of grind (20 %), steam conditioning (20 %) and formulation (40 %) (64).

Ingredients and formulations

Ingredient processing significantly influences the physical and chemical properties of starch, protein and fiber, thereby affecting pellet quality. Research indicates that the inclusion of fibrous materials and proteins can enhance pellet durability, while fats tend to diminish it. The addition of fibrous co-products can improve hydration properties and affect the physicochemical characteristics of feed mash, leading to variable pellet durability (15.8 % to 91.1 %) (65). Incorporating protein sources enhances the nutritional quality and durability of pellets, as demonstrated by the positive effects of additives like corn starch and sugar beet on pellet quality. Conversely, the inclusion of fats has been shown to reduce pellet durability and overall quality, highlighting the need for careful formulation in feed production (66).

Drying process

The impact of temperature on weight gain in diets based on pelleted maize was also investigated (67). Accordingly, the pelleting maize-based diets at 65 °C led to a greater increase in weight compared to pelleting at 75 °C and 85 °C. There were lower drying losses (2 %) in solar drying, compared to higher weight/nutrient losses (3-15 % for grass fodder, 25-30 % for legumes) in conventional sun drying (68). Solar-dried clovers had higher chlorophyll levels and significantly more crude protein (10.18 %), crude fiber (3.22 %) and total ash content (4.8 %) compared to sun-dried clover (69). Advanced drying methods, such as those utilizing infrared and conductive heating, allow for precise moisture control, which is crucial for maintaining fodder quality and preventing microbial contamination (70). Convection drying has been shown to enhance the nutritional value of fodder, with minimal changes in protein and ash content post-drying (71).

Grinding process

In fodder pelleting, the choice of grinding method significantly impacts particle size, energy efficiency and pellet quality. The hammer mills and centrifugal grinders are commonly used, with specific screen sizes and grinding durations affecting the final product. However, the choice ultimately depends on specific operational goals and material characteristics. Hammer mills are widely used for their efficiency but can have high energy consumption. The choice of screen size (e.g., 2 mm, 2.8 mm and 3.6 mm) directly influences particle size and flowability, with smaller screens yielding finer articles and better flowability (72).

Centrifugal grinders can operate at lower energy densities. The rotor speed and screen hole diameter (4, 6 and 8 mm) use lesser energy and produce coarser particles

Table 2. Different techniques in feeding pelleting

S.No	Techniques	Working principle	Remarks	References
1	Pellet crumbling	Extrusion	Enhanced digestibility & improved efficiency	(54)
2	Micronization	Size reduction	Increased bioavailability of nutrients	(55)
3	Pelletizing with steam	Conditioning	Enhanced binding & improved pellet durability.	(56)
4	Hydraulic pellet press	Compression	Uniform density	(57)
5	Molasses coating	Encapsulation	Moisture protection & nutrient-enhancement	(58)
6	Extrusion pelleting	Plasticization	Nutrient enhancement	(59)
7	Flat die pellet mill	Extrusion	Affordable & simple technique	(60)
8	Ring die pellet mill	Compression	Superior quality & durability of pellets	(61)
9	Cold pelleting	Extrusion.	Enhanced efficiency & preservation	(62)

(73). Grinding is essential in feed manufacturing, improving feed ingredient palatability, increased surface area for enzyme interaction, maximizing nutrient absorption and digestion by reducing particle size, thus ensuring cattle health (53).

Conditioning process

The conditioning process involves adding moisture and applying heat to feedstock to enhance pellet formation, with optimal steam temperatures maintained between 80-85 °C and moisture levels of 12-13 % before pelleting and 14 % after pelleting (74). This process boosts production capacity, improves pellet durability and enhances the physical, nutritional and hygienic quality of feed. It activates natural binders, gelatinizes starch and increases feed plasticity, contributing to better binding and durability. Moderate conditioning temperatures improve the digestibility of essential amino acids like lysine and methionine, crucial for protein synthesis and overall animal health. However, excessive heat can lead to the Maillard reaction, reducing the availability of heat-sensitive amino acids, such as lysine and tryptophan, thereby compromising feed quality (75). The mild temperatures below 85 °C balance amino acid preservation with pellet durability (76) while prolonged conditioning improves moisture penetration, binding and pellet hardness (31). Nevertheless, high temperatures can destabilize additives like phytase, affect nutrient availability and damage protein integrity, reducing digestibility and feed efficacy (77).

Moisture content

Increasing the feed temperature from 97.2 °F to 190 °F through steam addition raised the conditioned mash moisture content by 4.2 %, which led to an improvement in pellet quality (78). A negative correlation between moisture content and bulk density, as well as particle density, in groundnut hull pellets (79). Wheat straw pellets with the lowest moisture content had the highest bulk density, while sorghum stalk pellets with the highest moisture content had the lowest bulk density (80). Steam treatment significantly enhances the durability of pellets. Additionally, mechanical interlocking plays a crucial role, contributing approximately 50 % to the durability of the treated pellets (81). Moisture addition linearly enhanced pellet quality and conversion efficiency, improving yield and nutrient retention during pelleting (82).

Steam pressure

The selection of steam pressure during pelletization is crucial for achieving optimal pellet quality and durability. The increasing in pressure from 20 to 200 MPa correlates with enhanced pellet durability, emphasizing the importance of optimal pressure settings (63). Increasing conditioning steam pressure significantly improves pellet durability (83). Dry steam conditioning did not enhance pellet quality and pellets produced under these conditions exhibited 7-10 % lower durability compared to those conditioned with steam (84).

Nutrient composition

The pelleting technique enhances the nutrient concentration and availability in fodder crops, facilitating improved digestion and utilization by livestock (Table 3). However, there is a risk of heat-sensitive nutrient degradation during the pelleting process. Consequently, meticulous monitoring and adjustment of feed formulations are vital to maintaining optimal nutrient levels for animal nutrition.

Binding agents

Binding agents in feed pelleting for livestock enhance pellet quality by improving binding properties, reducing fines, ensuring water stability, achieving uniform pellet size and shape and minimizing dust formation (91). Common binding agents include molasses, lignosulfonates, starches, gelatinized starches and vegetable oils. The selection of binding agents depends on factors like feed type, nutritional needs and processing conditions. Molasses, for instance, not only improve pellet quality but also serve as an energy source (92). The choice of binding agent is crucial for optimizing pellet characteristics and meeting livestock requirements (93).

Biochemical changes during pelletization

Fodder pelletization for cattle induces several significant biochemical changes in the feeding composition. The application of heat and pressure during the pelletization process leads to the gelatinization of starch, rendering it more digestible for livestock. Simultaneously, proteins undergo denaturation, altering their structure and potentially enhancing digestibility. The Maillard browning reaction, resulting from the interaction between amino acids and sugars at elevated temperatures, contributes to the visual appearance, flavor and aroma of the pellets. However, it renders amino acids unavailable for protein synthesis (75).

Pelleting has the potential to enhance protein and amino acid digestibility by inducing protein denaturation during feed ingredient processing. This denaturation process aids in deactivating anti-nutritional factors, thereby enhancing the overall nutritional value of feed ingredients. The increased density of pellets facilitates transportation,

Table 3. Effect of pelletization process on nutrient composition

Effect on nutrient composition	References
Lower ADF (14.1 %) and NDF (24.31 %) content in lucerne pellets than hay	(85)
Higher calcium and lower oxalate levels in pelleted legumes	(86)
Lower tannin (28.1 mg/kg of DM) and oxalate contents (5.72 mg/kg of DM) of legume pellets	(35)
Pelleting increases the apparent ileal digestibility (AID) of dry matter, crude protein and energy by up to 27 % in specific diets	(87)
The heat involved in pelleting reduces pathogens and increases digestible starches, improving feed efficiency for livestock	(88)
Pelleted feed has been shown to improve dry matter intake and average daily gain in small ruminants compared to unpelleted forms	(89)
Though pelleting enhances digestibility, it can reduce the retention of vitamins A, E, B2 and B6, necessitating potential over-supplementation	(90)
Increased concentrations of calcium (0.909 %), magnesium (0.474 %) and potassium (2.454 %) in ragi straw pellets compared to unpelleted ragi straw	(18)

storage and feeding efficiency, while the compression of ingredients improves nutrient accessibility and overall digestibility by breaking down cell walls. Moreover, the heat generated during pelletization helps reduce microbial contamination, ensuring feed safety (94).

Impact of feeding pellets on the growth and productivity of livestock

A 9.2 % increase in milk yield by replacing 40 % of concentrated feeds with *Stylosanthus* pellets (95). A higher dry matter intake (0.264 kg/day) in dairy cows receiving pellet feeding, resulting from the grinding and pelleting process (96). Feeding dairy cattle with moringa leaf pellets improved milk yields without compromising organoleptic characteristics, suggesting their value as a supplement in arid regions. Milk yields ranged from 28.1 to 40.7 kg in the group fed with moringa leaf pellets compared to 20.9 to 33.4 kg in the group fed with bermuda grass alone (97).

Impact of pelleted fodder on the growth and development of goat and sheep

The utilization of expander extrusion to implement a complete pelleted diet resulted in elevated dressing percentages and a greater proportion of lean meat in Nellore ram lambs, as opposed to traditional feeding methods (13). There was a significant weight gain in black Bengal goats fed with a complete pelleted feed composed of 40 % rice straw and 60 % concentrate (98). The impact of pelleted legume fodders, including *Leucaena leucocephala*, *Desmodium cinereum* and *Gliricidia sepium*, on Anglo-Nubian and Boer goats has been previously investigated (99). Pelleted legume fodders enhanced milk production in Anglo-Nubian (587 ml/day) and Boer (475 ml/day) goats compared to those fed with unpelleted legume fodders. Goats fed with napier grass pelleted ration showed higher body weights (22.7 kg). Increased crude protein digestibility in Black Bengal goats fed with a compound pellet diet (50 % ground napier grass + 50 % concentrate) compared to mash and conventional feeding methods (100). West African dwarf sheep fed with various forage legume pellets exhibited higher crude protein digestibility, improved dry matter digestibility and increased body weight compared to sheep fed with guinea grass alone (101). A higher daily average weight gain in lambs fed with pelleted total mixed ration compared to unpelleted total mixed ration has been reported previously (47). Feeding gram straw-based complete feed pellets improved growth performance, nutrient utilization, rumen fermentation in goats and cost of production were also improved (102). Pelleting total mixed rations enhances feed intake and weight gain in fattening lambs while reducing feeding time and wastage. It does not affect nutrient digestibility or serum metabolites but increases short-chain fatty acids and lowers rumen pH. It shortens fattening time without compromising meat quality and enhances economic efficiency by improving feed conversion and growth performance (48).

Conclusion

Fodder pelletization offers transformative potential in enhancing livestock nutrition and productivity, making it particularly beneficial for small-scale farmers. Pelletized feeds improve feed efficiency, digestion and nutrient absorption, providing a balanced diet and promoting better health, increased milk yield and improved reproductive performance in livestock such as cattle and goats. The economic advantages include reduced feed waste, lower transportation and labor costs and minimized selective feeding, which leads to efficient feed consumption and savings. Additionally, pellets are easier to store and transport, especially useful during fodder scarcity periods, while their prolonged preservation reduces wastage. Although pelletization optimizes feed quality, challenges like nutrient degradation during processing should be considered. Adopting this approach can support sustainable, cost-effective livestock production, enhancing overall farm economics. Positive outcomes, including increased milk yield and improved reproductive performance in cattle and goats, reinforce the value of pelletization, though further research is needed to resolve mixed results regarding weight gain in goats.

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Authors' contributions

VSM designed the methodology, data curation, formal analysis, writing- original draft preparation, SSD planned the conceptualization, investigation and resources, RT performed the validation and supervision, PR helped in supervision and resource collection. Validation, Writing- Reviewing and editing done by SA. The formal analysis, supervision and visualization by RVB. Reviewing was done by RS. Supervision, writing-reviewing and editing performed by VA.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

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